THE USES OF THE SLIME MOLD LIFECYCLE AS A MODEL FOR NUMERICAL OPTIMIZATION

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CHAPTER I

I. INTRODUCTION

Past years have seen the introduction of new and difficult optimization problems. Many creative algorithms have been devised to solve these problems. Such algorithms include components from fields including evolution, biology, chemistry, and ecology. These fields have inspired researchers to devise algorithms with names such as Genetic Algorithms, Differential Evolution, Ant Colony Systems, and Particle Swarms [Goldberg 1989, Price et al. 2005, Dorigo and Stützle 2004, Kennedy and Eberhart 1995]. Still, the main driving force behind this creativity is to solve optimization problems that are considered hard or intractable quickly and efficiently.

This work's purpose is to conceptualize slime mold as a viable optimization algorithm, provide evidence of its usefulness, and introduce modifications and possible improvements to the existing slime mold optimization algorithm. The final product of this work will be an algorithm capable of solving a vast array of single-objective optimization problems to optimal or near optimal values in a reasonable amount of time. Study of *Dictyostelium discoideum* (Dd), a popular slime mold in biological literature, was necessary to devise the optimization algorithm presented in this work [Kessin 2001].

Before discussing Dd, it is important to understand the problem that will be undertaken. The focus of this work is solving numerical single objective function optimization problems; therefore, a definition of the problem is provided here. Within a single objective optimization problem, it is assumed that there exists a function *f* or set of piecewise functions $\{f_1, □ ,f_n\}$ that define a single function *f* that need not be continuous. From here on the(se) function(s) will be referred to as an objective function. It is also assumed that the objective function is composed of a set of variables $\{x_1, □ ,x_n\}$ that form the search (or decision) space. These variables will be referred to as the decision variables. Typically, it is assumed that these variables are constrained to some area and that one or more maxima or minima exist for the objective function. The solution to such an optimization problem is, without loss of generality, the minimization of the objective function. The optimum value *f** for a function *f* can be expressed formally as follows:

$$
\begin{aligned}
&f^* = f(x_1^{\min}, x_2^{\min}, \ldots, x_n^{\min}) \text{ such that} \\
&f^* = f(x_1^{\min}, x_2^{\min}, \ldots, x_n^{\min}) < f(x_1, x_2, \ldots, x_n) \\
&\forall \{x_1, x_2, \ldots, x_n\}
\end{aligned}
$$

within the bounds of the search space. Minimization may be used without loss of generality because minimizing $-f(x)$ is equivalent to maximizing $f(x)$. I.e. any maximization problem may be turned into one of minimization [Deb 2001].

Many methods exist to solve an optimization problem for a single objective function. Given a function that is continuous and has a first and second derivative, its minimum can be found directly. Many problems exist in real life, which however, do not meet these qualifications. Therefore, more advanced methods are necessary to solve problems that are not continuous or do not have a derivative. Methods such as Steepest Descent, Newton's method, Levenberg-Marquardt, and others make use of the first or second derivative or a compromise between the two, to progressively or quickly move close to a local minimum by moving opposite direction of the gradient or via the Hessian toward a solution [High 2005]. Other existing classical methods offer a direct search within the bounds of the space in an attempt to find a solution. Most classical methods are not guaranteed to find a global optimum unless some criterion is met (such as a continuous function with multiple derivatives or a function of low order, i.e. quadratic) [Corne et al. 1999]. Such methods typically find only a local optimum for most problems and can typically be improved by using multiple starting points for the algorithms.

Artificial Intelligence (AI) inspired methods have been implemented in the past 50 – 60 years to offer differing methods with different advantages to solve the optimization problem. Most AI inspired methods are based on some man-made or biological process that occurs in the real world. Many of these methods are population based as well. Genetic algorithms try to mimic the real life process of crossover and mutation that occurs when cells undergo meiosis [Goldberg 1989, Mitchell 1998]. Ant colony systems make use of the idea of pheromones that ants use to follow each other to a food source [Dorigo and Stützle 2004]. Simulated annealing was inspired by the process of heating and cooling metal then reheating it to make metal stronger [Chen 1997]. Particle swarm algorithms use the idea of bird flocking [Kennedy and Eberhart 1995]. Each of these algorithms yielded interesting and promising results. Still research is ongoing and often AI inspired algorithms are only used when direct approaches and algorithms such as Steepest Descent and Levenberg-Marquardt are inefficient or fail [Corne et al. 1999]. Provided this short history of optimization, we go on to discuss Dictyostelium discoideum and its uses as a model for numerical optimization.

In this dissertation, the lifecycle of *Dictyostelium discoideum* (Dd) is presented as a model for numerical optimization. Before discussing this model, the lifecycle is explained. Dd is an amoeba that can undertake a complex lifecycle involving several stages. Such amoebae begin their life from binary fission — the splitting of one cell into two. These amoebae are vegetative; that is, they forage in their environment. Vegetative Dd typically live in peat and humus and they eat bacteria such as *Escherichia coli* that live in such environments. Once vegetative amoebae expend the resources in their area (i.e. the bacteria), they begin to starve. After a 4 to 6 hour period of starvation, Dd enter a new stage in their lifecycle. One of the starving amoebae begins to emit a pheromone called cyclic Adenosine Monophosphate (cAMP). This amoeba is referred to as a pacemaker [Kessin 2001]. Provided there are a number of the same amoebae within the same localized area (a 1 cm^3 area), a signal cascade begins [Dallon and Othmer 1997]. Other starving amoebae are stimulated to release cAMP and move toward the pacemaker. This phase of the Dd lifecycle is referred to as aggregation. The signal cascade of the aggregative phase draws amoebae in the locality of the pacemaker near it. The attraction of the amoebae toward a cAMP gradient is so strong that “streams” are formed. As the amoebae are moving toward the pacemaker in streams, they begin to release cellulose, which has a slimy consistency. The amoebae move closer and closer toward the pacemaker until they form a mound. Amoebae within the mound enclose themselves in cellulose and self-organize into a head and a tail. Once self-organization is complete the group of amoebae is a slug. The slug head directs movement of the tail toward a light source. Movement toward a light source is with the intent of moving all amoebae within the slug to the top of the soil or humus they previously inhabited. As the slug reaches a lit area, it culminates to form a fruiting body. Members of the slug’s tail die to form a stalk, and members of the head climb the stalk to form spores at the top of the stalk. At this point, the fruiting body is almost like a dandelion. Various environmental factors cause the spores to be removed from the fruiting body and distributed to new locations in the environment. These include spores being eaten by worms and birds and being redistributed in their droppings. Another environmental factor allowing for redistribution is that spores may be washed away by rain or blown away by wind. Once a spore has been dispersed in the environment, upon germination it becomes a vegetative amoeba again, and the Dd lifecycle begins anew [Kessin 2001, Segel 2001].

Literature shows three different classes of studies of the Dd lifecycle using computational models. These are educational simulations, biological simulations, and discrete optimization tasks. Many of the educational simulations in literature are quite simple. While very informative, they present a simulation of only a portion of the Dd lifecycle – usually the aggregative, mound, and slug stages. Both the simulations presented by Resnick [1994] and Matthews [2002] present 2D simulations of the slime mold lifecycle starting with starving, randomly dispersed amoebae and allow them to aggregate and form slugs using simulated cAMP that is deposited on a 2D cellular automaton. The only difference between the two algorithms is the implementation. The Resnick [1994] slime mold simulation was implemented in StarLogo as an example of parallelism whereas the Matthews [2002] simulation was implemented in Java as an example of a cellular automaton. In comparison to the biological simulations, Matthews’ and Resnick’s simulations appear quite simple.

Of the biological simulations, the earliest reviewed in this work is that of Glazier and Graner [1993]. In 1993, they proposed a Cellular Automata (CA) model for cell sorting and differentiation. This is of particular importance because later models for the slug phase of Dictyostelium discoideum, such as those of Maree and Hogeweg, use cell sorting as a major portion of their simulation [2001]. The models of Segel [2001] and Maree, Panfilov, and Hogeweg [1999, 2001] take from the Glazier and Graner model to form a hybrid CA/Partial Differential Equation (PDE) model to allow for visualization of Dd movement during the mound, slug, and fruiting body stages of the Dd lifecycle. More recent work presented by Erban and Othmer [2007] provides insight into the use of PDEs to model the movement of amoebae during the aggregative stage, and suggests that movement under the conditions where no chemical stimulus exists occurs at random. Movement of amoebae during the vegetative stage is assumed to follow similar equations to those presented in the work of Erban and Othmer, though on a smaller scale [2007].

Few efforts outside of educational studies or biological simulations have focused on the use of Dd or other slime molds as an optimizer. In fact, the author does not know of any numerical optimization algorithms based upon slime molds other than his own [Monismith and Mayfield 2008]. Existing studies of slime molds as optimizers focus on its uses as a discrete optimizer. Rothermich presents a study of slime mold as an optimizer for a resource allocation problem for an information ecosystem in his thesis [2002]. Rothermich’s [2002] model is primarily based upon the educational simulations of Resnick [1994]. Another researcher, Yokoi, in 1995, devised a slime mold based optimization algorithm for the traveling salesman problem. His model is based upon the Potts Hamiltonian like the biological simulation of Glazier and Graner [1993]. Although, it appears to work well, no follow up work has been based upon it. Another interesting effort at optimization using slime molds exists, although it is not computer based. In 2000, Nakagaki was able to get a live slime mold of the genus *Physarum polycephalum* to find its way through a maze to food using the shortest path. Each of these examples shows that slime molds have the potential to be optimizers.

Figure 1.1: Slime Mold from Fort Worth, TX, possibly *Physarum*.

To investigate slime mold as a numerical optimizer, the cellular slime mold Dd was chosen for study. Its lifecycle exhibits two of the key elements of an evolutionary algorithm —exploration and exploitation [Goldberg 1989]. The first stage of this lifecycle —the vegetative stage, in which, individual amoebae search for food, can be contrasted with exploration. Amoebae in this stage follow folate gradients in a search for bacteria (food) [Pollitt et al. 2006]. Similarly, in many optimization algorithms such as the Downhill Simplex Algorithm, Evolutionary Strategy, and Pattern Search, movement in a downhill and explorative manner is performed at the beginning of a search [Corne et al. 1999, Spendley et al. 1962, Hooke and Jeeves 1961]. Once Dd amoebae deplete their food source, they begin to starve. Several hours after starvation, Dd amoebae emit cAMP in an effort to aggregate [Marée et al. 1999 □Migration□]. The combination of a directed search algorithm such as PSO and a nearest neighbor data structure upon which a virtual attractant representing cAMP may be stored closely mimic the movement seen during the aggregative phase. Next, amoebae join together tightly in a mound and shield themselves from the rest of the environment with a slime sheath [Marée et al. 1999 □Phototaxis□, Kessin 2001]. This life stage could be mimicked in a numerical optimization algorithm as the formation of a data structure representing multiple individual search agents with similar goals. Thereafter, in biology, the mound becomes a slug that moves the amoebae toward a lit area where a fruiting body may be formed [Marée et al. 1999 □Phototaxis□, Segel 2001, Kessin 2001]. An analogous structure in optimization would be the aforementioned mound data structure with movement attributed to all its members. Finally, biological amoebae are redistributed in the environment as spores [Kessin 2001, Segel 2001]. Similarly, a slime mold numerical optimization algorithm could relocate the members of a slug data structure and reset their movement to that of vegetative individuals.

This dissertation includes a detailed study of the elements that were briefly discussed above. The literature review presented herein provides a detailed view of the lifecycle of Dd. The biology of Dd is reviewed first. Next, the educational simulations by Resnick [1993] and Matthews [2002] are presented. In conjunction with these simulations, a review of cellular automata (CAs) is provided [Ilachinski 2001]. The biological simulations of Dd for each portion of its lifecycle are discussed in detail. Both the educational and biological simulations give rise to the necessity of one additional tool. This is the ε-Approximate Nearest Neighbor (ε-ANN) algorithm [Arya and Mount 1998]. Additionally, in the literature review, existing optimization algorithms are discussed. These include classical algorithms, direct search algorithms, and evolutionary algorithms. In particular, Differential Evolution (DE), Particle Swarm Optimization (PSO), a Real Coded Genetic Algorithm (RCGA), Pattern Search, Downhill Simplex, and Razor Search are presented in detail [Price et al. 2005, Corne et al. 1999, Kennedy and Eberhart 1995, Coello Coello and Lechuga 2002, Herrera et al. 1998, Hooke and Jeeves 1961, Spendley et al. 1962, Bandler and MacDonald 1969]. After completing the literature review, the steps used to convert Dd from a lifecycle to an algorithm are shown. The Slime Mold Optimization Algorithm is then defined.

Following the explanation of the Slime Mold Optimization Algorithm, several updates to the Vegetative, Mound, and Slug states are introduced that allow for new variations of the existing algorithm. These include replacing the Vegetative state with modified versions of the Razor Search and Downhill Simplex algorithms. Furthermore, a new form for the slug is introduced that is closer to the true biological form. With the Slime Mold Optimization Algorithm and its variants defined, results are introduced. To illustrate the value of the Dd lifecycle as an optimization algorithm, results from this algorithm for a sizeable function suite are provided [Monismith and Mayfield 2008].

Comparisons are made between the Slime Mold Optimization Algorithm and existing Evolutionary Algorithms (EAs) including DE, PSO, and RCGA. Comparisons are also made to the Hooke-Jeeves Pattern Search Algorithm. Thereafter, results from the variants of the Slime Mold Optimization Algorithm are presented. These results are compared against the EAs and the original Slime Mold Optimization Algorithm. Results as presented are competitive with those of the RCGA and PSO algorithms, but the DE results are significantly better than most of those obtained from the Slime Mold Optimization Algorithm. Analysis of the results includes discussion of averages of minimum objective function values obtained from the algorithms, average runtimes, and error of results. Following analysis and comparisons, possible future works are presented. These include updates to improve the existing algorithm, the addition of population dynamics to the Slime Mold Optimization Algorithm, and the need for theoretical study of the algorithm to verify its efficacy [Monismith and Mayfield 2008].

CHAPTER II

II. REVIEW OF LITERATURE

Optimization using slime mold as its basis requires multi-disciplinary study. First, a study of existing optimization algorithms is necessary to provide background, insight, and inspiration. The algorithms studied are of the same class as the one being created. They are all direct search algorithms of one form or another that do not require the computation of a derivative [Corne et al. 1999]. Many of these algorithms have taken inspiration from biology, and they serve as a natural starting point for the creation of a new optimization algorithm based in biology [Passino 2005]. Next, study of the organism Dictyostelium discoideum (Dd) is necessary as it is the basic unit of the type of slime mold that will be scrutinized. Its lifecycle will be dissected to illustrate the portions necessary for building an optimization algorithm [Kessin 2001]. Finally, simulations of the slime mold are investigated. Existing biological simulations that use both cellular automata and differential equations are discussed [Glazier and Graner 1993, Erban and Othmer 2007, Marée et al. 1999 □Migration□, Marée et al. 1999 □Phototaxis□, Dallon and Othmer 1997, Marée and Hogeweg 2001, Segel 2001]. Educational simulations of slime molds provide some insight as to how a slime mold optimization algorithm might be created, and initial trials for optimization with slime mold and previous works build the final foundation for a slime mold optimization algorithm [Resnick 1994, Matthews 2002]. Thus, the literature review for this work is divided into three sections: Optimization, Biology of Dd, and Slime Mold Simulations.

Section 2.1 Optimization Algorithms

In this section, several existing single-objective numerical optimization algorithms will be discussed. These algorithms have provided both inspiration and new ideas for the author's work. Since the focus of this work is to explore numerical optimization in a generalized sense, discussion of numerical optimization algorithms that are derivative-based will be omitted. Such algorithms include Steepest Descent, Newton's Method, Levenberg-Marquardt Method, and many others [Corne et al. 1999, Passino 2005]. The discussion of algorithms in this chapter will include Direct Search methods and Evolutionary Algorithms.

Direct Search methods refer to those optimization methods that do not require computation of a derivative [Hooke and Jeeves 1961]. Rather, these methods rely on some type of heuristic to search for an optimum value. Such heuristics typically rely on moving in the direction of a peak (for maxima) or a valley (for minima). This can be accomplished by random exploration, pattern based movement, or combinations thereof. Since these methods do not rely on the computation of a derivative, they can solve optimization problems that are not differentiable. Direct Search methods often use only a single starting point or very few starting points. As a result, these methods often become trapped in local optima like derivative-based methods. So when using these methods many programmers run a direct search algorithm from multiple starting points and choose the best result [Hooke and Jeeves 1961, Spendley et al. 1962, High 2005].

Evolutionary Algorithms (EAs) refer to a class of optimization algorithms that draw inspiration from nature and typically make use of a population that uses cooperation or competition to search for an optimum function value [Corne et al. 1999]. These algorithms are similar to Direct Search algorithms in that they typically do not require computation of a derivative during the search. These algorithms are, however, more advanced than direct search in that they use populations of starting points, hereafter referred to as individuals, that work together to search for an optimum objective function value. The heuristics used in an Evolutionary Algorithm vary widely and may include ideas such as population dynamics, genetic evolution, population evolution, bird flocking, etc. Each of these algorithms all, however, has the following similarities: an EA starts with a population of individuals that are initialized in some random fashion, the algorithm iterates and allows some or all of the individuals contribute toward the search, and the best objective function value is retained after each iteration. EAs build on this basic outline and can be very simple or quite complex depending upon the heuristic used [Arabas et al. 1994, Corne et al. 1999, Passino 2005, Price et al. 2005].

Included in this chapter are several existing Direct Search and Evolutionary Algorithms. First, the Pattern Search of Hooke and Jeeves is discussed along with the transformations to it to create the Razor Search algorithm. Next, the Simplex Algorithm of Hext and Spendley is considered. These direct search algorithms are considered in a later chapter for use in the first stage of the author's Slime Mold Optimization Algorithm. Next, evolutionary algorithms are discussed. These include a Real-Coded Genetic Algorithm, the Particle Swarm Optimization Algorithm, and Differential Evolution. These will be used both for comparisons and inspirations to the author's algorithm in later chapters.

Section 2.1.1 Pattern Search

The Pattern Search algorithm was one of the first optimization algorithms that allowed for optimization without computation of a derivative. This is one of the algorithm's main advantages over classical approaches. Search for a minimum or maximum function value is performed by exploring in multiple directions (i.e. dimensions) using a fixed or varying step size. The algorithm makes use of a direction vector to decide whether to search forward or backward by one step in each dimension.

Once a suitable direction is achieved, the algorithm attempts a pattern step. That is, a second move is made in the same direction as the successful move. The reason for doing so is heuristic. Given the fact that a successful move was made in a particular direction, it is reasonable to assume that continuing to search in the same direction might yield positive results (i.e. the move should be at least partially in the direction opposite the gradient) [Hooke and Jeeves 1961]. A variant of this method exists using a line search in the pattern move direction. The line search attempts to find the best value in that direction, so a different pattern move in a different direction will be necessary on the next iteration of the algorithm [High 2005].

The pattern search method of Hooke and Jeeves is detailed below in Algorithm 2.1: `PatternSearch`. This algorithm iterates until either a convergence criterion is met or until a fixed number of objective function evaluations has occurred. Initially, a starting point x_0 is selected and evaluated as f_0; then, iterations begin. During iteration, the starting point and starting objective function value are both copied into temporary variables, and an exploration is performed. If the exploration succeeds, a pattern move is attempted by determining the search direction, θ, and moving further in that direction [Hooke and Jeeves 1961]. Further explorations and pattern moves are attempted as long as the results of such moves are significant (i.e. they pass the Bell-Pike Test) and progress toward better function values [Bell and Pike 1966]. Once a pattern move fails, the magnitude of the search, denoted as δ, is decreased by a factor of α. Note that α is a constant in the range (0, 1) and is typically set to a value between 0.1 and 0.2. Iterations continue until the convergence criterion is met or until the maximum number of function evaluations has been met [Hooke and Jeeves 1961]. Pseudocode for the pattern search algorithm is provided below.

Algorithm 2.1: `PatternSearch`

```
Do,
    x    $x_0$ (copy $x_0$ and $f_0$ into x and f)
    f    $f_0$
    Explore(ref f, x)

    While (f < $f_0$ and numEvals < MAX_EVALS and Bell-Pike Test Passes),
        $\theta$    x – $x_0$ (compute the direction of the valley)
        $x_0$    x
        x    $x_0$ + $\theta$
        $f_0$    f
        Evaluate f(x) and count the evaluation.
        Explore(ref f, x)
        Perform the Bell-Pike Test for progress.
    End while.

    If(f < $f_0$)
        $f_0$    f
        $x_0$    x
    Else If(not converged and numEvals < MAX_EVALS),
        $\delta$    $\delta$ * $\alpha$
    End if.
```

```
While not converged and numEvals < MAX_EVALS.
```

During pattern search it is necessary to search for a good direction in which to move. Exploration in multiple directions allows for such movement. In Algorithm 2.2: `Explore`, a vector S is initialized to one and used to indicate the direction of an exploratory move using the values 1 or -1 to denote a positive or negative direction along each dimension. Movements are attempted in the direction of each dimension, one dimension at a time, using this module. After a movement is attempted, the module checks to see if the move improved the previous function value. If the move was indeed an improvement, that move is saved and the next dimension is tested. Otherwise, a move is made in the opposite direction and tested for improvement. This move is saved if it is an improvement; however, in the case of a move forward or backward resulting in no improvement in function value, both moves are ignored and the next dimension is tested [Hooke and Jeeves 1961]. Pseudocode for the `Explore` module is provided below.

Pattern search is an effective search algorithm when searching for an optimum in a function that is singly modal. Problems occur with this algorithm in multi-modal functions. Using a poor starting point may result in the function being trapped within local minima. Multiple starting points may alleviate this problem; however, minima that lie along a line or point with a narrow opening angle may have a low probability of being found. For many functions, whether differentiable or not, using pattern search with multiple starting points will deliver optimal or near optimal results as long as reasonable step sizes are used [Hooke and Jeeves 1961, High 2005].

Algorithm 2.2: `Explore (ref` f_0`, x)`

```
For I = 1 to NUM_DIM
      $S_i$    1
End for.

For I = 1 to NUM_DIM,
      $x_i = x_i + S_i * | \delta |$
      Evaluate f at x.

      If ($f < f_0$),
            $f_0$    f
      Else,
            $S_i$    $-S_i$
            $x_i$    $x_i + 2 * S_i * | \delta |$
            Evaluate f at position x.

            If ($f < f_0$),
                  $f_0$    f
            Else,
                  $x_i$    $x_i - S_i * | \delta |$
            End if.
      End if.
End for.
```

Section 2.1.2 Razor Search

Razor search is an extension of the "Direct Search" method of Hooke and Jeeves [1961]. Razor search attempts to improve upon the Pattern Search method by allowing for random search in a different direction once direct search does not yield improved results. This method is interesting because it can make direct search effective on functions with an extremely narrow opening angle to a minimum. In such functions, it can be quite difficult to achieve optimization using non-classical methods such as genetic algorithms, particle swarm, ant colony optimization, etc. Razor search is divided into four major parts. These are the Razor Search module itself and three additional modules to perform a modified version of the pattern search of Hooke and Jeeves. These additional modules perform the pattern search via the use of a main module and two additional modules to perform the exploration move and to find a reliable starting point for a pattern move [Bandler and MacDonald 1969].

In razor search, first, the objective function is evaluated at a starting point. This point may be chosen at random. Pattern search is performed at this starting point. Additionally, criteria are set for the maximum number of iterations κ and reductions in the current minimum step size ε using the formula below.

$$\varepsilon \leftarrow \varepsilon_{\min} \cdot \eta^{\kappa} \tag{2.1}$$

Note that η is a constant that is set heuristically, and $\varepsilon_{\min}$ is the smallest step size that may be taken during a pattern search. Furthermore, if a finishing criterion is not met, the program iterates until a finishing criterion is met or until a fixed number of iterations has been completed; whichever comes first. During an iteration, a point nearby the last best point found is generated using the following formula:

$$x \leftarrow x_0 + \rho \cdot Rand(1,-1) \cdot \varepsilon\,, \tag{2.2}$$

Where x contains the generated point, x_0 is the variable containing the last best point, ρ is a scaling factor, ε is the minimum magnitude of the current move, and $Rand(1,-1)$ is a pseudorandom number generator that produces values between 1 and -1 with uniform probability. Using this new point, a pattern search is conducted in a different direction. If the results of the pattern search yield a better function value, the new value is saved. Additionally, a new valley (search) direction θ is computed using the following formula:

$$\theta \leftarrow x_0 - x\,. \tag{2.3}$$

Thereafter, a pattern move is performed using this direction. So long as this pattern move is beneficial, additional pattern moves are performed and the best location and function value are updated. Finally, the finishing criterion is checked. If the finishing criterion is not satisfied and the maximum number of iterations has not been expended, the program continues iterating [Bandler and MacDonald 1969]. Pseudocode for Razor Search is provided in Algorithm 2.3: `RazorSearch`.

Algorithm 2.3: `RazorSearch`

```
$\varepsilon$    $\varepsilon_{min} * \eta^{\kappa}$
Evaluate $f_0$ at it is initial position $x_0$.
PatternSearch($x_0$, ref $f_0$)

If the finishing criterion is satisfied,
      End program.
End if.

For j = 1 to $\kappa$,
      Obtain a new position x in a random direction using (Eq. 2.3).
      Evaluate x and store its result in f.
      $\varepsilon$    $\varepsilon / \eta$ (Decrease the smallest allowable step size)
      $\delta$    $||x - x_0||$

      If x is out of bounds,
            F    $\infty$
      End if.

      PatternSearch(x, ref f)

      If ($f < f_0$),
            $f_0$    f
            $\theta$    $x - x_0$
            $x_0$    x
      Else,
            f    $f_0$
            $\theta$    $x - x_0$
      End if.

      conv2    true

      While(conv2),
            x    $x_0 + \theta$
            $\delta$    $|| \theta ||^2$
            PatternMove(ref f, x, $x_0$)
            If ($f < f_0$),
                  $f_0$    f
                  $x_0$    x
            Else,
                  conv2    false
            End if.
      End while.

      If the finishing criterion is satisfied,
            End program.
      End if.
End for.
```

The Pattern Search method used as part of Razor Search is used in place of the second call to Algorithm 2.2: `Explore` in the Hooke and Jeeves Pattern Search [1961]. As a method of determining the step size, the magnitude of the search direction, θ, denoted as δ is used when an exploratory or pattern move is performed. This value is also used as the stopping criteria for the pattern search in conjunction with ε, which is the smallest allowable step size. This is the main difference between the Pattern Search of Hooke and Jeeves and the one used here. While the pattern search iterates, first an exploration is performed using copies of the point and function value passed in as parameters. Then, so long as the exploration is beneficial, the direction of the valley is computed and pattern moves are performed in that direction. If the move is not beneficial, the magnitude of the exploration is decreased. Iteration for pattern search continues until the magnitude of the exploration becomes too small (less than ε) [Bandler and MacDonald 1961].

During Razor Search exploration is necessary to achieve reasonable pattern moves and improvements in objective function values. This exploration is, in fact, performed in the same fashion as that of Algorithm 2.2: `Explore`. Therefore, the exploration module presented in Section 2.1.1 will be used again here as part of the Pattern Search for Razor Search presented in Algorithm 2.4 [Hooke and Jeeves 1961].

Algorithm 2.4: PatternSearch(x_0, ref f_0)

```
While ($\delta > \varepsilon$),
      x    $x_0$ (copy $x_0$ and $f_0$ into x and f)
      f    $f_0$
      Explore(f, x)

      If (f < $f_0$),
            While (f < $f_0$),
                  $\theta$    x – $x_0$ (compute the direction of the valley)
                  $x_0$    x
                  x    $x_0$ + $\theta$
                  $\delta$    $|| \theta ||^2$ (compute the magnitude of the step)
                  PatternMove(f, x, $x_0$)
            End while.
      Else,
            $\delta$    $\delta * \alpha$
      End if.
End while.
```

The pattern move module presented below serves to find a suitable exploration move for use in a following pattern move. Obviously, the method used in Razor Search for a pattern move is slightly different than that of Hooke and Jeeves [1961]. Notably, a variable *m* is used to provide three tries at possible explorations. Algorithm 2.5: `PatternMove` starts by assigning *m* a value of one. Thereafter, δ is compared to ε to ensure the exploration size is large enough. Next, a loop begins that will cycle at most three times. In this loop the objective function is evaluated at its current position. Then, an exploration move is attempted [Bandler and MacDonald 1969]. If the exploration succeeds (i.e. the move was an improvement and passes the Bell-Pike Test), the method returns because of its success [Bell and Pike 1966, Bandler and MacDonald 1969]. Otherwise, the value of *m* is checked. If *m* is one and the previous move was unsuccessful, the current pattern is not immediately thrown away. Rather, *m* is set to two and a move closer to the base point is attempted by decreasing the variable *δ*. If this closer move is unsuccessful, *m* is set to three and a move in the opposite direction is attempted. If the third try fails, the method is terminated [Bandler and MacDonald 1969].

Algorithm 2.5: `PatternMove (ref` f_0, x, x_0`)`

```
m    1

If ($\delta < \varepsilon$)
      Return;
End if.

While (true)
      Evaluate f at position x
      Explore(f, x)

      If (f < $f_0$)
            For I = 1 to NUM_DIM,
                  If( $|x_i - x_{0i}| > 10^{-6}|x_{0i}|$ )
                        $f_0$    f
                        Return.
                  End if.
            End for.
      End if.

      If (m = 1)
            m    2
            $\delta$    $\delta$ / 2
            x    $x_0$ + 0.5*$\theta$

            If ($\delta < \varepsilon$)
                  Return;
            End if.
      Else if (m = 2)
            m    3
            S    -S
            x    $x_0$ – 0.5*$\theta$
      Else
            Return;
      End if.
End while.
```

Section 2.1.3 Simplex Method

The Simplex Method of Spendley, Hext, and Himsworth is another direct search algorithm [1962]. It makes use of a geometric shape known as a simplex to perform numerical optimization. The shape of a simplex depends upon the dimensionality of the function as a simplex consists of N+1 points, where N is the number of dimensions in the objective function being considered. Creation of a simplex starts by choosing a base point $x^{(0)}$. Then N additional points are created based upon the formula below. Note that j represents a dimension; i represents the index of the point in question; and both i and j are in the range [1, N].

$$x_j^{(i)} = \begin{cases} x_j^{(0)} + \delta_1 & j = i \\ x_j^{(0)} + \delta_2 & j \neq i \end{cases} \tag{2.4}$$

These N+1 points form the simplex. Spendley, Hext, and Himsworth suggest δ_1 and δ_2 be chosen such that all points are equidistant from the base point $x^{(0)}$ [1962]. For a two dimensional objective function, the result is a simplex that is a triangle. For a three dimensional function the result is a tetrahedron. To ensure the points are equidistant, the following formulas may be used.

$$\delta_1 = \frac{(N+1)^{1/2} + N - 1}{N\sqrt{2}} \tag{2.5}$$

$$\delta_2 = \frac{(N+1)^{1/2} - 1}{N\sqrt{2}} \tag{2.6}$$

The user may multiply both δ_1 and δ_2 by a constant α to scale the distances between these points up or down; however, this constant should be the same for all points created as part of the simplex and may cause unexpected results during optimization [Spendley et al. 1962].

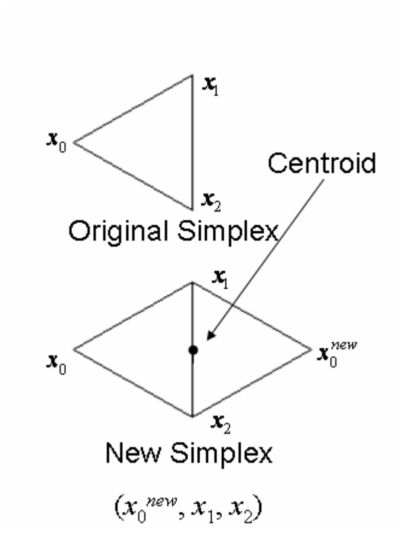


Figure 2.1: Simplex example [High 2005].

The objective function is evaluated at all N+1 points in the simplex, and the point that has the worst objective function value in the simplex is marked as the new base point, $x^{(0)}$. The simplex is then reflected about this worst point. The centroid of the remaining points, where i is in the range [1, N], is computed as follows.

$$x_C = \frac{1}{N}\sum_{i=1}^{N} x^{(i)} \tag{2.7}$$

The base (i.e. worst) point is then reflected about the centroid using the following formula.

$$x^{(new)} = x^{(0)} + \lambda(x_C - x^{(0)}) \tag{2.8}$$

A symmetric reflection is typically used and may be achieved by setting λ to 2. Reflection typically moves the new base point in the direction of a valley. This occurs because moving away from the worst point in a simplex is typically at least partially in the opposite direction of the gradient. To perform optimization via the Simplex Algorithm, this process is repeated until either the simplex reflects back upon itself or a single point within the simplex is repeated for M iterations, where M is defined in the formula below.

$$M = 1.65N + 0.05N^2 \tag{2.9}$$

Once the one of the aforementioned criteria is met, the size of the simplex is reduced (typically by half) and iteration continues. Iteration stops when the simplex becomes too small or the number of iterations surpasses a preset limit [Spendley et al. 1962].

Many variations upon the Simplex Algorithm exist. One of the most famous is the Nelder-Mead method. This method allows for both expansion and contraction of a simplex and is an excellent optimizer for some functions with low dimensionality [Torczon 1989]. Unfortunately, this optimizer fails in certain circumstances. In her dissertation, Virginia Torczon proved that the Nelder-Mead method fails on functions with a high degree of multidimensionality [1989]. For example, the Nelder-Mead method may fail on a 32-dimensional sphere function. Therefore, even though the Spendley [1962] method may converge to a local minimum, the simplex used therein will not collapse when used for general purpose optimization.

Algorithm 2.6: `Simplex`

```
Choose a base point.
Create the initial simplex using formulas (2.4),(2.5), and (2.6).
Evaluate and store f(x) at all simplex points.

While(numIterations < MAX_ITERATIONS)
      Find the simplex point j with the worst objective function value.
      Swap $x^{(0)}$ and $x^{(j)}$.
      Obtain the centroid using formula (2.7).
      Create $x^{(new)}$ using formula (2.8).
      Evaluate and store $f(x^{(new)})$.

      If($f(x^{(new)}) = f(x^{(0)})$),
            Decrease the size of the simplex and continue.
      Else if repetitions for any simplex point are greater than M,
            Decrease the size of the simplex and continue.
      Else,
            $x^{(0)}$    $x^{(new)}$
      End if.
      Retain the best objective function value.
End while.
```

Section 2.1.4 Genetic Algorithm

A Genetic Algorithm is an algorithm based upon population evolution. The theory behind population evolution is that fit individuals are selected to mate and during mating their genes are recombined and mutated to produce offspring. The best or fittest of these offspring survive to pass on their genes to a new generation. The same concepts are used in a Genetic Algorithm for optimization. For numerical optimization, an individual may be represented as a location within the search space and the corresponding objective function value [Goldberg 1989, Mitchell 1998, Passino 2005]. Many options then exist to "evolve" a population of individuals toward an optimal objective function value. In a Real-Coded Genetic Algorithm, individuals are selected from the population to produce children. Such individuals can be recombined in many ways. Typically this involves random selection from a subspace near or in between the locations of the parents. Mutation can be achieved by adding a small random value to the children. Finally, survival of the fittest can be realized by only retaining the children with the best objective function values [Herrera 1998, Mitchell 1998]. To better visualize the real-coded Genetic Algorithm, an example algorithm is provided.

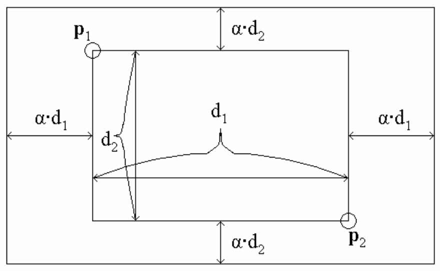


Figure 2.2: α-Blend Crossover Operator (BLX-α), redrawn from [Tsutsui et al. 1999].

The example of a real-coded GA presented in Algorithm 2.7: `RealCodedGA` includes four basic components of a GA: selection, recombination, mutation, and elitism (survival of the fittest) [Goldberg 1989]. First, tournament selection was used to choose parent individuals. Parents were chosen by comparing two randomly chosen individuals and selecting the one with the better fitness value. After choosing two parents, two children were produced by recombination [Goldberg 1989, Mitchell 1998]. For simplicity, the same number of children as parents is created in the example algorithm. The probability of recombination may be set near 60% for the algorithm presented in this work, though values between 50% and 95% will definitely be effective. During recombination, a real-coded crossover operator named the α-Blend Crossover (BLX-α) operator is used [Herrera et al. 1998]. This crossover operator creates a bounding box using the locations of the two parents to form bounds. The bounding box is extended to a size of 1.α times the distance between the locations of the two parents. Note that α is in the range [0,1), and if α is equal to zero the crossover is referred to as Arithmetic Crossover. So, if α = 0.5, the bounding box would be 1.5 times the distance between the parents in each dimension [Herrera et al. 1998]. An example of this is shown in Figure 2.2 above [Tsutsui et al. 1999]. In Algorithm 2.7: `RealCodedGA`, each pair of children is chosen from random locations within this bounding box. A mutation operator may be applied to the children after recombination. With, for example, a 0.5% probability, the mutation operator adds a small random value to a child [Herrera et al. 1998]. Once a generation is completed, a child population and a parent population exist. Pairs of parents that were not recombined are retained in the next generation. Children are compared to their parents, and those that exhibit better fitness are retained in the new population otherwise, their parents are retained [Goldberg 1989, Mitchell 1998].

These steps are performed on a population of a fixed size (e.g. 100 individuals), which is updated over a fixed number of generations (e.g. 1000 generations) or for a fixed number of function evaluations (e.g. 200,000 function evaluations). Each of the choices above builds a simple genetic algorithm that works quite well for single objective optimization [Goldberg 1989, Mitchell 1998]. That is not to say that this algorithm is without deficiencies. The GA algorithm presented here has difficulties with functions that have narrow opening angles to minima. Moreover, the crossover operator presented here may cause the algorithm to ignore dimensions in the search space; however, different arithmetic crossover operators exist that correct this problem [Herrera et al. 1998, Kita et al. 1999, Takahashi and Kita 2001]. Even with these deficiencies, for most problems the GA provides a simple, yet efficient comparison algorithm and will be used as such in the results section of this work.

Algorithm 2.7: `RealCodedGA`

```
Initialize a random location and evaluate the function value at that
location for each individual in a parent population of size NP.
Archive the best individual in the parent population.

For the number of generations,
      For i = 1 to floor(NP/2),
            Select a pair of parents to form children using a
            tournament selection.
            Create a pair of children by performing recombination on
            the parents with a fixed probability (e.g. 60%).
            If a pair of children was created,
                  Perform mutation on the children with a fixed
                  probability (e.g. 0.5%).
                  Evaluate the function values of the children.
                  Add the children to the child population.
            Else,
                  Add the parents to the child population.
            End if.
      End for.

      For i = 1 to NP,
            If child[i].fitness < parent[i].fitness)
                  parent[i]   child[i]
            End if.
      End for.
End for.
```

Section 2.1.5 Particle Swarm Algorithm

Creation of the Particle Swarm Optimization (PSO) algorithm was inspired by bird flocking and the "boids" simulation by C. W. Reynolds [1987]. Kennedy and Eberhart discovered that simulated bird flocking could be used for optimization purposes [1995]. The PSO algorithm makes use of a population of "birds" that are called particles. These particles consist of current and personal best locations and objective function values. Particles typically have a velocity as well. A population of particles mimics some of the properties of bird flight such as following a leader and individuality.

Particles follow the leader by moving in the direction of the particle with the best objective function value. They also exhibit individuality by moving in the direction of their personal best objective function value. Based on these properties, the PSO algorithm has been adapted to discrete and continuous optimization in both single and multi-objective functions [Kennedy and Eberhart 1995, Coello Coello and Lechuga 2002].

Numerical Particle Swarm Optimization makes use of a population of particles that start with uniformly distributed, randomly selected locations from the search space of a particular problem. Each of these points is moved about the decision space via the formulas below.

$$v_i(t+1) = \chi(v_i(t) + c_1 \cdot rand(0,1) \cdot (p_{best\_i}(t) - x_i(t)) + c_2 \cdot rand(0,1) \cdot (g_{best}(t) - x_i(t))) \qquad (2.10)$$

$$x_i(t+1) = x_i(t) + v_i(t+1) \qquad (2.11)$$

In the formulas above, $x_i(t)$ is the location of particle *i* within the state space at time *t*, χ is a constant used to avoid exorbitant velocity, $v_i(t)$ is the velocity of particle *i* at time *t*, $p_{best\_i}(t)$ is the personal best location of particle i at time t, $g_{best}(t)$ is the global best location at time t, and c_1 and c_2 are constants determined heuristically. With each time step, the position and the velocity of each particle is updated with respect to the formulas above. In addition, with each time step, the personal best of each particle is updated as necessary. Similarly, is the global best is updated for the entire set of particles [Kennedy and Eberhart 1995, Clerc and Kennedy 2002].

An example implementation of PSO similar to that of Algorithm 2.8: `ParticleSwarmOptimization` could make use of 100 particles that are updated through 1000 iterations. The standard PSO formula explained above for g_{best} may be used. In this formula, constants may be set to $c_1 = 2$ and $c_2 = 2$ as recommended by Kennedy and Eberhart [1995]. Smaller values such as $c_1 = 0.2$ and $c_2 = 0.2$ may be chosen to allow for additional exploration of the search space over the published constants [Coello Coello and Lechuga 2002]. The constant χ should be set to a number slightly less one such as 0.9 to allow for exploration and to prevent explosion of the population. This constant may be decreased as the algorithm converges to allow for smaller and finer movements near an optimal function value [Clerc and Kennedy 2002]. Like any stochastic optimizer, this one does, however, have problems finding minima in narrow valleys and in regions where there is an extremely low probability of finding a minimum. Even so, implementation of the algorithm as described above results in a decent optimizer with few deficiencies.

Algorithm 2.8: `ParticleSwarmOptimization`

```
Initialize random values for each particle.
Compute the $p_{best}$ for each particle.
Find the $g_{best}$ from the set of particles.

For the number of iterations,
      For each particle i,
            -Evaluate the following formulas:
             $v_i(t+1) = \chi( v_i(t) + c_1 \cdot rand(0,1) \cdot (p_{best\_i}(t) - x_i(t)) +$
               $c_2 \cdot rand(0,1) \cdot (g_{best}(t) - x_i(t)) );$
             $x_i(t+1) = x_i(t) + v_i(t+1).$
            -Evaluate the function value for particle i.
            -If the new function value for particle i is
             better than particle i's pbest, update particle
             i's pbest.
      End for.

      Update the $g_{best}$ if necessary.
End for.
```

Section 2.1.6 Differential Evolution

Differential Evolution (DE) is a population-based Evolutionary Algorithm (EA) that was created by Kenneth Price and Rainer Storn [Corne et al. 1999]. Much like other Evolutionary Algorithms, it makes use of mutation, recombination, and selection. The main difference between this algorithm and other EAs is that it uses the difference between two randomly selected vectors (i.e. x_{r1} □x_{r2}) for mutation. Much of the rest of the algorithm is quite similar to other EAs. It is important to note, however, that discrete recombination is used in the version of DE presented in this work, and selection based upon the better function value is used to determine whether a parent or a child vector is retained in the population [Price et al. 2005]. The details of this algorithm are described below.

Initialization of the Differential Evolution algorithm begins with a population of fixed size *NP*. In this population, each individual *i* is initialized to a uniformly distributed random location within the search space, and its objective function value is evaluated and stored within that individual. Additionally, a temporary individual is created for use when creating "child" individuals. Differential Evolution iterates for a fixed number of generations or until some finishing criteria is met. During each generation, a "child" is created for each individual *i* in the population. This is done by selecting 3 individuals at random from the population. These individuals, indexed *r1*, *r2*, and *r3*, are used in combination for both mutation and recombination. Indices are chosen such that *r1* C *r2* C *r3* C *i*. Mutation occurs by the formula listed below.

$$temp_j = p_j^{r3} + F \cdot (p_j^{r1} - p_j^{r2}) \qquad (2.12)$$

Note that *j* represents a dimension, *r1*, *r2*, and *r3* are indices, and *F* represents a mutation factor in the range (0,1+). Recombination, as noted before, is discrete. This recombination is performed using a crossover factor *CR*. *CR* is a constant probability factor in the range [0,1) used to make a decision whether to keep the value from dimension *j* of the parent *i* or to use the mutated value for dimension *j* from equation (2.12). In this work, at least one dimensional value within the child will contain a mutated value. After a child vector is created, its objective function value is evaluated.

If the child vector has a better function value that the parent with index *i*, the child replaces the parent. Otherwise, the parent is retained. This process occurs for each individual *i* within the population over a number of generations or until some finishing criterion is met [Price et al. 2005].

The DE algorithm, presented as Algorithm 2.9: `DifferentialEvolution` below, is one version (DE/rand/1/bin) presented in [Corne et al. 1999]. Reasonable values for the constant *F* range between 0.4 and 0.9 as indicated by graphs in [Corne et al. 1999]. Similarly, the decent values for the crossover constant *CR* range from 0.8 to 1.0, and the population size should be between 2 to 100 times the number of dimensions in the problem with 20 times the number of dimensions typically working best. Finally, the number of generations should be set to a reasonably large number such as 1000. This algorithm works quite well as a general purpose optimizer so long as initialization is uniform over the search space and parameters are set appropriately [Price et al. 2005].

Algorithm 2.9: `DifferentialEvolution`

```
Initialize a population "pop" of NP individuals each with a random
location.
Compute and store the objective function at each location.
Create an individual called temp.

For the number of generations,
      For each individual i,
            Choose 3 unique individuals at indices r1, r2, and r3 from
            the population at random.

            Assign j a random value between 0 and NUM_LOC-1, inclusive.

            For k = 0 to NUM_LOC-1,
                  If( rand(0,1) < CR | k = NUM_LOC-1 ),
                        temp[j]    pop[r3].location[j] +
                        F·(pop[r1].location[j] – pop[r2].location[j]);
                  Else
                        temp[j]    pop[i].location[j];
                  End if.

                  Ensure temp[j] is within the bounds of the problem
                  specification.

                  j    (j + 1) mod NUM_LOC;
            End for.

            Compute the fitness of temp.

            If(temp.fitness < pop[i].fitness),
                  pop[i].fitness    temp.fitness;
                  pop[i].location    temp.location;
            End if.
      End for.
```

```
    Archive the individual with the best fitness.
End for.
```

Section 2.2 Biology

In this section we discuss the biological aspects of slime mold. A commonly studied slime mold is the species *Dictyostelium discoideum*. Dd is of biological interest because it is one of a small group of amoeba that exhibit self-organizing behavior. This interest in Dd and other amoeba with self-organizing behavior exists in biological communities because these organisms exhibit behavior that represents a step between multicellular organisms (e.g. animals) and single celled organisms like bacteria and non-organizing amoeba [Kessin 2001]. Slime molds have also provided interest to computer scientists. The self-organizing behavior of slime mold lends itself to easily implemented parallel systems and to cellular automata [Resnick 1994, Matthews 2002].

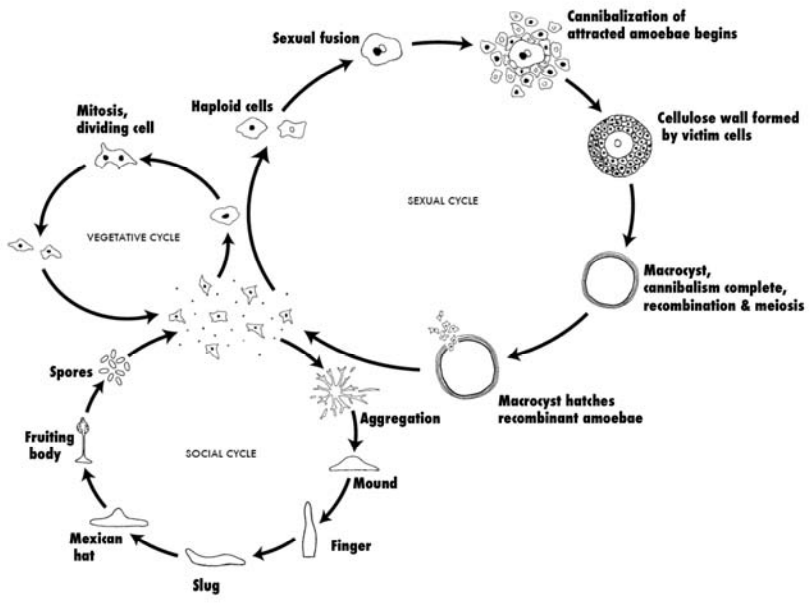

Sexual fusion
Cannibalization of attracted amoebae begins
Haploid cells
Mitosis, dividing cell
Cellulose wall formed by victim cells
SEXUAL CYCLE
VEGETATIVE CYCLE
Macrocyst, cannibalism complete, recombination & meiosis
Spores
Macrocyst hatches recombinant amoebae
Aggregation
Fruiting body
SOCIAL CYCLE
Mound
Finger
Mexican hat
Slug

Figure 2.3: Lifecycle of Dictyostelium discoideum [Brown and Strassman 2009]. Image used under the terms of the Creative Commons Attribution 3.0.

Computer scientists have built simple interactive models of slime mold in the past 15 years, and a few have attempted to use slime mold for discrete optimization [Rothermich 2002].

The lifecycle of Dd will be studied to better understand this amoeba and how it and other amoeba like it form slime molds. Dd takes on a number of states in its life cycle, as shown in the figure above. When food is readily available, Dd exists in a vegetative state. It uses pseudopods for its movement and forages for bacteria and decaying materials such as logs. In the absence of live food, Dd may attempt to attract food by releasing folic acid, a typical nutrition source for bacteria. Dd act as individuals in this stage of their lifecycle and exhibit no self-organizing or swarm-like behavior. They may also procreate in this stage by binary fission or they may hibernate as a microcyst (small group of dormant cells) or macrocyst (large group of dormant cells) [Kessin 2001]. This stage of the Dd lifecycle is relatively uninteresting when compared to the other stages.

Dd exhibit cooperative swarm-like behavior only upon starvation. During extended starvation, Dd amoebae release a chemical called cyclic Adenosine Monophosphate (cAMP). This chemical is like a pheromone and attracts the amoebae. Movement of the amoeba is opposite the gradient of cAMP and detection of this chemical during starvation causes a Dd amoeba to release additional cAMP [Dallon and Othmer 1997, Kessin 2001, Erban and Othmer 2007]. When released in a group of starving amoeba, cAMP causes the nearby amoeba to initiate a signaling cascade that causes a streaming effect toward the first amoeba, called a pacemaker, which released cAMP. This step is referred to as aggregation [Kessin 2001, Erban and Othmer 2007]. Dd move in streams toward this pacemaker until a mound is formed. Dd amoebae in the mound engulf themselves in slime to provide protection for the group [Kessin 2001]. The Dd also organize themselves into motile slug with a head and a tail, which represent the amoeba that will form a stalk and spores respectively [Marée et al. 1999 □Migration□, Marée et al. 1999 □Phototaxis□, Kessin 2001]. The slug moves toward a light source so a fruiting body consisting of a stalk and spores may be formed. Spores from the fruiting body are eaten and deposited as waste by animals or deposited by wind [Kessin 2001, Pollitt 2006]. Stimulus from a food source causes these spores to activate as new vegetative cells [Kessin 2001]. Each of these steps is elaborated upon in this section, beginning with the vegetative state and ending with the fruiting body state [Kessin 2001]. In further sections their simulations and applications will be discussed.

Section 2.2.1 Vegetative Amoebae

Vegetative amoebae are individual amoebae that are independent and have little or no interaction with other amoebae in the environment. When Dd are vegetative, they exist in soil, humus, and decaying logs. Dd hunt bacteria in these environments as they are as much as 1000 times bigger than their prey. Dd may also eat yeast. In most cases, Dd hunt their bacterial prey by detecting folate gradients. They do so because folate (Vitamin B9) is a common food source of bacteria. Dd even possess the ability to emit folate to attract their prey [Kessin 2001, Pollitt 2006, Erban and Othmer 2007].

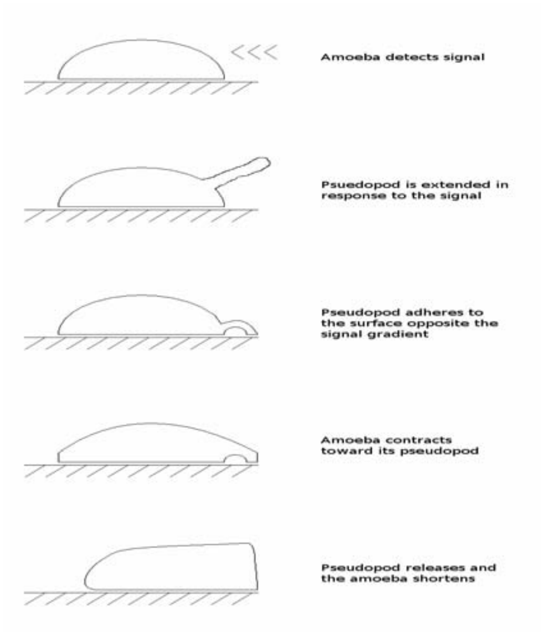

Amoeba detects signal
Psuedopod is extended in response to the signal
Pseudopod adheres to the surface opposite the signal gradient
Amoeba contracts toward its pseudopod
Pseudopod releases and the amoeba shortens

Figure 2.4: Example of amoeboid cell movement.
Redrawn from [Kessin 2001].

Movement of these amoebae is similar to the movement in some mammal cells such as leukocytes (white blood cells). This is one of the reasons that Dd is well studied. During movement Dd amoebae may move at a speed up to 20 μm/min [Dallon and Othmer 1997, Erban and Othmer 2007]. Movement is achieved through the use of pseudopods. These pseudopods are similar to arms, but they have chemical sensitivity at the ends and are also capable of adhering to surfaces at the ends. Movement is typically preceded by sensory perception. First, an amoeba receives a signal such as stimulus from a folate gradient. Dd are able to ascertain the approximate direction of a gradient across their cell bodies. Depending on the type of signal, the amoeba may decide to move in the direction of the gradient or to move opposite it. If, for example, the initial stimulus was folate, the amoeba would decide to move opposite or nearly opposite the folate gradient. Dd have a similar response to cyclic Adenosine Monophosphate (cAMP). Ammonia elicits a movement in the direction of the gradient, to direct Dd away from this noxious substance [Kessin 2001, Marée and Hogeweg 2001]. After ascertaining the appropriate direction of movement, the amoeba then extends a pseudopod, which has the appearance of a protrusion [Kessin 2001].

The pseudopod adheres to a surface in the direction of the stimulus or opposite it depending upon the type of stimulus. Chemotactic sensors at the end of the pseudopod provide additional sensory information. Depending on the type of signal and the direction of movement, the amoeba may decide to move in that direction or to retract the pseudopod. During movement, a Dd amoeba contracts its body wall in the direction of the pseudopod. Thereafter, the tension in the direction of the pseudopod in conjunction with cell motility would cause the amoeba to de-adhere from its previous location and move toward the new location. An example of the movement previously described is shown in the figure above. It is important to note that such movement may not occur if detection of a negative stimulus occurs at the end of the protrusion [Kessin 2001]. Interestingly, several versions of the simplex optimization method described in section 2.1.3 have been based upon this type of movement [Torczon 1989].

Of further interest are the differing stages of life Dd may enter in response to environmental stimuli while in the vegetative state. The first of these is the microcyst. A microcyst is an amoeba that is encapsulated in cellulose. It is in most cases dormant and is formed in response to multiple conditions. These are the simultaneous presence of starvation and either increased osmotic pressure (too much water in the environment) or ammonia (a negative stimulus) [Kessin 2001, Marée and Hogeweg 2001]. These stimuli cause a Dd amoeba to form a cellulose coating in place of its cell wall and to go dormant until environmental conditions are more suitable. The second of these life stages is the macrocyst. This stage is typically elicited by two or more well fed amoebae that are of different sexual types. The cells fuse together and form a large cyst with a cellulose wall. Additional amoebae may be attracted to join the cyst prior to formation of the cellulose wall by the cyst's release of cAMP. The cells within the macrocyst reproduce to form new Dd amoeba through meiosis. The third and final life stage vegetative Dd may enter is the aggregation stage [Kessin 2001]. Entrance into this stage will be described in the next section.

Section 2.2.2 Aggregation

Aggregation is initiated by starvation of a group of Dd that are in close proximity. It is the first step that Dd take involving self-organizing activity. The self organizing activity taken on by amoebae is multi-faceted. First, amoebae must realize that they are starving. Next, one amoeba, referred to as a pacemaker, must begin signaling that it is starving. Other nearby amoebae follow suit by aggregating toward the pacemaker. A cascading signaling process then occurs causing more and more starving amoebae to aggregate. Finally, the aggregate realizes when to shut off the signal when enough amoebae converge [Kessin 2001]. The details of each of these steps are quite interesting and are explained in this subsection.

Aggregation is initiated by a single Dd amoeba called a pacemaker within 6 to 10 hours after starvation. The aggregative process occurs over a 1 cm^3 area in which as many as one million Dd amoebae may exist. Pacemaker amoebae occur at a frequency of 1 in 1000 to 10000 amoebae; however, the mechanism by which an amoeba is chosen to be a pacemaker is unknown [Dallon and Othmer 1997, Kessin 2001]. It is known that the amoeba chosen as the pacemaker begins to emit a chemical called cyclic adenosine monophosphate (cAMP). This chemical is a normal attractant of Dd amoebae. While the pacemaker is emitting cAMP, other starving Dd within close proximity of the pacemaker become highly receptive to cAMP. This receptivity is initiated by a genetic factor that initiates this receptivity in response to starvation [Kessin 2001]. Note that without the existence of a pacemaker, movement of Dd amoebae may be aberrant during starvation [Pollitt 2006].

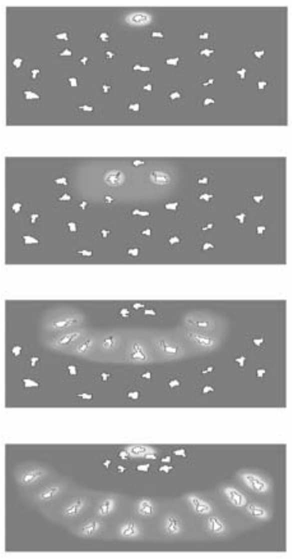


Figure 2.5: Example of cAMP waves and amoeboid cell movement during aggregation. Redrawn from [Kessin 2001]

The genetic factor that causes high receptivity to cAMP also causes amoebae to extend their pseudopods in the direction of cAMP (i.e opposite a cAMP gradient) at a high frequency (approximately 95% of the time) [Erban and Othmer 2007]. The cAMP emitted by the pacemaker disperses over a small (in terms of micrometers) area only attracting amoebae in its immediate vicinity. This is only enough cAMP to attract a few amoebae. To form a mound, the amount of cAMP dispersed must cover a larger area (1 cm^3), and, as expected, starving Dd within the vicinity of the pacemaker move toward the pacemaker and begin releasing cAMP [Dallon and Othmer 1997, Kessin 2001]. This process repeats with starving Dd further from the pacemaker. Because detection of cAMP by Dd degrades cAMP, the process of aggregation occurs in waves as shown in the figure below [Dallon and Othmer 1997, Kessin 2001].

cAMP waves continue outward from the pacemaker in a progressive fashion as shown in the figure above. The directedness of the waves also causes amoebae to aggregate as in streams as shown above. The process of signal uptake, movement, and further expression of cAMP increases the amount of cAMP in an area exponentially. The expression of cAMP eventually may become too high and attract too many Dd. To prevent this occurrence, Dd amoebae employ a genetic cell counting factor which enables them to stop expressing as much cAMP when a significant number of cells begin aggregating to form a mound. The expression and exponential growth of a chemical by cells until equilibrium or a limiting factor is reached is also known as the signal transduction pathway (STP) [Dallon and Othmer 1997, Kessin 2001, Erban and Othmer 2007].

Section 2.2.3 Mound

The third stage in the slime mold lifecycle is the mound. As the aggregation stage ends, Dd amoebae are located in close proximity to each other. There are typically thousands of amoebae in close proximity in a group that is so tightly packed that it looks like a mound. As the amoebae aggregated toward the pacemaker they also began to excrete a slime-like substance consisting of cellulose and a glycoprotein. This substance is used to form a sheath that will encapsulate the amoebae within the mound. The sheath serves several purposes: it protects the mound from nematodes (predators of Dd); it serves to conserve the volume of the mound; and it also allows for containment of signaling molecules pertinent to the mound□s movement when it becomes a slug [Kessin 2001].

While in the mound, amoebae also begin organizing themselves. The Dd amoebae sort themselves into two different types: prestalk and prespore. These types obviously determine whether a particular amoeba will become a spore or will die to become part of the stalk of the fruiting body. These two types always occur at a rate of 1/5 prestalk and 4/5 prespore. The way that amoebae are chosen to become prestalk or prespore is also quite interesting. The fittest amoebae are always chosen to become spores [Segel 2001, Kessin 2001]. These amoebae are those that had previously led a good life; that is, they consumed a large amount of resources. Unfortunately, those amoebae that did not eat as much are chosen to be prestalk, and interestingly those amoebae that were the result of binary fission (asexual reproduction from one cell splitting into two) are also chosen to be prestalk because they appear to have eaten less during their lifetimes [Segel 2001]. Organization has a second purpose that is even more interesting. Prestalk amoebae move toward one end of the mound to become a head in the slug stage. They become sensitive to light and particular chemicals. They are also able to send chemical messages to the prespore amoebae that make up the tail of the slug. The mound becomes a mobile slug once amoeboid organization is complete [Savill and Hogeweg 1997, Marée et al. 1999 □Migration□, Marée et al. 1999 □Phototaxis□, Kessin 2001, Marée and Hogeweg 2001].

Section 2.2.4 Slug

The slug stage of the Dd lifecycle is quite interesting. It is of particular interest to biologists because the slug has the outside appearance of a multicellular organism, but is not actually a multicellular organism. This stage in the Dd lifecycle represents an intermediate ecological step between a single celled organism and a multicellular one [Kessin 2001]. The slug is an aggregate of individual amoebae that are self-organizing. These amoebae are organized into a head and tail. Of great interest to biologists are the movement of the slug and its reactions to various environmental stimuli [Savill and Hogeweg 1997, Marée et al. 1999 □Migration□, Marée et al. 1999 □Phototaxis□, Marée and Hogeweg 2001, Kessin 2001]. These interesting facets of the slug stage will be discussed in this subsection.

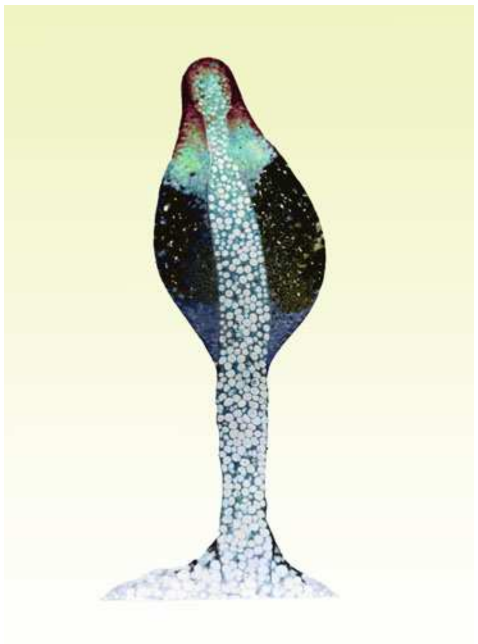
We know that the slug is divided into a head and tail, but of particular interest is the composition of these portions of the slug and their reactions to various stimuli. The head is composed of 1/5 of the amoebae within the slug. It consists solely of prestalk amoebae, and these amoebae direct the movement of the slug. The amoebae in the head move in a scroll wave (vortex) pattern and primarily react to light (phototactic) and chemical (chemotactic) stimuli [Marée et al. 1999 “Migration”, Marée et al. 1999 “Phototaxis”, Kessin 2001]. The head directs movement toward light in an attempt to ensure amoebae are in an open area when culmination and formation of the fruiting body occurs. Chemotactic movement primarily occurs to move the slug away from noxious chemicals such as ammonia [Marée and Hogeweg 2001, Segel 2001, Kessin 2001]. The head directs the movement of the remaining 4/5 of amoebae by emitting cAMP signals. All of these tail amoebae are prespore cells. Since the slug is encapsulated in cellulose and glycoproteins, the cAMP signals will only stimulate cells within the slug. This causes directed movement of the tail amoebae in a column-like fashion. This movement is similar to the treads of a tank [Kessin 2001].

Timely movement of the slug toward an area where culmination may occur is essential as the amoebae within it are expending resources without the ability to eat. The amount of time required for such migration may be a matter of hours or days; however, if a suitable area cannot be found, all amoebae within the slug may perish. Some experiments have indicated continued slug movement toward a light source until death. This can occur if the light source is continually moved away from slug. Thus, stability within the slug's environment is essential for formation of the fruiting body [Kessin 2001].

Section 2.2.5 Fruiting Body and Spore Dispersal

The fruiting body is the final self-organizing stage that starving Dd amoebae undertake. During this stage, prestalk amoebae, which were the head of the slug, slow their movement and reorganize themselves into a stalk. As each prestalk amoeba becomes part of the stalk, it dies. While prestalk amoebae are becoming stalk, the prespore amoebae also reorganize themselves. The prespore amoebae surround the prestalk amoebae as they become the stalk, and slowly climb the stalk. As they climb, the prestalk amoebae undergo metamorphosis that changes them from amoebae to spores. These spores are then eaten by nematodes or other animals and are deposited in new locations. Spores may also be blown away by wind, eaten and redeposited in the droppings of birds or nematodes, or washed away [Kessin 2001].

The fruiting body stage begins with culmination, the point at which movement of the slug stops movement and begins formation of the fruiting body. According to Kessin, the exact cause for culmination is unknown, but it is suggested that possible build-up of ammonia from developing prespore cells causes the expression of two genes (ecmA and ecmB) known to be expressed during culmination [2001]. Once the slug culminates, it begins to form a shape similar to a Mexican Hat. During formation of the Mexican Hat, the head, which contains prestalk cells, begins to point vertically, and the prespore cells move beneath the head to form a mound-like structure. The mound centers itself beneath the prestalk amoebae. Thereafter, prestalk amoebae from the head move down through the center of the prespore mound. Prestalk cells then extend downward through the mound of prespore amoebae. The prespore cells also begin moving up the stalk as it is being formed. Once the prestalk cells reach the bottom of the prespore mound, they begin to form a basal disc along with rearguard cells. This disc anchors the stalk to the ground. The stalk continues extending upwards and thinning. As prestalk amoebae take their place in the stalk, they die. Prespore amoebae move toward the top of the stalk and metamorphosis to spores (dormancy) by encapsulating themselves [Kessin 2001].



Copyright, M.J. Grimson & R.L. Blanton, Biological Sciences Electron Microscopy Laboratory, Texas Tech University [Grimson and Blanton 2009].

Figure 2.6: Example of a Fruiting Body.

The Dd lifecycle does not end with the fruiting body. Spores are dispersed so the vegetative stage may begin anew. Dispersal typically happens in one of two ways. Infrequently, spores may be dispersed by wind; although this is not considered by many researchers to be a normal cause of spore dispersal. More often, spores are eaten by the natural predators of Dd nematodes. Nematodes are small worms, and they will eat Dd amoebae and Dd spores. Interestingly, Dd spores pass through the digestive tract of nematodes without disruption or degradation. Eaten spores are deposited as waste from nematodes allowing for their dispersal. After dispersal, spores must be germinated to activate spores to become vegetative amoebae [Kessin 2001]. In the next section, simulations of slime molds in various forms are discussed. In particular, a continuation of the biological discussion is provided in the next section in the form of biological simulations of the different stages of the lifecycle.

Section 2.3 Slime Mold Simulations

In this section the means to transform Dictyostelium discoideum (Dd) from biology to simulation and later to an optimization algorithm are discussed. This process is neither simple nor easy. We know from the previous section that there are many steps to the Dd lifecycle from single celled amoeba to fruiting body. Simulations for each of these portions of the lifecycle exist and vary in complexity, but most share common traits. Many models employ a grid or lattice on which Dd exist or where portions of the cell surface are modeled. Most allow this grid or lattice to be a cellular automaton and allow amoeba to interact with it if it is the world in which they exist. Models of cell surfaces allow for interactions between amoeba surfaces (i.e. between CAs) and for self interactions. Some model amoeba as CAs or a combination of some CA/PDE/statistical model. In this section, we first investigate some of these models, and then we move to educational models for additional study.

Biological studies involving simulation of Dd are quite diverse. These studies include those of single celled amoeba and their vegetative movement, aggregative movement, mound formation, slug chemotaxis and phototaxis, and fruiting body formation. Each of these will be discussed in this section. Additionally, several educational studies of Dd as CA have been made. Resnick introduced a model of aggregation and slug formation to teach high school students about parallelism using the StarLogo language. Matthews also created an educational model of Dd. His model is intended to provide an example of how CAs work. Both of these models will also be discussed in this section even though these models primarily deal with the aggregation and slug states. Discussion of many of these models necessitates preliminary information on CA.

So, in this section we will first discuss CA, including a formalism for the types of CAs used in the rest of this work. Then, we will discuss existing models for differing portions of the Dd lifecycle. Next, the educational models will be discussed. Initial suggestions will be made about how Dd could be used as an optimization algorithm. Finally, the nearest neighbor and approximate nearest neighbor algorithms will be discussed in the context of their possible use in Dd simulations. These algorithms will be used in the next chapter as part of the presented optimization algorithm.

Section 2.3.1 Cellular Automata

So, what is a cellular automaton? The answer is a complicated one because so many variations of CAs exist. In fact, there is no single formalism to define all CA. Nevertheless, CAs do share some traits. They are automata and are deterministic and typically discrete in both space and time. CAs were invented by John von Neumann. He conceived them in the 1950s as a tool to model biological systems. Since then they have been used as such, but they have also been used for many other systems. On the same note, most CAs share five traits that are explained in Ilachinski's book on CA [2001]. For informational purposes those traits are listed here.

- A grid/lattice of cells (typically 1, 2, or 3-Dimensional)
- Homogeneous cells (all cells share the same properties)
- Interactions between individual cells are only local (referred to as neighborhood)
- Cells take on only discrete values or states
- Update of cell states is based upon a set of rules

So, knowing these facets of a CA, a formalism for CAs used in this work will be created. This will serve as the basis for the CAs that will be described throughout this work [Ilachinski 2001].

To provide the formalism for the CAs used in this work, we will divide the CA into several parts similar to those listed above. These parts are provided in the list below.

- State space
- Rules
- Neighborhood
- Boundary conditions
- Starting State

In our description, the state space will be first to be described. Then, we will describe cell locations, states, and boundaries. Finally, we will discuss neighborhoods and rules to complete the formalism [Ilachinski 2001].

We know that a CA uses a lattice or grid as its state space. It is also know that these spaces are of low dimensionality. Furthermore, this grid may be viewed as a discrete space. As such, it may be bounded or infinite. The space may also be toroidal, have holes, etc. The locations within the grid will be referred to as cells. Their values will be taken from a discrete set. These value may be anything, but since they are discrete, they may be mapped to the range 0, 1, □ , *q*, without loss of generality. Thus, we may define a set Γ to contain this range.

$$\Gamma \equiv \{0,1,\ldots,q\} \tag{2.13}$$

This set of values will serve as the possible values each cell may take on [Ilachinshi 2001, Monismith and Mayfield 2008].

Given our set of values, we may now investigate cell locations. A cell location is a discrete location in the grid. This location may be represented as a tuple that typically indicates the location along each dimension of the grid; for example, a tuple may be listed as (i, j, k, □). Each of these locations represents a cell that may take on a location from the set Γ at each discrete time step. We denote single cells as σ using a tuple to denote their location and a time t to denote their value at the current time step. A formal definition of σ is provided below.

$$\sigma_{i,j,k,\ldots}(t) \in \Gamma \tag{2.14}$$

Now the grid, Σ, also referred to as the state space, may be defined as the set containing all cells $\sigma_{i,j,k,\square}$ as shown below.

$$\Sigma \equiv \{\ldots, \sigma_{i,j,k,\ldots}, \ldots\} \qquad (2.15)$$

Note that the bounds of this space may be defined as necessary to the problem in question. They may be limits upon the number of cells along each dimension, intermittent limits, etc. These bounds will be referred to as B. Discussion of bounds will always be specific to the problem in question and as such will not be discussed further here [Ilachinski 2001, Monismith and Mayfield 2008].

Of additional importance are the local interactions between each cell. Relationships between each cell $\sigma_{i,j,k,\square}$ are defined first by a neighborhood. As the word implies, these neighborhoods typically consist of relationships between nearby grid locations. These may be applied to any N-dimensional CA. Typically, two different types of neighborhoods are used with CAs. These are called von Neumann and Moore neighborhoods. A Neumann neighborhood only uses the immediate nearest neighbors as the neighborhood for each cell. An example is shown in Figure 2.7 below.

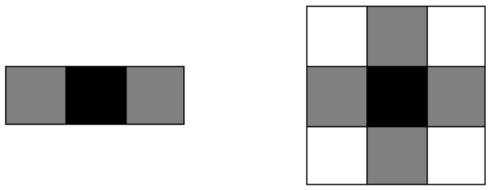


Figure 2.7: 1-D and 2-D von Neumann neighborhoods. Grey cells are the neighborhoods of black cells Redrawn from [Auer and Norris 2001].

A Moore neighborhood uses as neighbors the cells with centers within distance *nHD* of the center of the cell in question. Note that *n* is an integer with value greater than or equal to one, and D is the number of dimensions in the state space. Examples of the Moore neighborhood are provided in the figure below. The neighborhood used in a CA in this section will be referred to as *N* [Ilachinski 2001, Monismith and Mayfield 2008]

Now, we will discuss rules. Rules for a CA determine the update of the entire CA grid Σ with each discrete time step. Rules must also take into account the neighborhood and dimensionality of the state space used. A single rule will be denoted as φ. Rules work as mappings. They typically map a group of cell values (e.g. those from a neighborhood) to a single cell value as shown below.

$$\varphi : \Gamma \times \Gamma \times \ldots \times \Gamma \rightarrow \Gamma \qquad (2.16)$$

In many cases φ is a function; however, this is not required. Rules may be grouped together into a set that represents all possible rules for a CA. This set will be denoted as Φ, and it will be used to complete our formalism [Ilachinski 2001, Monismith and Mayfield 2008].

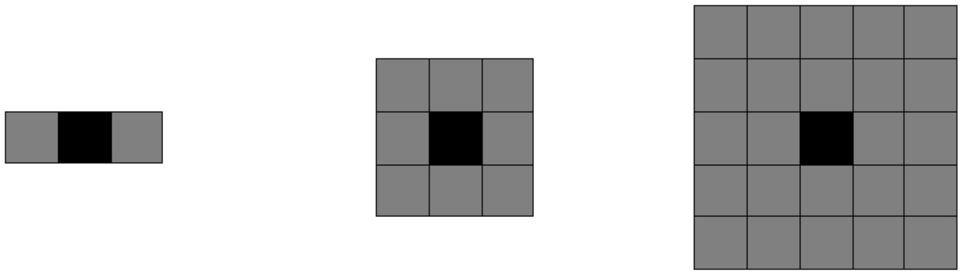


Figure 2.8: Moore Neighborhoods.
1-D Moore neighborhood and 2-D Moore neighborhoods of size one and two, respectively.
Grey cells are the neighborhoods of black cells [Auer and Norris 2001].

We may now complete our formalism for the CA. We have defined the state space (grid), Σ, the neighborhood, *N*, the set of rules, Φ, and boundaries, *B*. A starting state however, has not yet been defined. This is the set of initial values for all cells. We will denote the starting state as *S* and it will be defined as shown below.

$$S \equiv \{\ldots, \sigma_{i,j,k,\ldots}(0), \ldots.\} \qquad (2.17)$$

Given this definition, the basic formalism for the CAs used in this work may be constructed. A CA, *C*, may be defined as a combination of a state space Σ, neighborhood, *N*, rules, Φ, boundaries, *B*, set of values for each cell, Γ, and starting state *S* as shown below.

$$C \equiv \{\Sigma, B, \Phi, S, N, \Gamma\} \qquad (2.18)$$

This concludes the discussion of the formalism. In the next section, existing models of Dd will be discussed [Ilachinski 2001, Monismith and Mayfield 2008].

Section 2.3.2 Biological Simulations

Computer simulations and formulaic representations of the movement and formation of key steps in the Dd lifecycle have been of great interest to the biological community in the past 50 years. The reasoning behind such interest is that these simulations allow biologists to verify that their models of movement and chemical uptake are correct and to compare them against biological observations. Such simulations are available for all portions of the Dd lifecycle, but particular interest has been paid to the aggregative, slug, and fruiting body stages as many of the mechanisms present in these stages of the Dd lifecycle are highly correlated with the mechanisms of human cell interaction and motility. Modeling of the vegetative stage is lumped together with the aggregative stage in the work of Erban and Othmer because the mechanics used in both the vegetative and aggregative stages are extremely similar [2007]. Models of these two stages are by PDEs. The mound, slug, and aggregative stages have been modeled in several different studies including those of Marée and Hogeweg [2001], Savill and Hogeweg [1997], and Segel [2001]. Dispersion, on the other hand, is not well studied from a modeling perspective. The relatively chaotic aspects of dispersion, including wind, rain, and birds, effectively prevent any model, other than random relocation of amoebae, from being accurate. Because of the importance of such models to the biological community and the possibility of obtaining insight into their use or modification as a part of a numerical optimization algorithm, the primary focus of this subsection will be the study of biological simulations of Dd amoebae.

The first of the simulations investigated in this subsection are the cell taxis models of Erban and Othmer. Recall that taxis is the movement of a cell in response to a stimulus. As previously noted, Dd exhibits taxis in response to chemical stimuli such as cAMP, referred to as chemotaxis. This response is available to Dd amoebae because they are able to sense chemical gradients across their cell walls. Using this sensor information Dd amoebae are able to ascertain the correct direction of motion. Erban and Othmer note that during chemotaxis Dd undergoes four stages of movement. These are first extending a pseudopod at the amoeba's front edge, then, attaching to a substrate, next, squeezing its cytoplasm forward through contraction of the cell body, and finally detaching its tail from the substrate to squeeze the rest of the cell body toward the pseudopod's location. Their model of this movement is through a series of partial differential equations, some of which are presented here, in brief.

With the description of motion, we may go on to discuss how motion may be modeled in a formulaic sense. First, it is important to note that eukaryotic cells such as amoebae and some mammalian cells move on a substrate (surface) by modifying the shape of their cell bodies, e.g. by extending a pseudopod. During this movement volume and density of the cell as a whole is conserved. Thus, any equation representing amoeboid cell movement must take this into account. Erban and Othmer note this fact from previous works when defining a formula for cell movement [2007]. They define cell movement based upon the flux of a cell (its change in volume over time) as in the formula below.

$$\mathbf{j} = -D\nabla n + n\mathbf{u}_c \tag{2.19}$$

In this formula, $\mathbf{j}$ is the amoeboid cell's flux, D is the diffusion constant of the chemical stimulus, n is the density of the amoeba, and $\mathbf{u}_c$ is the velocity of the amoeba. Since an amoeba's velocity is dependent upon the presence and gradient of a chemical signal, the velocity $\mathbf{u}_c$ may be defined as shown below.

$$\mathbf{u}_c = \chi(S)\nabla S \tag{2.20}$$

In the equation above, S represents the chemical stimulus and $\chi(S)$ is the function representing the amoeba□s sensitivity to chemical stimulus. Since cell density is conserved if we assume no change in osmotic pressure and no cell death, the flux equation may be differentiated to present a formula for conservation of density as shown below.

$$\frac{\partial n}{\partial t} = \nabla(D\nabla n - n\chi(S)\nabla S) \tag{2.21}$$

Erban and Othmer explain that an additional formula for the change in distribution of the chemical stimulus may be necessary in addition to the equation above [2007].

To completely model the Dd and chemical stimulus environment, much additional information is required. Work presented by Erban and Othmer shows that with the inclusion of equations to represent the position, velocity, and chemical signal strength, it is possible to produce a velocity transport jump equation that represents most of the factors Dd amoebae and like cells encounter in their environments as they chemotaxis [2007]. Such extended equations include internal Dd variables and chemical stimulus evolution equations. Furthermore, Erban and Othmer derive simplified equations to simulate the movement of amoebae in the presence of a chemical stimulus such as cAMP [2007]. The extended equations are beyond the scope of this work; however, the simulation equations from the Erban and Othmer paper are presented below [2007].

$$\frac{dx}{dt} = v\,,\ \frac{dv}{dt} = \frac{\gamma q - v}{\tau_d}\,, \tag{2.22}$$

$$\frac{dq}{dt} = \frac{\nabla S(x,t) - q}{\tau_a} \tag{2.23}$$

In the equations above, x represents the position of the amoeba, v represents its velocity, q represents the amoeba□s internally sensed gradient of the signal, τ_a represents the decay rate of the chemical signal, and τ_d represents the time necessary for the amoeba to orient itself toward the signal. Since Dd and other cell types occasionally exhibit random errors in the sensing of chemical stimuli, a small percentage of movements in the model are purposefully random [Erban and Othmer 2007]. Additionally, the model is useless to represent Dd in the presence of no chemical stimulus. In fact, Dd amoebae are assumed to extend pseudopods randomly if no stimulus is available [Pollitt 2006, Erban and Othmer 2007].

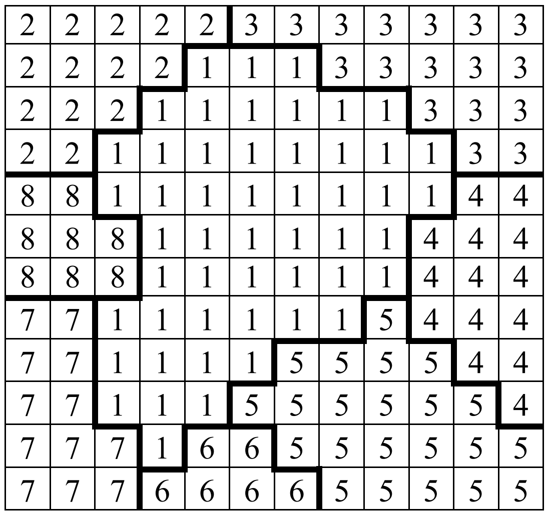
Of the models used for the mound and slug stages, that of Glazier and Graner appears to hold the most merit in a classical sense [1993]. It is often cited and used or modified to build models for mound formation and slug movement. This 2-D model was created in 1993 to provide solid evidence that only portions of the Dd cell body need be used to model the cell sorting that occurs during Dd mound formation and between animal cells. The Glazier and Graner [1993] model makes use of a discrete Potts

Hamiltonian equation to represent the total surface energy of a single amoeboid cell as represented on a lattice. Note that the Potts Hamiltonian is typically used to model magnetic spins on a lattice. This Hamiltonian attempts to represent many amoebae or other types of cells as groups of like spins on a lattice. In the Glazier and Graner [1993] model usually only two different types of cells are considered such as prespore and prestalk amoebae. This equation is presented below.

$$\begin{aligned} H_{Potts} = & \sum_{(i,j),(i',j')\text{ neighbors}} J(\tau(\sigma(i,j)), \tau(\sigma(i',j'))) \cdot (1-\delta_{\sigma(i,j),\sigma(i',j')}) + \\ & \lambda \sum_{\text{spins } \sigma} (a(\sigma) - A_{\tau(\sigma)})^2 \cdot \Theta(A_{\tau(\sigma)}) \end{aligned} \tag{2.24}$$

In the equation above, the Hamiltonian, H_{Potts}, represents the total surface energy of a lattice point, σ(i,j) represents the spin of one lattice site (which amoeba it belongs to), τ(σ) represents the cell type associated with the spin σ (e.g., prespore or prestalk), J(τ, τ) represents the surface energy between different cell types, a(σ) is the area (number of lattice sites) occupied by the amoeba, A_τ is the number of lattice sites amoebae of type τ should occupy, and λ is a Lagrange multiplier used to indicate the strength of the conservation of volume. Θ(x) = {0, x < 0; 1, x 7 0}is a step function used to turn the area constraint on or off as a third cell type with no area constraint is used to represent the lattice in the Glazier and Graner model [1993].

Glazier and Graner [1993] implemented a simulation of their model using three cell types. The first two types referred to as light and dark types have high and low surface energies, respectively. The third type has no area constraint and is used to represent the area upon which the amoebae exist (i.e. the lattice). Note that this third type is actually a cellular automaton (CA), and the other types are automata that interact with the CA. Lattice sites occupied with a light or a dark cell contained a number corresponding to the unique spin of that particular cell. As shown in Figure 2.9, use of these spins allowed for edges between different cells to be identified. Simulation of this model is actually quite simple. A large number of lattice sites are selected at random, and their spins are switched to a neighboring spin located within a Moore neighborhood according to an annealing schedule. This schedule is based upon the Hamiltonian in Equation 2.24. Results of the Glazier and Graner [1993] simulation show that the differing surface tensions between light and dark cells causes those of each type to migrate toward one another and bundle with like types, effectively allowing for cell sorting without any centralized form of intelligence. More recent simulations make use of Potts Hamiltonian equation as part of a CA and a PDE model to create a 3D representation of the slug and fruiting body stages of the slime mold life cycle [Savill and Hogeweg 1997, Marée et al. 1999 Migration, Marée et al. 1999 Phototaxis, Marée and Hogeweg 2001, Segel 2001]. Both the Erban and Othmer model [2007] and the Glazier and Graner model [1993] provide interesting cues for future work, which will be discussed in Chapter 4.



2	2	2	2	2	3	3	3	3	3	3	3
2	2	2	2	1	1	1	3	3	3	3	3
2	2	2	1	1	1	1	1	1	3	3	3
2	2	1	1	1	1	1	1	1	1	3	3
8	8	1	1	1	1	1	1	1	1	4	4
8	8	8	1	1	1	1	1	1	4	4	4
8	8	8	1	1	1	1	1	1	4	4	4
7	7	1	1	1	1	1	1	5	4	4	4
7	7	1	1	1	1	5	5	5	5	4	4
7	7	1	1	1	5	5	5	5	5	5	4
7	7	7	1	6	6	5	5	5	5	5	5
7	7	7	6	6	6	6	5	5	5	5	5

Figure 2.9: Amoebae as modeled by Glazier and Graner [1993].

Section 2.3.3 Educational Simulations

Two educational studies of slime mold have been previously noted in this chapter. Those noted were Matthews' [2002] study from Generation5.org and Resnick's [1993] study in *Turtles, Termites, and Traffic Jams*. Resnick [1993] employed a parallel version of Logo called StarLogo in his work, and Matthews [2002] used Java along with a visual interface in his work. The examples provided in both studies are similar in form and application. Therefore, we will only discuss one in this section. Since Matthews' example is more detailed, we will discuss it and formalize his model [2002]. This model will divide the slime mold and its environment into a state space with cells and neighborhoods and will include rules by which amoeba may update this space and exist within it.

The models used by both Resnick [1993] and Matthews [2002] are cellular automata and begin with a state space (i.e. environment) for the slime mold to live in and modify. This state space is two dimensional in both models and is represented as a toroidal space. One may visualize this space as a grid or image as shown in the figure below, with sides that wrap around. Amoebae populate this state space and interact with it. As one might expect, this state space is a cellular automaton and may be updated at discrete time steps; i.e. it will be updated after every amoeba in the state space takes one step [Resnick 1993, Ilachinski 2001, Matthews 2002]. Additionally, if a grid is used as the state space it will be bounded to a fixed size.

The model used by both Matthews [2002] and Resnick [1993] assumes that the amoebae have already begun starvation. At this point in the lifecycle, it is known that amoebae deposit cAMP. Matthews' [2002] model assumes that the state space is represented as a color image. Note that RGB values for color images each range from zero to 255 as triples with zero representing the absence of a color and 255 representing the full intensity of a color. Empty cells are represented as black, i.e. the triple (0, 0, 0).

Cells containing an amoeba are represented as red, (255, 0, 0). Amoebae interact with their world by depositing cAMP, but different amounts may be deposited in different locations. Therefore, it makes sense to allow amoebae within our state space to deposit cAMP within cells in the search space. cAMP values could be represented by arbitrary values, but since Matthews is using an image to represent the state space, cAMP values are allowed to range from 0 to 255 and will be represented as green [2002]. If an amoeba is located in a cell that contains cAMP, only the color green will show (i.e. cAMP will not be shown in this case). Additionally, at most one amoeba may occupy a single cell at any given time step [Matthews 2002].

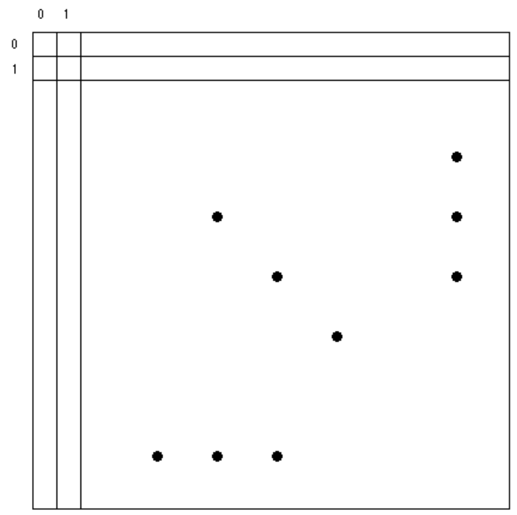


Figure 2.10: Example grid for slime mold state space. Redrawn from [Monismith and Mayfield 2008]

A number of rules are employed to make the slime mold state space appear to act as a real slime mold world. First, it is assumed that amoebae move one from one cell to another cell in the Moore neighborhood of size one in a single time step. An amoeba may not move into a cell that is occupied by another amoeba. This movement occurs at random in the simulation if there is no cAMP in the Moore neighborhood. If there is cAMP in the Moore neighborhood of an amoeba, that amoeba moves to the empty cell containing the most cAMP (verify). If there are no empty neighboring cells, the amoeba cannot move. Amoebae deposit cAMP at their previous location after each move. The amount that they deposit is a fixed integer. Because cAMP values will be displayed as green with their values ranging from zero to 255, adding cAMP to a cell should be done using a small integer value *x* in the range [2, 10]. Formally, each cell that contained an amoeba in the previous time step is updated according to the formula below, where *k* is the maximum cAMP value for a cell.

$$\sigma_{i,j}(t+1) = \begin{cases} \sigma_{i,j}(t) + x, & \text{result} \le k \\ k, & \text{result} > k \end{cases} \tag{2.25}$$

cAMP is also assumed to evaporate from every cell after each time step. Evaporation should be slower than deposit, so less cAMP is assumed to evaporate than is deposited. Matthews implemented evaporation using the following formula.

$$\sigma_{i,j}(t+1) = \begin{cases} \sigma_{i,j}(t) - 1, & \sigma_{i,j}(t) > 0 \\ 0, & \sigma_{i,j}(t) = 0 \end{cases} \tag{2.26}$$

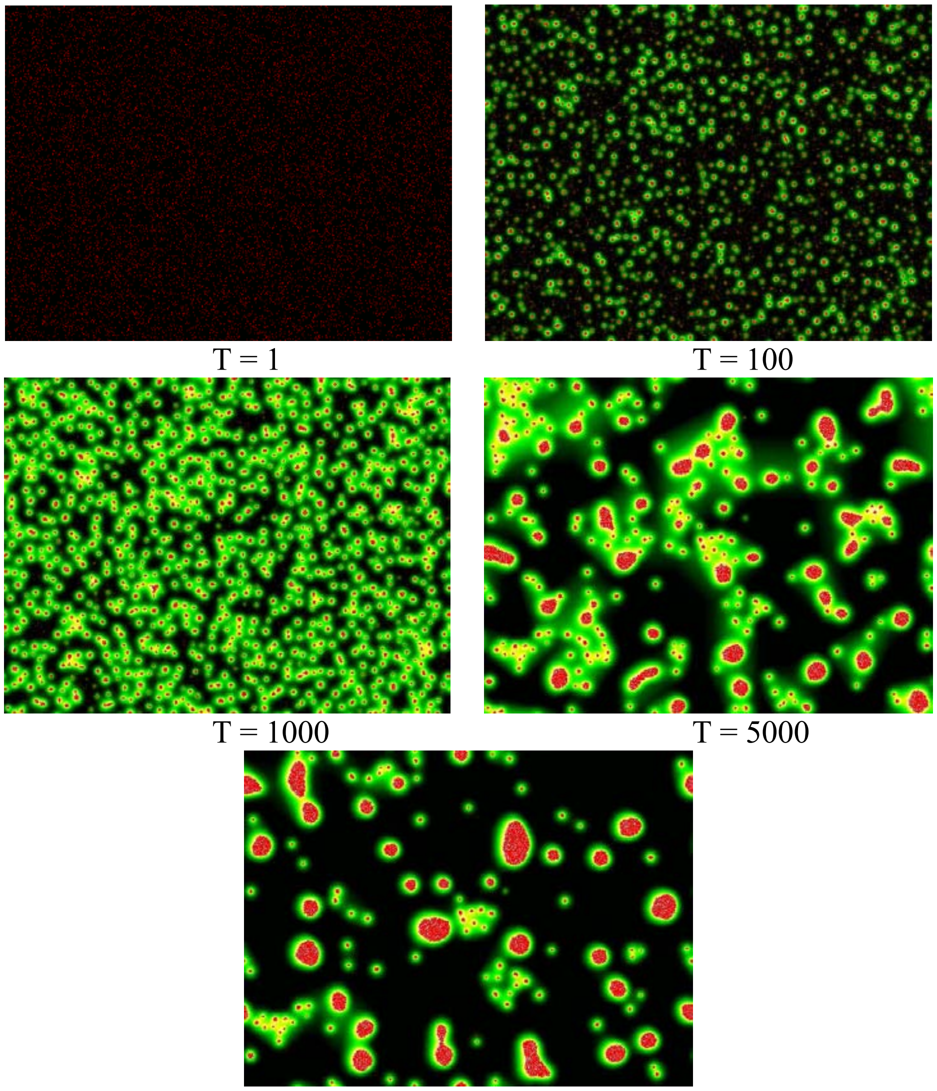
Note that once there is no more cAMP within a cell, no more evaporation may occur. The last rule that is used within the state space is a spreading rule. It is assumed that cAMP spreads from one cell to another after each time step. This is related to the dissipation and evaporation that occurs with cAMP in the wild. To implement cAMP spreading, a smoothing operator is applied to the Moore neighborhood of every cell. The operator works by averaging all the cAMP values in the Moore neighborhood of a cell, including the value in that cell. This allows a portion of every cell's cAMP to spread out over its Moore neighborhood. In areas where there is a high concentration of cells containing cAMP, this will have little effect, but in those areas where there are low concentrations of cAMP, smoothing will attract amoeba and cause them to form mounds. The smoothing operator rule is defined below.

$$\sigma_{q,r}(t+1) = \begin{cases} \displaystyle\sum_{i=q-1}^{q+1} \sum_{j=r-1}^{r+1} \frac{1}{9} \sigma_{i,j}(t), & \text{result} \le k \\ k, & \text{result} > k \end{cases} \tag{2.27}$$

The smoothing operator has another interesting effect. On the outer edges of mounds, a cAMP gradient is formed. This effect can be seen in the images below as a green halo surrounding a group of amoeba. The gradient on the outer edges of a mound causes the mound to attract additional amoeba toward it. Movement of the amoebae within the mound eventually causes the mound to eventually move like a slug [Matthews 2002, Monismith and Mayfield 2008].

The images below depict different time steps in Matthews' simulation of the slime mold [2002]. The first image depicts the starting state consisting of starving amoebae, which are all colored red. Empty space is shown as black. These amoebae begin moving, making one move per time step and depositing cAMP along the way. After 100 time steps, small mounds are formed. After 1000 time steps, few individuals are left. The small mounds have generated large halos of cAMP that engross groups of amoebae. At times 5000 and 10,000, the small mounds have joined together to form slugs. Eventually, all of the slugs will join together to form a single slug in this simulation.

The educational simulation provided here may be formalized to provide added insight as to the process of creating a CA-based simulation of a population. Such simulations involve two major parts a world in which the amoeba exist and the amoeba themselves. We will refer to the world as W and the set of amoeba as A. First, the world consists of a state space Σ consisting of all the cells in which the amoebae exist. The world also has limiting boundaries B that define the size and shape of the space [Ilachinski 2001, Monismith and Mayfield 2008].



T = 10,000

Figure 2.11: Example from James Matthews' Slime Mold Program. Results from time steps T = 1 through T = 10000 [Matthews 2002].

Additionally, the world uses a Moore Neighborhood, N, and a set of local values for each cell, Γ, that are in the discrete range [0,255]. Finally, the world has a starting state, S, with all cells being initially set to zero and rules that apply to it alone; those being the evaporative and smoothing rules explained above, which could be included in a set Φ. Each of these properties defines a world W that fits the definition of a CA as explained in section 2.3.1.

$$W \equiv \{\Sigma, B, \Phi, S, N, \Gamma\} \tag{2.28}$$

The world is, however, uninteresting without amoebae that will interact with it and deposit cAMP. Therefore, amoebae must be defined and formalized as well as an addition to the CA, *W*. Note that an amoeba may exist within a cell in the state space, and it has additional rules to interact with the state space. As explained above, each amoeba deposits cAMP with each time step; it also attempts to move to another cell in its neighborhood after each time step; lastly, only one amoeba may exist in one cell at any given point in time. These rules may be contained within a set *R*. Each amoeba has a location within the state space denoted as *L* and an initial location denoted as L_0. Thus, a single amoeba a_i may be defined as follows below.

$$a_i = \{R, L, L_0\} \tag{2.29}$$

The set of amoeba *A* that interacts with the world *W* may then be defined as follows below.

$$A = \{\ldots, a_i, \ldots\} \tag{2.30}$$

Thus, the complete CA for the slime mold world and its amoeba would consist of a set containing the world *W* and the set of amoebae *A*.

$$\text{Slime Mold CA} = \{W, A\} \tag{2.31}$$

With this formalism, one can easily construct a simulation of a slime mold [Ilachinski 2001, Monismith and Mayfield 2008].

Section 2.3.4 Moving to Optimization

In this final section of chapter 2, initial attempts to convert the lifecycle of Dd to a numerical optimization algorithm are discussed in brief. The first attempt made by the author was completely based upon the algorithm presented in the previous section [Matthews 2002]. This implementation was somewhat effective, but introduced several problems. The first of these problems was the use of a grid as an overlay onto the search space of the objective function. In short, this approach proves effective for functions of low dimensionality; however, it is quite obvious that this approach requires $O(n^d)$ operations at minimum where n is the least number of cells along one dimension of the CA and d is the dimensionality of the search space [Lu and Yen 2003, Yen and Lu 2003]. Grids using an adaptive size may work, but the same problems will be faced, only on a slightly smaller scale.

A slightly faster approach to the grid problem would be to use a sparse 1-dimensional grid based upon uniformly distributed initial search locations. This can be accomplished by producing a grid based upon a nearest neighbor algorithm. This process limits the number of operations performed upon the grid with each iteration to O(kn) where k is the number of neighbors of each grid point, and n is the number of grid points. This process has an cost of $O(kdn^3)$ operations for a naïve implementation where n is the number of initialization points, d is the dimensionality of the problem, and k is the number of neighbors. This process is also costly because the grid locations may need to be reassessed after several iterations [Arya et al. 1998]. A less costly grid can be created using the ε-Approximate Nearest Neighbor algorithm. This algorithm has a lower initialization cost of O(dn log(n)), making it more suitable for use as part of an optimization algorithm. Thus, in this section the nearest neighbor and approximate nearest neighbor algorithms will be discussed to better familiarize the reader with them [Arya et al. 1998, Mount and Arya 2006].

First, the nearest neighbor algorithm is investigated. This algorithm is a brute force algorithm used to find the nearest neighbors of all the points in a set. Any distance measure may be used in the algorithm; however, we will only consider the L_2 distance measure in this work. The L_2 distance measure is defined as follows below.

$$dist = \| \vec{x} - \vec{y} \|_2 = \sqrt{\sum_i (x_i - y_i)^2} \tag{2.32}$$

The nearest neighbor algorithm is quite simple. Given a set *S* of *n* vectors, all with the same dimensionality, the user of the algorithm chooses an integer value *k* that must be in the range [1, n]. Typically, *k* is chosen to be less than or equal to *D*, the dimensionality of each vector. The algorithm then ascertains the *k* vectors from *S* that are closest in distance to each of the *n* vectors in *S*, using the prescribed distance measure. The brute force method of doing this is to compute the distance from each vector to every other vector in the set and store the distances in a table. Then for each vector *v* in the set *S*, choose the *k* vectors with the shortest distances to *v* [Arya et al. 1998].

Algorithm 2.10: `K_NearestNeighbors(k, S)`

```
Create a table T of distances from each vector to every other vector.
Create an array L of size S.size containing empty lists.

For each vector v in S,
      For i = 0 to k-1,
            Find the nearest vector x to v using T.
            Add x to L[v].
            Mark x as used.
      End for.
End for.
```

Because the time costs of the k-nearest neighbor algorithm are high, many attempts have been made to improve upon it. The ε-Approximate Nearest Neighbor (ε-ANN) algorithm of Mount and Arya has proven to be an effective algorithm for finding neighbors in a reasonable amount of time, and the authors of the algorithm have provided a package form so that researchers need not go to the trouble of recreating this complex algorithm [Mount and Arya 2006]. Therefore, discussion of this algorithm will be limited to a short description of the data structures used, benefits, and fallacies.

The ε-ANN algorithm offers substantial time savings over the naïve nearest neighbor algorithm through the use of box-decomposition trees and allowances for nearest neighbors to be approximated. Box-decomposition trees are similar to KD-trees and allow for partitioning of a space based upon its dimensionality and the number of points that lie within the space. Partitions are made along each dimension to divide sets of points, and data structure linkages are made between divisions to indicate divisions when neighbors are to be found. Divisions in the tree are made until the number of points contained within each node is few. Doing so allows for a search for neighbors in the tree to be executed quickly. Actual creation of a box-decomposition tree is more complicated than the previous discussion, but the discussion is enough for the reader to grasp an understanding of how ε-ANN works. After creation of the tree, the algorithm may ascertain the k approximate nearest neighbors of any given point. These neighbors are referred to as approximate because the algorithm searches for neighbors within a hypersphere of radius $(1 + \varepsilon)*r$, where r is the distance to the nearest neighbor of the point in question. Using this property, ε-ANN can find the k approximate nearest neighbors of a point with relatively good accuracy for spaces having upwards of 16 dimensions [Arya et al. 1998, Mount and Arya 2006].

In the next chapter, the creation of the Slime Mold Optimization Algorithm will be discussed [Monismith and Mayfield 2008]. Results and some comparisons to existing algorithms will also be provided. Continuing work on this optimization algorithm will be discussed in a further chapter. Consequently, each of the previously discussed topics is of importance to the creation, testing, or comparison to the algorithm that will be discussed in the next chapter and to future work to be completed upon the algorithm.

CHAPTER III

III. SLIME MOLD OPTIMIZATION ALGORITHM

In the previous chapter, discussion of the lifecycle of *Dictyostelium discoideum* (Dd) and simulations thereof was provided. Additionally, many examples of existing optimization algorithms were reviewed. This information laid the groundwork for the discussion of a new optimization algorithm. In this chapter, the move is made from biology and simulation to an algorithm capable of numerical optimization. Here the Slime Mold Optimization Algorithm is presented and discussed in detail. This algorithm uses a multi-step process for optimization with each step being related to a stage in the lifecycle of Dd [Monismith and Mayfield 2008].

Briefly, the portions of the Slime Mold Optimization Algorithm are presented below. This algorithm is able to solve single objective optimization problems using a multi-step approach mimicking the lifecycle of the slime mold [Monismith and Mayfield 2008]. The approach begins with the vegetative state, which allows for directed random movement of agents representing amoebae. This movement is similar to that of a slug searching for food along a folate gradient [Kessin 2001]. These agents, referred to as amoebae, search for new personal optima within the search space of an optimization problem. Before amoebae begin moving, their initial locations are stored and used as the nodes in a grid [Monismith and Mayfield 2008]. This grid and the linkages between its nodes are built using the ε-Approximate Nearest Neighbor (ε-ANN) algorithm [Arya et al. 1998]. The vegetative stage ends when a significant number of amoeboid agents have difficulty finding new optima. At this point amoebae enter the aggregative state. They begin depositing an arbitrary amount of "cAMP" (represented as an integer value) at each node (i.e. cell) within the grid. Cells are attracted in the direction of their personal best and in the direction of the nearest cAMP source. These amoebae are drawn toward a pacemaker amoeba that is chosen as the best location within the group [Monismith and Mayfield 2008].

Algorithm 3.1: Slime Mold Optimization Algorithm

```
1.  For each amoeba,
2.      Assign the amoeba a random location within the search space.
3.      Evaluate the objective function at that location.
4.      Initialize the amoeba's personal best objective function value and location.
5.      Set the amoeba's state to VEGETATIVE.
6.  End for.
7.  Archive the best objective function value from the population of amoebae.
8.  Input the locations of each amoeba to ε-ANN and create a mesh based on the results.
9.  For each time step ,
10.     For each amoeba,
11.         Switch (Amoeba state)
12.         Case VEGETATIVE: VegetativeMovement; End Case.
13.         Case AGGREGATIVE: Aggregation; End Case.
14.         Case MOUND: MoundFormation; End Case.
15.         Case SLUG: SlugMovement; End Case.
16.         Case DISPERSAL: Dispersal; End Case.
17.         End switch.
18.     End for.
19.     Convert an aggregate to a mound if such an aggregate exists.
20.     Convert a mound to a slug if a mound exists.
21.     Disperse any slugs that have not updated their personal bests for a significant
        amount of time.
22.     Update the grid if necessary.
23. End for.
```

Once most of the aggregative amoebae are densely populated about the pacemaker, these agents are allowed to enter the mound stage. The mound stage encompasses the formation of a new data structure relating all the previously aggregative amoebae to each other through the use of another ε-ANN grid. This grid separates the mound from the other elements of the population that may be in different states. After this data structure is created, all amoebae within the mound are converted to the Slug state. In the slug state, amoebae are limited to make smaller movements in relation to the size of the slug and distances between each of its members. After improvements fail for a number of time steps, the amoebae within the slug are dispersed randomly through the search space. Their states are set back to vegetative and the cycle begins again [Monismith and Mayfield 2008]. Pseudocode for the Slime Mold Optimization Algorithm is provided above in Algorithm 3.1.

This chapter provides a detailed discussion of the slime mold optimization algorithm. It is based upon existing algorithms including stochastic random search, particle swarm, and ε-ANN [Corne et al. 1999, Kennedy and Eberhart 1995, Arya et al. 1998]. The algorithm provides a multi-tiered approach to solve single objective optimization problems. Detailed discussion of this algorithm begins with its initialization and the data structures used therein, including the ε-ANN grid. Additionally, each of the stages of the Dd lifecycle, as used in the algorithm, is described. We start with the vegetative stage to describe the random search used. Next, the data structure and methodology used for the aggregative state are provided. Finally, the data structure for the mound stage and movement for the slug stage are detailed. Results for the slime mold optimization algorithm and their analysis are provided in the final section of this chapter [Monismith and Mayfield 2008].

Section 3.1: Initialization and Preliminary Data Structures

The Slime Mold Optimization Algorithm begins, much like other EAs, with initialization. Initialization includes several key data structures: an ε-Approximate Nearest Neighbor tree that will represent the grid, a population of amoebae, a list of mounds, a list of pacemakers, the individual amoebae, and an archive [Corne et al. 1999, Monismith and Mayfield 2008]. Additionally, various calculations are made and random number generators are initialized. These steps are detailed in this section.

Initialization begins with the amoebae themselves, but before their initialization can be discussed their structure must be described. An amoeba is represented as an object, and as such it has many important member variables and methods. Since an amoeba is a representation of an individual in an evolutionary algorithm it has as it's most important parts a search space location and an objective function value [Corne et al. 1999]. Each amoeba also has a personal best location and a personal best objective function value [Kennedy and Eberhart 1995]. In addition to the normal EA individual variables, each amoeba includes a grid position and a state. These are used to denote the amoeba's position in the ε-ANN grid and its current functional state, which may be VEGETATIVE, AGGREGATIVE, MOUND, SLUG, or DISPERSIVE. Amoebae each contain additional variables pertinent to their current state. These indicate movement via pseudopodia and "hunger" in the vegetative state; time spent aggregating in the aggregative state; and velocity in the slug state [Kennedy and Eberhart 1995, Kessin 2001, Monismith and Mayfield 2008]. State specific variables will be discussed in detail in respective sections later in this chapter.

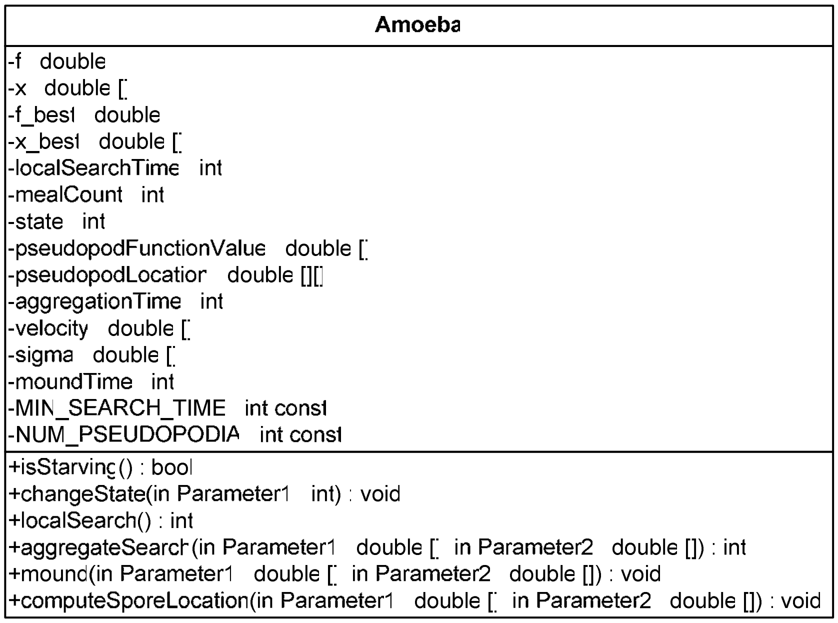

Amoeba
-f double
-x double [
-f_best double
-x_best double [
-localSearchTime int
-mealCount int
-state int
-pseudopodFunctionValue double [
-pseudopodLocation double [][
-aggregationTime int
-velocity double [
-sigma double [
-moundTime int
-MIN_SEARCH_TIME int const
-NUM_PSEUDOPODIA int const
+isStarving() : bool
+changeState(in Parameter1 int) : void
+localSearch() : int
+aggregateSearch(in Parameter1 double [in Parameter2 double []) : int
+mound(in Parameter1 double [in Parameter2 double []) : void
+computeSporeLocation(in Parameter1 double [in Parameter2 double []) : void

Figure 3.1: UML diagram of the Amoeba object.

Given the data structure for each amoeba, population initialization can be examined. The population is an array of amoebae. Its size is fixed at initialization. Each amoeba in the population is initialized with a random starting location chosen from a uniform distribution, and its objective function value is computed. Likewise the personal bests are set based upon the initialization values. Each amoeba's state is initialized to vegetative, and its grid position is set to be the same as its index in the population array. All other amoeba variables are initialized to zero or empty [Monismith and Mayfield 2008].

After the amoeba population has been initialized, several additional steps must be taken to ensure proper functionality during iteration. First, an array is created to allow for counting of amoebae at each ε-ANN grid point during aggregation. This will allow for an aggregate (mound) to be created once a size threshold has been met. Additionally, an array is created to contain the initial amoeba positions. This array of positions is used to initialize the ε-ANN data structure and to retain the locations for this data structure throughout the runtime of the program. Indices of each data point relate to a grid position. These indices also match with the previously created aggregation count array. After the ε-ANN data structure has been initialized, approximate nearest neighbors may be found. These neighbors may be used to compute the average distance between data points along each dimension. They may also be used to direct movement during the aggregation phase when cAMP is being deposited at positions in the grid. Finally, an archive is created, and the best position from the initial population is stored within the archive [Monismith and Mayfield 2008]. Thereafter, the iteration portion of this evolutionary algorithm begins.

Section 3.2: Vegetative Search

Iteration of the slime mold optimization algorithm begins with the vegetative search. This search is based upon the vegetative state of the Dd amoeba. Vegetative amoebae are independent agents that search for food. Models of their movement when searching for food are abundant. These range from simple random movement to complicated statistical models or differential equations. Choosing a search strategy to represent the vegetative stage of the Dd lifecycle thus includes many possibilities [Kessin 2001, Erban and Othmer 2007]. These choices include directed random search, simplex search [Spendley et al. 1962], and variants of direct search, especially that of [Hooke and Jeeves 1961]. Each of these can be or is shaped to represent the type of search carried out by a live amoeba. That is, these types of searches can represent searching for food independently via the use of a pseudopod, and they are good at finding local minima. For the slime mold optimization algorithm, a directed random search will represent the vegetative search [Monismith and Mayfield 2008]. Other search variants will be considered in the next chapter.

Initial reading about slime molds from a modeling perspective presented movement during the vegetative state as a directed random search for food [Matthews 2002, Resnick 1994]. Information about amoebae and their movement, however, indicates otherwise. Amoebae have pseudopods that they extend to perform a search for food. Modeling the exact movement of an amoeba is a difficult task, though. Thus, the approach used here is a directed random search that is intended to represent pseudopod extension. Additionally, amoebae transition from a vegetative state to an aggregative state. This transition is made through starvation. An adequate representation of starvation from the standpoint of numerical optimization is time spent searching. The ratio of updates to personal bests to time spent searching is a good representation of an amoeba□s □food□intake [Monismith and Mayfield 2008].

We now provide a run through of the steps taken by an amoeba during its vegetative state. Using a fixed number of pseudopodia, the directed random search chooses a new location for a psuedopod along each dimension using the formula below [Corne et al. 1999, Monismith and Mayfield 2008].

$$pop_i(t).pseudopod_k.x_j = c \cdot N(0,1) \cdot E_j(d_{neighbor}) + pop_i(\mathrm{t-1}).\mathrm{x}_\mathrm{j}, \tag{3.1}$$

This formula is evaluated for each pseudopod *k* of an amoeba. In the formula above, $\mathrm{E}_\mathrm{j}(d_{\mathrm{neighbor}})$ is the average distance to a neighbor along dimension j, and the constant *c* may be reduced as time progresses. After each pseudopod has been created, the result $pop_\mathrm{i}(\mathrm{t}).pseudopod_\mathrm{k}.f$ is evaluated for each pseudopod. Performing this search for each pseudopod is equivalent to performing a local search about the amoeba, which is what a real amoeba does with its pseudopodia. Once the objective function has been evaluated, the best result from the pseudopodia is compared to $pop_\mathrm{i}(t).f^*$, the best objective function value for the amoeba, and, if the best pseudopod result is better than $pop_i(t).f^*$, it replaces $pop_i(t).f^*$. Likewise, $pop_i(t).x^*$ is replaced with the search space location of the best pseudopod [Monismith and Mayfield 2008].

Provided with all the pseudopodia and their results, we must determine if the amoeba is starving and obtain new values for the amoeba□s location and objective function value, i.e. $pop_i(t).f$ and $pop_i(t).x$, respectively. These values are chosen either at random or using a roulette wheel. The decision between making a random move and a roulette wheel is based upon a probability p. With probability p, a pseudopod is chosen at random for a move, and with probability 1 □p, a pseudopod is chosen based upon the strength of its objective function value to replace $pop_i(t).f$ and $pop_i(t).x$. Additionally, with every time step, the local search time counter is incremented. If one of the pseudopodia provided an improvement to $pop_i(t).f^*$ and $pop_i(t).x^*$, then a □meal□counter is incremented to indicate that the amoeba was □fed□during that time step. The use of these counters allows for starvation to be determined by a formula. Starvation may be represented as the ratio of the time the amoeba has spent without improvement (i.e. without a meal) to the total time spent searching. We can decide if an amoeba is starving via the probability equation below [Arabas et al. 1994, Yen and Lu 2003, Monismith and Mayfield 2008].

$$p\left(x < \frac{t_{\text{unimproved}}}{t_{\text{lifetime}}} \right) \tag{3.2}$$
$$g(x) = 1, \text{ for } 0 \le x \le 1,$$

In the equation above, which is employed for an amoeba after it has searched for a fixed number of time steps, x is a random variable with uniform distribution g(x), $t_{\text{unimproved}}$ is the time spent without a meal and t_{lifetime} is the total time spent performing local searches. Provided x is less than the ratio above, the amoeba is determined to be starving; otherwise, the amoeba is assumed to be well fed. Once an amoeba is starving, its state is changed to AGGREGATIVE [Monismith and Mayfield 2008].

Algorithm 3.2: Vegetative Movement

```
1.  $pop_i(t).localSearchTime$    $pop_i(t).localSearchTime + 1$
2.  For each pseudopod $k$,
3.      For each dimension $j$,
4.          $pop_i(t).pseudopod_k.x_j$    $c$*$E_j(d_{\text{neighbor}})$*N(0,1) + $pop_i(t\text{-}1).x_j$
5.          Ensure that the result above is within the bounds of the problem space.
6.      End for.
7.      $pop_i(t).pseudopod_k.f$    f($pop_i(t).pseudopod_k.x$)
8.      Retain the best pseudopod as $pop_i(t).pseudopod.f^*$ and its location as
9.      $pop_i(t).pseudopod.x^*$.
10. End for.
11. If ( $pop_i(t).pseudopod.f^* < pop_i(t).f^*$ )
12.     $pop_i(t).f^*$    $pop_i(t).pseudopod.f^*$
```

```
13.     $pop_i(t).x^*$      $pop_i(t).pseudopod.x^*$
14.     $pop_i(t).mealCount$      $pop_i(t).mealCount + 1$
15. End if.
16. If ( rand(0,1) < $p$ )
17.     Select a pseudopod, $n$, by its fitness $f$ using a roulette wheel.
18. Else,
19.     Select a pseudopod with index $n$, at random.
20. End if.
21. $pop_i(t).f$      $pop_i(t).pseudopod_n.f$
22. $pop_i(t).x$      $pop_i(t).pseudopod_n.x$
23. If (rand(0,1) < ($pop_i(t).localSearchTime$ - $pop_i(t).mealCount$)/$pop_i(t).localSearchTime$
24.   and $pop_i(t).localSearchTime$ > MIN_SEARCH_TIME),
25.     Change the state of the amoeba to AGGREGATIVE.
26.     Update the amoeba□s grid location using the ε-ANN grid.
27. End if.
```

Algorithm 3.2: Vegetative Movement, provided above, details the sequence of events that occur during vegetative movement. To recap, this algorithm allows for a local search by one amoeba. That amoeba searches in a fixed number of directions for at least MIN_SEARCH_TIME time steps. If a pseudopod is an improvement over the personal best of the amoeba in question, the best location, $pop_i(t).x^*$, and objective function value, $pop_i(t).f^*$, are updated. Update in the position of the amoeba is provided through random selection of a pseudopod with probability p and selection of a pseudopod by roulette wheel with probability p-1. Starvation occurs when the local search time has surpassed the minimum starvation age, MIN_SEARCH_TIME, and a random variable is less than the ratio of lack of meals to local search time, i.e. Eq. (2) is met. Provided these circumstances, the amoeba is converted to the AGGREGATIVE state and its ε-ANN grid location is recorded [Monismith and Mayfield 2008].

Section 3.3: Aggregative Search

Aggregative search is the first state in which amoebae are involved in a cooperative effort. This state begins with a search for the nearest grid location with the most cAMP. Once this location is found, it is tagged for use while searching. Next, the search begins. The aggregative search allows amoebae to move in a directed fashion toward the area with the most cAMP. Amoebae make movements in a similar fashion to particle swarm following their own personal bests and being attracted to the area with the most cAMP. As amoebae in this state move, they drop cAMP on the grid [Resnick 1994, Matthews 2002, Monismith and Mayfield 2008]. The closer they are to reaching a minimum, the more cAMP is dropped. Once enough amoebae have aggregated about a single location, the aggregate becomes a mound. Cells that exist in an aggregative state for too long a time will revert to the vegetative state. The steps of the aggregative state are discussed in detail below [Monismith and Mayfield 2008].

At the beginning of an aggregative search step, a search must be made for the nearest grid location with a large amount of cAMP. To do so, an ε-ANN search is made for the nearest neighbors about the closest grid point to the amoeba□s current location, $pop_i.x$. An example of an ε-ANN grid is provided below.

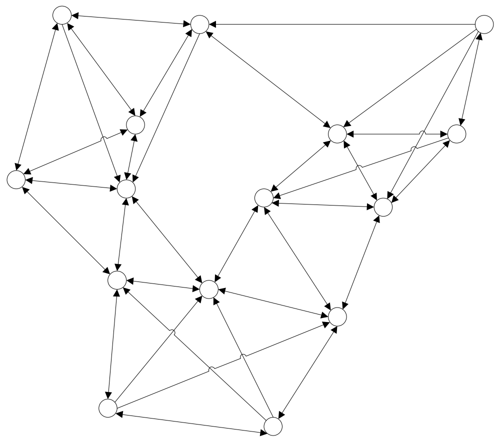


Figure 3.2: Approximate Nearest Neighbor Mesh, 2-D with 4 neighbors per node [Monismith and Mayfield 2008].

Next, out of these nearest neighbors a search is made for the grid location with the most cAMP. This location is tagged for later use. After finding the largest cAMP source, a move is made [Monismith and Mayfield 2008].

Making a move during the aggregative phase is a multi-step process. It is quite similar to the process used during particle swarm, as both velocity and position update formulae are used. First, the elapsed aggregation time is incremented. Next, a velocity is computed based upon the direction of the cAMP source and the direction of the previous best location found. A small value from a normally distributed pseudorandom number generator is added to this velocity to protect against a null velocity. The formula for velocity update is provided below [Kennedy and Eberhart 1995, Monismith and Mayfield 2008].

$$\begin{aligned} pop_i(t+1).v_j &= c_1 \cdot pop_i(t).v_j + c_2 \cdot (grid_{best\_cAMP\_Neighbor}(t).x_j - pop_i(t).x_j) + \\ & c_3 \cdot (pacemaker(t).x_j - pop_i(t).x_j) + c_4 \cdot E_j(d_{neighbor}) \cdot N(0,1) \end{aligned} \tag{3.3}$$

In this formula the velocity for amoeba i at dimension j is represented as $pop_i(t).v_j$ for time t. The grid location containing the amoeba□s neighboring ε-ANN grid point is provided as $grid_{best\_cAMP\_Neighbor}.x_j(t)$ at dimension j. The location of the best aggregating amoeba is represented as $pacemaker.x_j(t)$ at dimension j and time t. The average distance between grid locations along dimension j is represented as $E_j(d_{neighbor})$. Constants c_1, c_2, c_3, and c_4 are set to values less than one to reduce the population explosion effect that may occur when using particle swarm formulae. After the new velocity has been computed, the velocity is used to update the current position. The formula for position update is provided below [Kennedy and Eberhart 1995, Monismith and Mayfield 2008].

$$pop_i(t+1).x_j = pop_i(t).x_j + pop_i(t+1).v_j \tag{3.4}$$

At this point the algorithm must ensure that the new location is within the bounds of the problem space. If it is not, the location must be adjusted to the bounds of the space along the appropriate dimension. The location may then be evaluated using the objective function to provide a new objective function value. Provided the new objective function value is a new personal best for the amoeba, the personal best for that amoeba is updated, and the maximum amount of cAMP is deposited at the closest grid location. If a new personal best is not found, cAMP proportional to the strength of the amoeba□s new objective function value is deposited at the nearest grid location. The formula for cAMP deposit at a grid location is provided below [Matthews 2002, Monismith and Mayfield 2008].

$$grid_i(t+1).cAMP = \begin{cases} grid_i(t).cAMP + c \cdot \left(norm\left(\dfrac{pop_i(t+1).f}{pop_i(t+1).f^*} \right) \right), \mathrm{grid}_i(t+1).cAMP < \mathrm{k} \\ \mathrm{k},\ grid_i(t+1).cAMP \geq \mathrm{k}. \end{cases} \tag{3.5}$$

In this formula, we see that the grid update is provided based upon the ratio of the amoeba□s personal best to its current location. The maximum amount of cAMP in that may be deposited in a single state space location at a particular time step is provided as the constant *c*, and the total amount of cAMP at a grid location may not exceed the constant *k* [Matthews 2002, Monismith and Mayfield 2008].

Once a new location for the amoeba has been found, the grid is updated, and transition to another state must be considered. Amoebae can transition to the mound state if two conditions are met. First, there must be at least as many amoeba in the AGGREGATIVE state as there are possible neighbors at one particular grid location. Next, the amoebae must pass the following formula test.

$$p\left(x < \frac{grid_{\mathrm{i}}(t).aggregateCount \text{ - } minAggregateCount}{aggregateCountThreshold} \right) \tag{3.6}$$
$$g(x) = 1, \text{for } 0 \leq x \leq 1.$$

In the equation above, x is a random variable with distribution defined by $g(x)$. Additionally, *minAggregateCount* is the fewest number of amoebae that may exist as an aggregate, and *aggregateCountThreshold* is the preferred minimum number of amoebae that may exist as an aggregate. This is calculated as the population size (number of amoebae) divided by the number of neighbors and causes formula (3.6) to have little effect when large numbers of neighbors are used. $grid_{\mathrm{i}}(t).aggregateCount$ is the current number of amoebae that exist at position *i* in the grid. If the criterion above is met, a mound is created at the grid location in question. All amoebae within the vicinity of the grid location are converted to the MOUND state, and a data structure for the mound is created. If said criteria are not met, the group of aggregating amoebae are not converted to the mound state. Amoebae that stay in the aggregative state for too long a time and for which the following criterion is met are reverted to the vegetative state.

$$p\left(\frac{grid_i(t).aggregateCount}{pop_i(t).aggregationTime} < x\right) \qquad (3.7)$$
$$g(x) = 1, \text{for } 0 \le x \le 1$$

In the equation above, *x* is a random variable with distribution defined by *g*(*x*). This allows for the amoebae to continue with further local searches and gives them a chance to join another aggregate [Arabas et al. 1994, Yen and Lu 2003, Monismith and Mayfield 2008].

Algorithm 3.3: Amoeba Aggregation

---

1. Find the grid location nearest the amoeba□s current location, $pop_i(t).x$ in the ε-ANN tree and store said location in $pop_i(t).gridLocation$
2. Performing the previous search also yields the amoeba□s nearest neighbors in the grid. Determine which of those neighbors has the most cAMP. Retain the index of that neighbor as *neighborWithMostCAMP*.
3. If more than one neighbor has the same amount of cAMP as the previously chosen neighbor, choose one of the neighbors with the largest amount of cAMP at random, and store that grid location□s index as *neighborWithMostCAMP*.
4. $pop_i(t).aggregationTime \quad pop_i(t).aggregationTime + 1$
5. Evaluate equations (3.3) and (3.4) for each dimension of the decision space.
6. Determine the amount of cAMP to deposit using equation (3.5), and deposit that amount of cAMP at grid index *neighborWithMostCAMP*.
7. If the new objective function value is a personal best, update $pop_i(t).f^*$.
8. If the personal best of $pop_i(t)$ has been updated check to see if the archive should be updated as well.
9. If $pop_i(t)$ fails either equation (3.6) or (3.7), revert to the VEGETATIVE state.
10. Otherwise, increment the aggregate count at grid index *neighborWithMostCAMP*.

Section 3.4: Slime Mold World

Up to this point, references have been made to the grid, but it has not been discussed in detail. The grid is a cellular automaton that is the focal point for interaction between aggregating amoebae. This interaction is facilitated by the deposit of cAMP on the grid and its spread and evaporation similar to that explained in Section 2.3.3 [Matthews 2002]. Therefore, updates to these equations will be provided. Moreover, in this section the data structure used to create the grid and the modifications to the grid update functions will be provided.

The base unit of the cellular automaton is the cell. Cells of the state space in this work are represented as an object with a number of attributes [Ilachinski 2001]. For the algorithm in this work, these include a cAMP value, a neighborhood derived from the ε-Approximate Nearest Neighborhood, a location within the bounds of the problem space, and a count of the number of amoebae attempting to aggregate at a given cell. Additionally, constants are provided as a part of this data structure to place upper and lower limits on the cAMP values and the aggregate count [Monismith and Mayfield 2008]. A UML diagram of this structure is presented below.

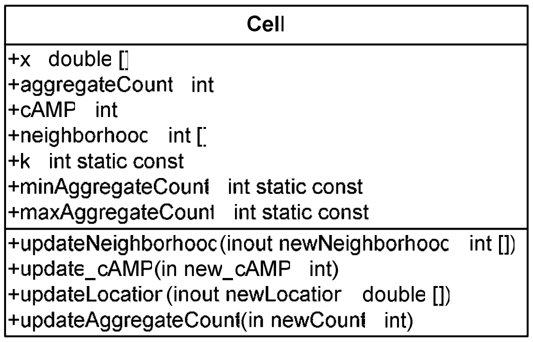

Cell
+x double [
+aggregateCount int
+cAMP int
+neighborhooc int [
+k int static const
+minAggregateCount int static const
+maxAggregateCount int static const
+updateNeighborhooc(inout newNeighborhooc int [])
+update_cAMP(in new_cAMP int)
+updateLocatior (inout newLocatior double [])
+updateAggregateCount(in newCount int)

Figure 3.3: UML diagram of the Cell data structure.

The helper methods provided in the UML diagram above allow for the update of cells as needed by the amoebae and the automaton.

The Cellular Automaton (CA), which may be referred to as the Slime Mold World, consists of a grid of cells, represented as an array, with its neighborhood represented based upon data obtained from an ε-ANN tree [Monismith and Mayfield 2008]. After its construction, the ε-ANN tree may be queried to find the approximate nearest neighbors of each cell [Mount and Arya 2006]. During initialization of the slime mold optimization algorithm, locations are stored in the ε-ANN data structure as an array in the same order they are stored in the grid, which is also an array. Thus, their array indices are the same. Therefore, initialization of the neighborhood via ε-ANN queries is straightforward □it only requires the index values returned be stored in the corresponding grid location. A UML diagram of the Slime Mold CA is provided below.

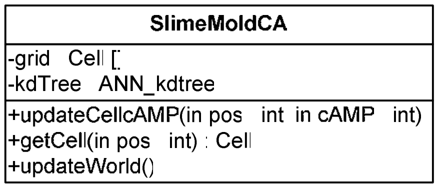

SlimeMoldCA
-grid Cell [
-kdTree ANN_kdtree
+updateCellcAMP(in pos int in cAMP int)
+getCell(in pos int) : Cell
+updateWorld()

Figure 3.4: UML diagram of the Slime Mold CA data structure.

In the diagram above, functions to update the grid are provided. Of the provided functions, the first serves to allow the amoebae to update the amount of cAMP in a cell by depositing it during the aggregative state. The next function allows for access to the values of particular cell. The last function allows for update of the entire CA via the evaporation and spreading functions explained in section 2.3.3 [Matthews 2002]. Evaporation for the CA is carried out using the formula below.

$$grid_i(t+1).cAMP = \begin{cases} grid_i(t).cAMP - 1, & grid_i(t).cAMP > 0 \\ 0, & grid_i(t).cAMP = 0 \end{cases} \tag{3.8}$$

The formula above allows for the slow removal of cAMP from the grid via evaporation in the same manner as the evaporation formula of section 2.3.3 [Matthews 2002, Monismith and Mayfield 2008]. The formula for spreading or smoothing of cAMP, which is also quite similar to that of the previous chapter, is provided below.

$$grid_i(t+1).cAMP = \begin{cases} \dfrac{1}{q+1}\sum_{j=0}^{q} grid_{h(j)}(t).cAMP, & grid_i(t+1).cAMP \le k \\ k, & \text{otherwise} \end{cases}$$
$$h(j) = \begin{cases} grid_i(t).neighborhood_j, & j < q \\ i, & j = q \end{cases} \tag{3.9}$$

Note that in the formula above, *q* represents the number of neighbors used in the algorithm, and the function *h*(*j*) allows for computation of the indices of the approximate nearest neighbors, which are needed to complete the smoothing function. This formula is different than the smoothing formula of section 2.3.3 in only one aspect; it makes use of the CA's ε-ANN information to allow for update of cAMP [Matthews 2002, Monismith and Mayfield 2008].

Section 3.5: Mound Formation

At the end of the aggregative stage, Dd amoebae begin to form a mound. These amoebae encapsulate themselves in a slime sheath, thus separating them from the rest of the world [Kessin 2001]. For the slime mold optimization algorithm, mound formation is represented as the formation of the data structure to encapsulate a group of aggregating amoebae that will later emulate the slug stage of Dd. Since mound formation is represented by the formation of a single data structure, this step in the algorithm only requires one time step. For mound formation to begin, a cell and group of amoebae must meet the criterion of formula 3.6. In form, this data structure is much like the neighborhood, CA, and population of the entire slime mold algorithm because it is simply a smaller version of the automata in which the main population exists [Monismith and Mayfield 2008].

During formation of the mound, there are several important initialization steps that must be taken before conversion to the slug state. To amortize the costs of creating ε-ANN trees across iterations, only one mound is created per time step. To create the mound, first, a search is made for the grid location (cell) with the largest number of associated amoebae. The number of amoebae in the aggregative state at this grid location is tested using formula 3.6. Provided this grid location satisfies formula 3.6, each amoeba in the aggregative state that is associated with that grid location has its state changed to the mound state. The mound data structure is then created including a reference to each of these amoebae as part of the data structure. Continuing with the mound formation, an amoeba is chosen from the members of the mound to become the head of the slug. The amoeba chosen as the head is the amoeba with the best function value out of all the amoebae that are part of the mound. During the slug stage, the head of the slug will be represented as the amoeba with the best objective function value. The location of this amoeba will be used in a particle swarm formula to drive other amoebae in the slug (i.e. the members of the tail) toward better objective function values [Monismith and Mayfield 2008].

The last part of forming the mound involves creating a neighborhood for the amoebae of the mound to move about when they become part of the slug. This neighborhood may be represented as an ε-Approximate Nearest Neighborhood, with the ε-ANN tree, which is either a KD-tree or Box Decomposition Tree, as the key data structure of the neighborhood [Arya et al. 1998]. The new neighborhood that is created is separate from that of the main population of the slime mold optimization algorithm; although, it functions in a similar manner. Just like the ε-ANN data structure of the main algorithm, this data structure is used as a mesh overlaid on the decision space. The main purpose of this mesh is to compute distances between amoebae within the mound and to establish a quick means of locating an amoeba□s neighbors while in the slug stage. An example of the mesh used for the mound and slug stages is presented below in conjunction with the mesh used for the population of all amoebae.

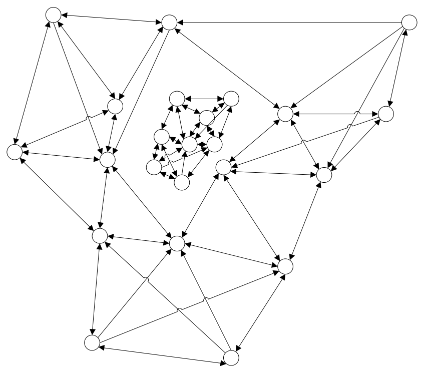


Figure 3.5: Approximate Nearest Neighbor Mesh and Mound Mesh (inner mesh), 2-D with 4 neighbors per node [Monismith and Mayfield 2008].

Above, in Figure 3.5, the smaller mesh represents the mound and the larger mesh represents the mesh for the entire population of amoebae. This figure also shows that there are no linkages between the mound and population meshes [Monismith and Mayfield 2008].

Once the necessary pieces for the mound data structure are intact, it may be used as part of the slug. The mound consists of a population of amoebae, a mesh representing neighborhoods, and the average distance between mesh locations. It is quite similar to the data structures used for the main population [Monismith and Mayfield 2008]. In the next section, when it is used as the attributes of the slug its functionality will become quite different than that of the population as a whole.

Algorithm 3.4: Mound Formation

```
1. If there are any aggregating amoebae and $grid_{maxAggInd}$.aggregateCount >
   numNeighborsFind the grid location nearest the amoeba□s current location, $pop_i(t).x$
   in the ε-ANN tree and store said location in $pop_i(t).gridLocation$
2. Performing the previous search also yields the amoeba□s nearest neighbors in the grid.
   Determine which of those neighbors has the most cAMP. Retain the index of that
   neighbor as *neighborWithMostCAMP*.
3. If more than one neighbor has the same amount of cAMP as the previously chosen
   neighbor, choose one of the neighbors with the largest amount of cAMP at random,
   and store that grid location□s index as *neighborWithMostCAMP*.
4. $pop_i(t).aggregationTime \quad pop_i(t).aggregationTime + 1$
5. Evaluate equations (3.3) and (3.4) for each dimension of the decision space.
6. Determine the amount of cAMP to deposit using equation (3.5), and deposit that
   amount of cAMP at grid index *neighborWithMostCAMP*.
7. If the new objective function value is a personal best, update $pop_i(t).f^*$.
8. If the personal best of $pop_i(t)$ has been updated check to see if the archive should be
   updated as well.
9. If $pop_i(t)$ fails either equation (3.6) or (3.7), revert to the VEGETATIVE state.
10. Otherwise, increment the aggregate count at grid index *neighborWithMostCAMP*.
```

Section 3.6: Slug Search

From a biological perspective, once Dd mound formation is complete, Dd amoebae have organized themselves into two separate and equally important sections. These are the head and tail of the slug. The head and tail allow for the slug to become motile. Amoebae in the head emit cAMP to direct motility in the tail [Hogeweg and Savill 1997, Marée et al. 1999 □Migration□, Marée et al. 1999 □Phototaxis□, Marée and Hogeweg 2001, Kessin 2001]. The equations of such movement, however, are still being researched by the author. Therefore, slug movement for the Slime Mold Optimization Algorithm is simplified. Instead of using multiple amoebae for the head, a single amoeba is used. The remaining amoebae in the slug perform similar movements to those used in the aggregative stage, with some modification [Monismith and Mayfield 2008]. This section details the slug data structure and the search methodology therein.

The slug object consists of the mound structure discussed in the previous section and two important update methods. The first of these is a method to update the ε-ANN mesh, for which two possible implementations are presented. One of these is based upon the change in spread of the amoeba populating the slug, and the other simply updates the mesh and its associated tree with each time step. The second is a method to provide information about the slug to the amoebae that are part of it as they move. This method is necessary because the amoebae operate independently using the slug data structure only as a means of communication. The information provided includes the average distance between slug members based upon the ε-ANN mesh, the location of the amoeba representing the head of the slug, and the location of the approximate nearest neighbor with the best current objective function value. This search includes the aforementioned information, which is used as part of a search formula similar to equations 3.3 and 3.4 [Monismith and Mayfield 2008]. The two methods described above are presented below in detail.

In many aspects, the search methodology for the slug is similar to that used by the individual amoebae of the slime mold world. It makes use of an ε-ANN mesh for a nearest neighbor search and it makes use of a population, although the population is smaller than that of the main population and a slightly different nearest neighbor search. The slug search also makes use of particle swarm formulae for its movement. There are some slight differences between the amoebae of the slug and the amoebae of the entire slime mold world. First, the slug population is isolated from the rest of the slime mold world. Thus, there are no cAMP interactions between members of the slug and the rest of the world population. Instead, interactions only occur between members of the slug. During each time step, each member of the slug is given an opportunity to move from its current location to a new one. Before movement begins, an approximate best neighbor is found using the slug□s ε-ANN tree that was created in the mound stage. The best neighbor and head of the slug are used together as part of a particle swarm velocity formula as described below.

$$\begin{aligned} slug_i(t+1).v_j &= c_1 \cdot slug_i(t).v_j + c_2 \cdot (slug_{bestANNNeighbor}(t).x_j - slug_i(t).x_j) + \\ & c_3 \cdot (slug_{head}(t).x_j - slug_i(t).x_j) + c_4 \cdot E_j(d_{neighbor}) \cdot N(0,1) \end{aligned} \tag{3.10}$$

In the formula above, the velocity for the *i*th amoeba of the slug along dimension *j* of the search space at time *t* is represented as $slug_i(t).v_j$. Similarly, the location for the same amoeba in the objective function space is represented as $slug_i(t).x_j$. The locations of the head amoeba and best neighboring amoeba are represented using the same notation but with the subscripts *head* and *bestANNNeighbor*, respectively. To recap, the head amoeba is the amoeba within the slug having the best objective function value and corresponding location. The average distance to a neighboring amoeba along dimension *j* is represented as $E_j(d_{neighbor})$ [Kennedy and Eberhart 1995, Coello Coello and Lechuga 2002, Monismith and Mayfield 2008]. Since the Clerc and Kennedy work has shown that large constants for PSO equation will cause population explosion, constants c_1, c_2, c_3, and c_4 are chosen such that they sum to one to prevent amoebae from overshooting the coverage area of the slug by a large distance [2002]. This formula allows for the amoeba to move both in the direction of its best neighbor and the slug□s pacemaker with slight jitter from the random component to continue movement during those cases where the positions of an amoeba and its neighbor or the head might be one and the same. The position update formula is presented below. It allows for the update of the position of the amoeba using the velocity formula above.

$$slug_i(t+1).x_j = slug_i(t).x_j + slug_i(t+1).v_j \tag{3.11}$$

This formula is the same as equation 3.4 and serves the same purpose. Once the location vector, $slug_i(t+1).x$, has been computed, its dimensional values are compared to the bounds of the decision space along each dimension. Any dimensional value of $slug_i(t+1).x$ that falls outside of the decision space bounds is clamped to the bound. Thereafter, the objective function is evaluated at $slug_i(t+1).x$ and its result is stored in $slug_i(t+1).f$. Such movement occurs for each amoeba that is part of the slug [Kennedy and Eberhart 1995, Monismith and Mayfield 2008].

Although equations (3.10) and (3.11) are similar to (3.3) and (3.4), their purposes are quite different. The equations of this section serve along with the ε-ANN mesh to provide a dense search that exploits the coverage area of the slug. Conversely, equations 3.3 and 3.4 serve as a middle ground to drive amoebae from the exploration search as explained in section 3.2 toward an area that should be exploited because a possible minimum exists in that location [Goldberg 1989, Mitchell 1998, Corne et al. 1999].

The second method tied to the slug stage is the ε-ANN mesh update method. This method is necessary to locate the approximate nearest neighbors of the amoebae within the slug. When implementing the algorithm, the author devised two different methods for locating neighbors of an amoeba. For the first method, the ε-ANN data structure is recalculated with each time step. By updating this data structure after each time step, the location of each amoeba within the slug corresponds exactly to the locations of the nodes of the kd-tree within the ε-ANN data structure. Since these nodes are the points from which nearest neighbors are computed, the neighborhood of the amoebae within the slug is exact. The location of the best nearest neighbor is found by querying the ε-ANN tree for each amoeba's approximate nearest neighbors then choosing the one with the best current objective function value. This method accurately assesses the locations of the amoebae but is quite costly in terms of system resources. When using the method above, the ε-ANN data structure must be recomputed after each time step for each slug that is used in the algorithm. Due to this problem, a second method is presented that is similar to the method used in Section 3.3 for the aggregate. In this method, the same ε-ANN tree is used for several time steps before being updated. Amoebae within the slug must update their positions with respect to the ε-ANN tree so that requests during a search for the nearest neighbor produce the correct result. This same principle is used with the ε-ANN tree of Section 3.3; however, the current version of the algorithm does not include cAMP deposit. Rather, it simply picks the best nearest neighbor amoeba. Update of the ε-ANN tree is necessary when the positions of the amoebae within the slug significantly differ from those in the ε-ANN tree. To check for a significant change, the centroid and standard deviation of the points within the slug are computed. These values are then used to compare the centroid of the ε-ANN mesh to the centroid of the points. If a significant change has occurred, the ε-ANN tree is updated to the current locations of the slug amoebae. An example of a formula that may be used to make this comparison is presented below.

$$p\left(x < \frac{\| \mu_{Slug\ \varepsilon\text{-}ANN} - \mu_{SlugAmoebae} \|}{\sigma_{Slug\ \varepsilon\text{-}ANN}} \right) \qquad (3.12)$$

$$f(x) = 1, \ for\ 0 \le x \le 1$$

In the formula above, the distance between the centroid of the slug□s ε-ANN mesh and the slug□s amoebae (computed as means) is normalized by the standard deviation of the slug□s ε-ANN mesh. Thus, the formula causes an update to the mesh as the distance between the centroids of the points nears the standard deviation of the ε-ANN mesh [Monismith and Mayfield 2008].

As the slug moves, two important values are tracked. The first of these factors is the number of time steps that the slug has spent moving. The second is the number of updates to the best result obtained by the slug. These variables can be used to determine when the slug data structure should be disposed. The reasoning behind this is simple □as the number of updates to the slug becomes fewer, the need for dense search over the coverage area of the slug lessens. A simple formula to decide when to end the slug stage is presented below.

$$p\left(x > \frac{\text{Number of slug best updates}}{\text{Time spent in the slug stage}} \right) \qquad (3.13)$$

$$f(x) = 1, \ for\ 0 \le x \le 1$$

The author□s implementation of the slime mold optimization algorithm allows for a constant number of updates to any particular slug before the above formula is used [Monismith and Mayfield 2008].

In nature, the end of the slug stage is followed by the beginning of culmination, i.e. formation of a fruiting body. The members of the tail of the slug would then die to form the stalk of the fruiting body, and members of the head would crawl up the stalk to be dispersed to new locations as spores [Kessin 2001, Segel 2001]. A simplification of these processes for optimization purposes is to restart the algorithm for all members of the slug. This means that each member of the slug is dispersed (i.e. randomly distributed) throughout the search space once the slug stage is complete. That is, once equation (3.13) is satisfied, members of the slug revert to the vegetative state and are placed at random positions in the search space. They do, however, retain a memory of their personal bests as obtained during all the previous stages of their lifecycles. These amoebae begin searching for new optima and continue to follow through the slime mold lifecycle [Monismith and Mayfield 2008].

Section 3.7: Slime Mold Optimization Algorithm

Having explained how each of the stages in the slime mold optimization algorithm work, we can now explain how they are put together. We first review initialization detailing its importance during the algorithm. After initialization, iteration begins. For a fixed number of iterations, each amoeba is given an opportunity to perform operations based upon its current state. Additionally, data structures including mounds and slugs are updated at the end of each iteration, if necessary. Update to the mesh, as described in section 3.4 is also performed at the end of each iteration [Monismith and Mayfield 2008]. We further elaborate upon the composition of the algorithm in this section.

During initialization a fixed number of amoebae data structures, as described in section 3.1, are allocated and initialized to random locations. Their objective function values are then evaluated, and the current location and objective function value is stored as the best location and objective function value, respectively, for each amoeba. Thereafter, the ε-ANN algorithm is used to create a mesh based upon the initial locations of each amoeba with a fixed number of neighbors for each vertex of the mesh. Each vertex in this mesh corresponds to one amoeba□s location. These vertices are also used as locations at which cAMP may be stored during the aggregative state. Each amoeba□s counters are initialized to zero and each amoeba□s state is initialized to VEGETATIVE. After each amoeba is initialized and the ε-ANN data structure has been created, the best location in the population is archived [Monismith and Mayfield 2008].

After initialization is complete, iteration begins. A fixed number of objective function evaluations is used during the Slime Mold Optimization Algorithm. This value is chosen heuristically. Once per iteration, each amoeba is given a chance to perform an operation based upon its current state of VEGETATIVE, AGGREGATIVE, MOUND, SLUG, or DISPERSIVE. Amoebae archive new global bests as necessary after executing the actions appropriate to their states. While an amoeba is in a particular state it performs appropriate actions corresponding to its state. That is, if an amoeba is in the vegetative, aggregative, or slug state, it moves according to the appropriate equations for that state. Amoebae in the dispersive state act slightly differently □they are relocated to a new random position. Amoebae in the mound state perform no actions as they are to be incorporated into a data structure. Therefore, there must be some action performed after iteration [Monismith and Mayfield 2008].

Several actions are carried out after each iteration. During an iteration, every amoeba is allowed to carry out its own state based action appropriate to its state. The actions executed after an iteration are to deal with the creation and destruction of data structures as amoebae aggregate, form a mound, move as a slug, and are ultimately dispersed to restart their lifecycle. So, the first of these steps after iteration is to take the world location at which there is the highest concentration of aggregating amoebae, and to decide if those amoebae need to be converted from an aggregate to a mound. This decision is made using equation 3.7. If the aggregate passes equation 3.7, the cell within the aggregate having the best objective function value is chosen as the pacemaker and all amoebae in the aggregative associated with the world position with the highest concentration of amoebae are converted to the MOUND state. Finally, a mound is created at that location. The next step taken after iteration is an update of the slug□s ε-ANN data structure. Depending on the type of implementation this either occurs after each iteration or after the iteration during which the slug has made significant movement. Thereafter, the kd-tree contained within the slug□s ε-ANN data structure is reformulated based upon the current locations of the amoebae within the slug. After mound creation and slug updates are considered, any slugs that have existed for more than a fixed number of iterations and have not had updates to their personal bests according to equation 3.13 are cleared. Then, the archive that is maintained to keep track of the overall bests throughout the algorithm is updated, if necessary. Finally, the slime mold world is updated. These updates are performed according to equations 3.8 and 3.9, which cause evaporation and smoothing to occur. Thus a number of important actions are carried out after each iteration [Monismith and Mayfield 2008].

So far we see that we have an algorithm with multiple stages □those being Vegetative, Aggregative, Mound, Slug, and Dispersal states. We have also seen that the algorithm also makes use of a grid based on the ε-ANN algorithm and that it requires several ancillary data structures to facilitate the aggregative, mound, and slug stages [Monismith and Mayfield 2008]. Having a full description of the algorithm, we move on to variants of the algorithm in Chapter 4 and testing, results, and analysis in Chapter 5.

CHAPTER IV

IV. VARIATIONS ON THE SLIME MOLD OPTIMIZATION ALGORITHM

Genetic algorithms, particle swarm optimization, and differential evolution have all led to many variants [Goldberg 1989, Arabas et al. 1994, Mitchell 1996, Clerc and Kennedy 2002, Coello Coello and Lechuga 2002, Price et al. 2005]. For example, there are many variations on the recombination operator in genetic algorithms [Goldberg 1989, Herrera et al. 1998]. A first look at the Slime Mold Optimization Algorithm along the same lines would be view it as a heuristic for building an evolutionary algorithm. The lifecycle of Dd, when used as a model for an optimization algorithm, lends itself to many possible variants. A top level look at the algorithm is provided in the figure below.

Vegetative State	Initial search algorithm using many individuals
Aggregative State	Force individuals that are no longer fruitful to converge around a □best location□
Mound State	Converging individuals are grouped together as part of a data structure
Slug State	Make use of another search algorithm for the individuals in the data structure designed to exploit their area of coverage
Dispersal State	Reset the members of the slug data structure

Table 4.1: List of states from the Slime Mold Optimization Algorithm [Monismith and Mayfield 2008].

Using this strategy, a variety of search algorithms could be substituted for those used in the vegetative and slug states. For the vegetative state, two such methods are presented. These include the use of the Razor Search Method and the Downhill Simplex Method in place of the random search methodology presented in section 3.2 [Bandler and MacDonald 1969, Spendley et al. 1962]. For the slug state a method using Differential Evolution is presented to use in place of the method in section 3.6 [Price et al. 2005]. Each of these modifications is discussed and elaborated upon in this chapter. Discussion of testing methods and results is provided in Chapter 5.

Section 4.1: Variations on the Vegetative State

The original Slime Mold Optimization Algorithm makes use of a directed random search for the vegetative state. While this search is simple and attempts to model the pseudopod-based movement of actual Dd amoebae, it is lacking in several aspects [Monismith and Mayfield 2008]. First, the distribution used in the random search is not amenable to rotation in the contours of the search space. This search methodology turns out to be similar to Evolutionary Strategy and faces the same limitations because of its distribution [Corne et al. 1999]. One possible improvement to it is to modify the strategy to take the covariance of the distribution into account when performing a search. Since this methodology may be quite time consuming, it is prudent to consider other search strategies that make movements similar to amoebae [Corne et al. 1999].

In this section, in an attempt to address some of the deficiencies of the original vegetative state, two variations on the vegetative state are presented. These include the use of the Downhill Simplex Algorithm for the first variant, and the Razor Search Algorithm for the second variant. These two algorithms were presented previously in Chapter 2. The use of such algorithms in the Slime Mold Optimization Algorithm requires modification for use in a single timestep. Thus, in the following subsections the modified versions of the timestep-based Downhill Simplex Algorithm and Razor Search Algorithm are provided [Spendley et al. 1962, Bandler and MacDonald 1969]. Furthermore, the reasoning for the use of such algorithms is presented.

Section 4.1.1: Downhill Simplex for the Vegetative State

The Downhill Simplex search presents an interesting option for use in the vegetative state because simplex movement is amoeboid. A simplex is a hyper-triangle, so it consists of D+1 points, where D is the number of dimensions. Another point is added to the simplex by reflecting the worst point in the simplex about the centroid of the other D points. Before the next timestep, the worst from the old simplex is discarded to create a new simplex. This movement is similar to the pseudopod movement that real amoebae use, wherein amoebae are able to measure a gradient across their body wall and make movement opposite that direction. One caveat we must consider is that real amoebae occasionally make mistakes when searching [Spendley et al. 1962]. Thus, to allow for the new algorithm to more closely match Dd movement and to allow some randomness that may allow escape from local minima, the Simplex search used as part of the Slime Mold Optimization Algorithm allow for incorrect movements to be made occasionally (5% of the time) [Erban and Othmer 2007].

To use the Downhill Simplex Algorithm in the vegetative state, several modifications are made to it. First, to fit in the timestep-based approach used in the Slime Mold Optimization Algorithm, the Simplex Algorithm is cut down to what amounts to a single timestep. This is effectively one simplex step. That is, determination of the worst point, the centroid of the remaining points, and movement opposite the direction of the worst point through the centroid. Algorithm 4.1 details the necessary steps to make one simplex step, and is quite straightforward. These involve determining whether to make a random move or an actual simplex move, finding the centroid of the points, ensuring the new point is not out of bounds, counting for repeats, decreasing the simplex size if necessary, and finally keeping track of any new personal or global bests [Spendley et al. 1962, Monismith and Mayfield 2008].

Algorithm 4.1: Vegetative Simplex Movement

```
1.  $pop_i(t).localSearchTime$      $pop_i(t).localSearchTime + 1$
2.  If Rand(0.0□ 1.0) < 0.95,
3.       Find the centroid of all simplex points, $simplexPoints_{0□ D}$, except the worst point.
4.  Else
5.       Find the centroid of all simplex points, $simplexPoints_{0□ D}$ except for a randomly
         chosen point, and swap that point with $simplexPoints_0$.
6.  End If.
7.  Do
8.       isOutOfBounds      false
9.       Find $x^{new}$ (This is based on Formula 2.8)
10.      If $x^{new}$ is outside the search space
11.           isOutOfBounds      true
12.           $\lambda$      $\lambda / 2$
13.      End If
14. While (isOutOfBounds)
15. Reset $\lambda$ if $\lambda$ C 2
16. $oldSimplexPoints$      $simplexPoints$
17. $simplexPoints_0$      $x^{new}$
18. Compute the objective function result
19. Find the new worst point in the simplex and swap it with $simplexPoints_0$
20. Count any repeats
21. If any repeats have occurred more than M times or if the newly created point, $x^{new}$, is
    equal to $oldSimplexPoints_0$,
22.      Decrease the simplex size.
23. End if.
24. If the size must be decreased,
25.      Compute a new set of simplex points of the appropriate size and evaluate their
         objective function values.
26.      Reset the repeat counts.
27.      Find the worst point in the simplex and swap it with $simplexPoints_0$.
28. End if.
29. If an improvement was made,
30.      $pop_i(t).mealCount$      $pop_i(t).mealCount + 1$
31.      Retain the improvement
32. End If.
```

Section 4.1.2: Razor Search Algorithm for the Vegetative State

Razor Search is an interesting algorithm that will be investigated for use in the Vegetative State. This algorithm is interesting because it allows for both step based movement like that of the Hooke and Jeeves Pattern Search and random movement when Pattern Search stalls. Often, such random movements can be made along a narrow valley, if one exists in the solution space. This search is also similar to amoeboid movement because it allows for step based movement to be made in a direction near the opposite of the gradient in many objective functions [Hooke and Jeeves 1961, Bandler and MacDonald 1969, Kessin 2001]. Promising results are apparent upon testing of this algorithm, as will be shown in Chapter 5.

To use this algorithm in the vegetative state, modifications must be made to the Razor Search algorithm. These modifications are similar to those used in the previous section for the Simplex Algorithm. That is, Razor Search must be modified for use on a timestep basis. In its form as presented in Algorithm 2.3, the method is ill suited for use in the Slime Mold Optimization Algorithm. Of particular importance is the lack of short iterative units that would correspond to single timesteps. As shown below in Algorithm 4.2, the modification involves dividing Razor search into several steps. The first of these involved is a Pattern Search based upon Algorithm 2.1 and limited to a small fixed number of iterations (e.g. 100). This step, though sometimes cumbersome in terms of performance, accounts for one timestep. The second step in the Vegetative State Razor Movement starts a typical razor search iteration as would be used in Algorithm 2.3. In this step, a random location is obtained based upon the end point of the previous pattern search. Thereafter, the third step begins. In the third step, another pattern search is performed from the previous random move. This is done to test the random move for effectiveness. The fourth step begins after the pattern search is complete. In this step, a valley direction is ascertained and a pattern move is attempted in the direction of the valley. Then, the fifth step begins. In the fifth step pattern moves are attempted to exploit the direction of movement toward the valley until such movement is no longer fruitful. Once movement is no longer fruitful, the algorithm returns to the second step where timestep based Razor Search movement begins again [Bandler and MacDonald 1969, Monismith and Mayfield 2008].

Algorithm 4.2: Vegetative Razor Movement

```
1. $pop_i(t).localSearchTime$      $pop_i(t).localSearchTime + 1$
2.
3. Switch ( RazorState )
4.     Case 0:  (in 1st pattern search)
5.     Run one pattern search iteration based on Algorithm 2.1.
6.     If the first pattern search is complete,
7.         Set RazorState to 1.
```

```
8.      End If.
9.      Break.
10.     Case 1: (beginning a Razor Search iteration)
11.     Get a random location using equation (2.2).
12.     Change RazorState to 2.
13.     Break.
14.     Case 2: (running a □test□Pattern Search as part of the Razor Search iteration)
15.     Run one Pattern Search iteration based on Algorithm 2.1.
16.     If the pattern search is complete,
17.         Set RazorState to 3.
18.     End If.
19.     Break.
20.     Case 3: (Once the pattern search is complete perform pattern moves)
21.     Find the new valley direction using equation (2.3)
22.     Perform one Pattern Move using Algorithm 2. .
23.     Change RazorState to 4.
24.     Break.
25.     Case 4: (Exploit the direction of movement by performing more pattern moves)
26.     Perform a Pattern Move using Algorithm 2. .
27.     If the Pattern Move yielded no improvement to the objective function value,
28.         Change RazorState to 1.
29.     End If.
30.     Break.
31. End Switch.
32. If an improvement to the objective function value was made,
33.     $pop_i(t).mealCount$      $pop_i(t).mealCount + 1$
34.     Retain the improvement
35. End If.
```

Section 4.2: Variations on the Slug State

The form of the slug state as presented in sections 3.4 □6 is quite different from what is presented in biology. The main reasons for this difference were lack of inspiration and limited biological research on the part of the author. As a quick fix, the data structure created in the mound state was originally based upon the structure of the aggregative state. This data structure and the related equations were used to ensure amoeba movement during the slug state was similar to movement during the biological aggregative state over a localized area [Monismith and Mayfield 2008]. To ensure a better correlation with what is found in nature, heavy modification was made to this portion of the algorithm. Implementation includes a search methodology that focuses on both the biological head and tail elements. Recall from section 2.2.4 that the head of the slug consists of 1/5 of the slug's population and the remaining 4/5 of the amoebae compose the tail [Kessin 2001]. The modifications to the slug stage in the Slime Mold Optimization Algorithm include this construct.

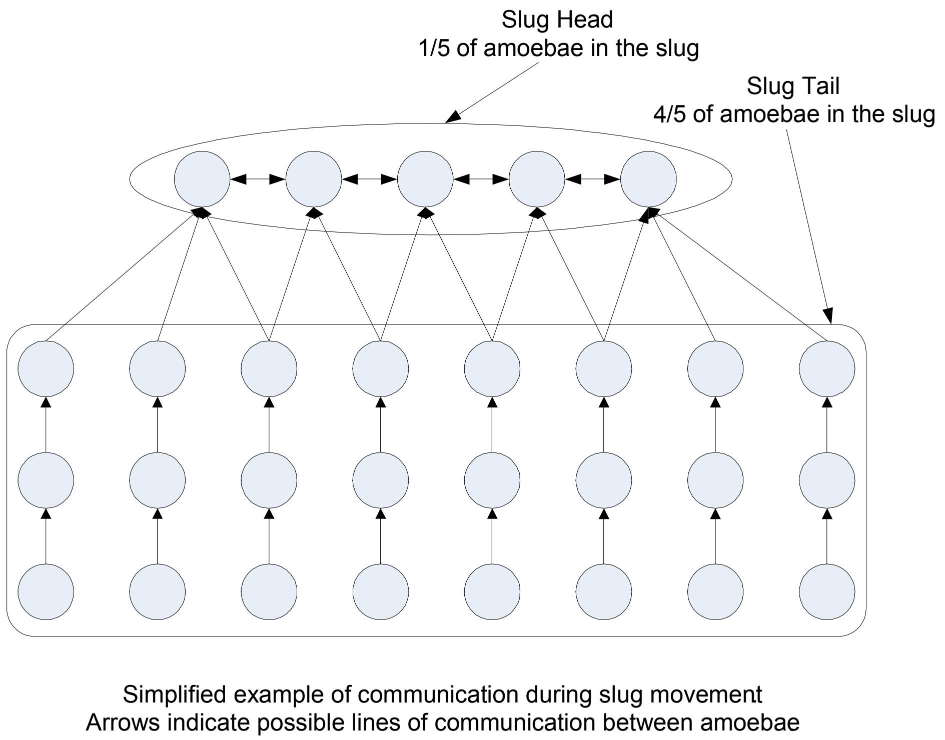

Slug Head
1/5 of amoebae in the slug
Slug Tail
4/5 of amoebae in the slug
Simplified example of communication during slug movement
Arrows indicate possible lines of communication between amoebae

Figure 4.1: Modification to the slug state.

The focus of this portion of research is to modify the slug to better follow equations in biology literature. To do so, the slug will be divided into a head and tail. The Dd slug head consists of the 1/5 of the slug population that are to become spores. Recall from Chapter 2 that these are the best fed amoebae from the mound [Kessin 2001]. An analogous formation for optimization purposes is a head consisting of the 1/5 of the slug population with the best objective function values. These individuals should direct the movement of the remainder of the slug, i.e. the tail. A simple way of doing this would be to let the head perform a search that can accurately determine the contours of the search space and allow the tail to perform a dense search of the area behind the head to ensure nearby minima are found. Forcing the amoebae in the tail to follow the head is simple, Equations similar to those used in the PSO are sufficient to elicit such movement [Janson and Middendorf 2005]. Choice of the proper movement in the head may prove much more difficult. Using Differential Evolution or a Genetic Algorithm should be suitable for the search being carried out by the head; therefore, DE will be tested for use in the head as part of this work. Another more interesting improvement to the head would be to try to implement the chaotic whorl movement used by real Dd slugs to move toward light [Kessin 2001, Marée et al. 1999 Phototaxis]. The author is currently researching the whorl movement; thus, such research will not be included as part of this work.

4.2.1 Differential Evolution

Replacement of the original slug algorithm with the Differential Evolution algorithm is quite simple. To start, a single instance of the DE algorithm may be used for each slug member (an amoeba with index □i□). This algorithm begins by choosing three random slug members (amoebae with indices a1, a2, and a3). These amoebae are assumed to be passed as parameters to Algorithm 4.3 as shown below. As in the standard DE algorithm, a random index, representing dimension k, is chosen to begin application of the DE algorithm to the amoeba□s location. A random value is tested against the crossover probability, CR, to cause either a crossover with a mutation factor F or to keep the original location along dimension k. Next, the algorithm ensures the new location for dimension k is not out of bounds. This process is repeated for each dimension k. At least one dimension in the new location is forced to include a crossover as shown in Algorithm 4.3. Finally, the algorithm computes a result based upon the new location and updates the location only if the new location results in a better objective function value. Additionally, the personal best of the amoeba with index □i□is updated if necessary. Although use of this portion of the DE algorithm does not fit directly into the scope of the movement shown in Figure 4.1, it will be used in the next section as part of the head movement for the slug [Price et al. 2005, Monismith and Mayfield 2008].

Algorithm 4.3: DE (Used for Head Movement)

```
1.  Parameters: a1, a2, a3 : Integer
2.  j      Rand(0□ D □1)
3.  for k      0 to D □1,
4.      if(rand(0.0□ 1.0) < CR or k = D □1)
5.          $temp_j$      $pop_{a1}(t).x_j + F \cdot (pop_{a2}(t).x_j$ □$pop_{a3}(t).x_j)$
6.      else
7.          $temp_j$      $pop_i(t).x_j$
8.      End if.
9.      Ensure $temp_j$ is not out of bounds.
10.     j      (j + 1) mod D
11. End for.
12. tempF      f(temp)
13. If ( tempF < $pop_i(t).f$)
14.     $pop_i(t+1).f$      tempF
15.     $pop_i(t+1).x$      temp
16. End If.
17. Update the personal best of $pop_i(t+1)$ if necessary.
```

4.2.2 DE + Followers

The DE + Followers slug search algorithm is a heavily modified version of the slug search as explained in sections 3.4 □3.6. It begins with creation of the slug data structure through the mound stage. The slug is initialized to the appropriate size and number of nearest neighbors, and a new sizing algorithm to determine the best head and tail sizes is applied. During the Mound stage, as amoebae are added to the slug, the DE + Followers algorithm inserts amoebae into the head and tail. During the slug search phase, instead of using the PSO equations, DE is used for the head of the slug, and a simple following algorithm is applied to force the tail amoebae to follow the amoebae pursuing the DE strategy in the head [Monismith and Mayfield 2008]. Details are presented for this algorithm in this subsection.

Creation of the slug begins at the end of the aggregative phase as presented in Chapter 3. Upon satisfaction of equation (3.6), the slug object is created based upon a number of amoebae that have aggregated at a particular grid location. The □normal□ operations for slug initialization may be carried out at that point (i.e. memory allocation for the ε-ANN tree and array of slug amoebae) [Monismith and Mayfield 2008]. Additionally, the head and tail may be sized. The preferred sizes for the head and tail are 1/5 of the amoebae in the slug for the head and 4/5 of the amoebae in the slug for the tail [Kessin 2001]. Issues may occur when there are too few amoebae within the slug. For example, the DE algorithm requires at least four locations to work. Thus there must be at least four amoebae in the head. Moreover, the slug must contain at least four amoebae, and in the case where there are less than twenty amoebae in the slug the numbers of amoebae in the head and tail must diverge from the biological requirements. To deal with this issue, the algorithm allows for a larger head than tail when there are too few members in the slug to meet the 1:4 head tail ratio. Additionally, initialization may be performed for head and tail counts and memory for the head and tail amoebae used when adding amoebae to the head and tail of the slug [Kessin 2001, Price et al. 2005]. Algorithm 4.4 briefly indicates the necessary instructions to determine the size of the head and tail.

Algorithm 4.4: DE + Followers Slug Movement (Head and Tail Sizing)

```
1. headCount      0, tailCount      0
2. If 0.2 * slugSize < numNeighbors
3.      headSize      numNeighbors
4.      tailSize      slugSize □numNeighbors
5. else
6.      headSize      0.2 * slugSize
7.      tailSize      slugSize □headSize
8. End If.
9. Allocate memory for head, tail, and centroids
```

The next part of the DE + Followers slug update is to add amoebae to the head and tail. This occurs in the mound stage after the slug object has been created. The mound algorithm from Chapter 3 is used to add these amoebae to the slug [Monismith and Mayfield 2008]. Additionally, amoebae must be placed in the data structures representing the head and tail. Initially, the head and tail are empty. Amoebae are placed in the head until it is filled. Once the head data structure is full, the algorithm attempts to replace amoebae in the head one at a time, moving the worst amoebae to the tail. A short algorithm to add amoebae to the head and tail is provided below as Algorithm 4.5.

Algorithm 4.5: DE + Followers Slug Movement (Adding amoebae to the Head and Tail)

```
1.  If headCount < headSize
2.      headAmoebae[headCount]     $pop_i$
3.      headCount     headCount + 1
4.  Else
5.      worstAmoeba     $pop_i$
6.      worstPosition     -1
7.      for j     0□ headSize □1
8.          if headAmoeba[j].f < $pop_i(t)$.f
9.              worstPosition     j
10.         End if.
11.     End for.
12. End if.
13. If worstPosition != -1
14.     tailAmoebae[tailCount]     headAmoebae[worstPosition]
15.     headAmoeba[worstPosition]     $pop_i$
16. Else
17.     tailAmoeba[tailCount]     $pop_i$
18. End if.
19. tailCount     tailCount + 1
```

DE based movement was provided in section 4.2.1, and that same movement as shown in Algorithm 4.3 may be used for members of the slug□s head. To complement this movement, an additional algorithm is provided below for tail movement. Amoeboid tail movement is driven by two factors. The first of these is the direction of the head. This is determined by the difference between the centroid of the head and the centroid of the tail. This value is normalized and then scaled by the average distance between all members of the slug. The second factor used is the nearest neighbor direction. Each amoeba has a nearest neighbor, and the one closest to the tail direction is used to aid in the computation of each tail amoeba□s new location. These two factors are multiplied by a random value, each scaled by half, and added to the amoeba□s old location to determine its new location. Algorithm 4.6 provides the details for amoeboid tail movement.

Algorithm 4.6: DE + Followers Slug Movement (Tail Movement)

```
1.  Find the nearest neighbor, with index nn, in the direction nearest the TailDirection.
```

```
2. Compute the NearestNeighborDirection as the distance between $pop_i(t).x$ and
   $pop_{nn}(t).x$
3. for j $\leftarrow$ 0 … D − 1
4.     $pop_i(t+1).x_j \leftarrow pop_i(t).x_j + 0.5 * \text{Rand}(0.0 … 1.0) * E_j[d_{\text{slugNeighbor}}] * \text{TailDirection}_j$
           $+ 0.5 * \text{Rand}(0.0 … 1.0) * \text{NearestNeighborDirection}_j$
5.     Ensure that $pop_i(t+1).x_j$ is within bounds.
6. End for.
7. Compute the new objective function value and update personal best if necessary.
```

Lastly, as part of the Slime Mold Optimization Algorithm, each slug must be updated after all amoebae have completed one timestep's worth of movement. The majority of updates for the slug presented in this section follow similar algorithms as that of the original slug update algorithm [Monismith and Mayfield 2008]. There is, however, one additional update that is required for the slug, as presented in this section. Before continuing to another iteration of amoeboid movement, the centroids for the members of the head and tail must be found. Once these values are determined, the general direction of tail movement is ascertained and normalized so it may be used in subsequent amoeboid movement. Algorithm 4.7 details the necessary updates for DE + Followers slug movement.

Algorithm 4.7: DE + Followers Slug Movement (Slug Update)

```
1. Compute centroids of the head and tail as headCentroid and tailCentroid.
2. Compute the tail direction (referred to as tailDirection) as the difference between the
   head and tail centroids.
3. Normalize tailDirection by the square root of its dot product.
```

Section 4.3 Conclusion

In this chapter, several modifications to the Slime Mold Optimization Algorithm were introduced. These included modification to the vegetative state to allow for the use of the Downhill Simplex and Razor Search algorithms as vegetative search algorithms [Spendley et al. 1962, Bandler and MacDonald 1969]. Additionally, the slug state was modified to allow for use of Differential Evolution as a search algorithm and to allow for DE's use as part of a slug containing a head and a tail [Kessin 2001, Price et al. 2005]. In the following chapter, results for the algorithms presented in Chapter 3 and those presented in this chapter will be provided and analyzed.

CHAPTER V

V. RESULTS AND ANALYSIS

In this chapter, results are provided for the Slime Mold Optimization Algorithm. Before discussing results, the test equations and testing procedures are discussed. Next, the Slime Mold Optimization Algorithm, as presented in Chapter 3, is tested against a large function suite provided in the Objective Function Appendix (Appendix A). This first round of testing is carried out using different numbers of amoebae, pseudopods, neighbors, and function evaluations. Analysis of results is presented, and results are then compared against those of existing algorithms, including Hooke Jeeves (HJ), DE, RCGA, and PSO. Thereafter, results for variations on the Slime Mold Optimization Algorithm are presented. These include replacement of the vegetative state with the Razor Search and Downhill Simplex algorithms. Additionally, results for the DE + Followers method (as described in section 4.2) using both Razor Search and the standard vegetative search are provided. Comparisons are provided for each modified algorithm using the same criteria as the standard slime mold optimization algorithm.

Section 5.1: Test equations and testing procedures

The first portion of the results includes testing each of the optimization algorithms over a variety of parameters using many objective functions. The objective functions include variation in dimensionality and contours, some feature high levels of multimodality, discrete steps, or minima that are cut off at a bound. Additionally, parameters for the Slime Mold Optimization Algorithm are varied so comparisons within the algorithm may be made. Furthermore, direct comparisons are made to results from other algorithms such as Differential Evolution, Particle Swarm Optimization, and Real-Coded Genetic Algorithms. Performing such a comparison as part of this work will give a better feel for the strengths and weaknesses of the slime mold optimization algorithm. Therefore, the focus of this section includes a discussion of the various test functions used, the method of testing functions using varying parameters, and comparisons to variations of the slime mold optimization algorithm and other existing algorithms.

The test function suite used in this work includes functions with varying degrees of difficulty including multi-modality, variation in dimensionality, discrete steps, and minima cut off at bounds. The reader is referred to the Objective Function Appendix (Appendix A) for formulae, bounds, and optimal objective function values and locations for the functions to be optimized. A list of these functions is also provided in Table 5.1. Of the functions, several are included which are unimodal and present little difficulty to general optimizers. These are the DeJong or Spherical Contours function which is a simple parabolic function that slopes downward toward a single optimum, the Easom function, which is a Gaussian centered at (π, π), and the functions S1, S2, and S3 which are downward sloping functions of two variables that are have a minimum at a bound [Chen 1997, GEATbx 2007, Choi and Mayfield 2009]. Each of these functions should present little difficulty to a general optimizer.

The McCormic, Goldstein and Price, Bohachevsky, Engvall, Branin rcos, and Six Hump Camel functions all present multiple modes. These functions are smooth, but include local and global minima across their search spaces. As such they are slightly more difficult to optimize than unimodal functions. Likewise, the Rosenbrock function and the Downhill Step Function are slightly more difficult to optimize than the Spherical Contours or Easom functions. Classical optimization methods may not work on these functions; therefore, the use of direct search methods such as EAs, Pattern Search, or Downhill Simplex is necessary [Chen 1997, GEATbx 2007]. Thus, it is expected that the Slime Mold Optimization Algorithm should have little difficulty in optimizing the functions above even as variations in dimensionality and bounds are introduced.

Rosenbrock 2D (1)	McCormic (2)	Box and Betts (3)	Goldstein (4)	Easom (5)	Mod. Rosenbrock 1 2D (6)
Mod. Rosenbrock 2 2D (7)	Bohachevsky (8)	Powell (9)	Wood (10)	Beale (11)	Engvall (12)
DeJong 2D (13)	Rastrigin 2D (14)	Schwefel 2D (15)	Griewangk 2D (16)	Ackley (17)	Langermann (18)
Michaelewicz (19)	Branin (20)	Six Hump Camel (21)	Osborne 1 (22)	Osborne 2 (23)	Mod. Rastrigin 2D (24)
Mineshaft 1 (25)	Mineshaft 2 (26)	Mineshaft 3 (27)	Spherical Contours 32D (28)	S1 (29)	S2 (30)
S3 (31)	Downhill Step (32)	Salomon 2D (33)	Whitley 2D (34)	Odd Square 2D (35)	Storn Chebyshev 9D (36)
Rana 2D (37)	Rosenbrock 10D (38)	Rosenbrock 30D (39)	Mod. Rosenbrock 1 10D (40)	Mod. Rosenbrock 1 30D (41)	Mod. Rosenbrock 2 10D (42)
Mod Rosenbrock 2 30D (43)	Spherical Contours 10D (44)	Rastrigin 10D (45)	Rastrigin 30D (46)	Schwefel 10D (47)	Schwefel 30D (48)
Griewangk 10D (49)	Griewangk 30D (50)	Salomon 10D (51)	Salomon 30D (52)	Odd Square 10D (53)	Whitley 10D (54)
Whitley 30D (55)	Rana 10D (56)	Rana 30D (57)			

Table 5.1: Objective Functions Used

Testing of the Slime Mold Optimization Algorithm will also involve many functions that are more difficult than those explained above. The Rastrigin, Schwefel, Griewangk, and Ackley's Path functions all present different variants of a pincushion function. That is they all have high numbers local minima that make the function appear as if it is a pincushion that has been molded to a particular form. Rastrigin's function is a pincushion overlaid upon a parabola as is the Griewangk function, although it has a tighter pincushion [Price et al. 2005]. The Ackley's Path function has a Gaussian conformation with a pincushion applied to it, and the Schwefel function has an almost random appearance to its pincushion [Price et al. 2005]. Since these functions have multiple minima they offer many positions in which an optimizer may become trapped, but since there are always other "pins" (i.e., minima) nearby, a good optimizer will be able to escape these traps that lie throughout the search space. The Modified Langermann’s function also presents multiple minima that are located in a close space, and thus, optimizers act similarly when working upon it [Chen 1997, Price et al. 2005]. The Wood, Beale, and Powell functions are all deceptively simple. For example, though the Powell function appears simplistic, Chen notes that it has a singular Hessian matrix at its minimum [1997]. These functions each present combinations of parabolic functions of varying powers. Instead of creating a pincushion landscape, they create a landscape with a few valleys that cause Direct Search methods to sometimes become trapped within a valley that is a local minimum [Chen 1997]. Two other functions that offer similar effects with different conformations are also included. These are the Michaelewicz and Mineshaft 3 functions. The Michaelewicz function offers a few minima that are hidden within nearly flat valleys, and the Mineshaft 3 function offers two extremely narrow Gaussian minima that are shaped like mineshafts and located within a flat plane. Both of these functions provide some difficulty to direct search methods and EAs because they offer locations far from the actual minima at which such optimizers may become trapped [GEATbx 2007, Monismith and Mayfield 2008]. Though the functions explained above present a moderate amount of difficulty to EAs, many such algorithms are able to optimize these functions provided enough time.

The next group of functions that will be tested on the Slime Mold Optimization Algorithm are quite difficult to optimize. The first pair of difficult functions is a pair of modified versions of Rosenbrock’s function. Such modification in the function changes the nearly planar valley of the original function to an edge via square root and absolute value operators. Using these operators yields two functions – a “flat ground bent knife edge” function and a “hollow ground bent knife edge” function. Since the optimum in both of these functions lies along an edge within a valley having a narrow opening angle, stochastic methods that are unable to correctly judge contours may take an infinite amount of time to reach the optimum or may converge incorrectly [Chen 1997]. Next, the discussion of difficult functions includes a group of functions that the author has modified and developed. These are the Mineshaft 1, Mineshaft 2, and Modified Rastrigin functions, and they were crafted using root functions for Mineshaft 1 and Modified Rastrigin and a Gaussian for Mineshaft 2. The low order roots and the narrow Gaussian cause these functions to exhibit minima that are located at the bottom of areas with extremely narrow openings, which makes optimization very difficult [GEATbx 2007, Monismith and Mayfield 2008]. Two other interesting functions are the Osborne 1 and 2 functions, which are least squares problems of 5 and 11 dimensions respectively. In his thesis, Chen notes that these functions may provide difficulty to stochastic optimizers, and the reason for such difficulty is as of yet unknown [1997]. In unpublished work, the author has verified that the Osborne functions do indeed prove difficult to optimize with both RCGAs and PSO algorithms. Several additional functions are included for testing from [Price et al. 2005]. These are Salomon's function, Whitley's function, Storn's Chebyshev function, the Odd Square function, and the Rana function. These functions are noted for their difficulty, high multimodality, and many of them may be scaled to varying degrees of dimensionality. The reader is directed to the Objective Function Appendix for formulae and 3D views (where applicable) of the functions described above.

The functions explained above will be used as part of a suite to test the Slime Mold Optimization Algorithm. Testing of the algorithm will be based upon several factors variation in the number of amoebae, maximum number of iterations, and number of neighbors. The results provided are the averages of the smallest objective function values obtained during attempts at finding the true minima over a fixed number of trials or runs of a particular optimization algorithm. Unless otherwise denoted, these averages will be over 100 runs or trials of an algorithm and the generic term, result, will refer to such an average. In addition, relative error is used to compare the Slime Mold Optimization Algorithm, its variants, the Hooke Jeeves algorithm, and Evolutionary Algorithms. Relative error is defined as the difference between an approximate and actual value divided by the actual value [Abramowitz and Stegun 1972]. The formula for the relative error between an actual minimum f^* and an approximate minimum f_{est}^* is provided below.

$$\text{Relative Error} = \frac{|f_{est}^* - f^*|}{|f^*|} \tag{5.1}$$

The percent error may also be calculated by multiplying the relative error by 100 [Abramowitz and Stegun 1972]. When $f^* = 0$, it is impossible to calculate the relative error. In that case, adding one to both the estimated minimum and true minimum allows for calculation of the relative error. Such calculation is used because doing so is equivalent to calculating the absolute error [Abramowitz and Stegun 1972]. Graphs in the latter sections of this chapter include variations in error of high orders of magnitude. To deal with this a variant of relative error called Log of Scaled Relative Error was devised and is defined below.

$$\text{LSRE} = \log\left(\frac{|f_{est}^* - f^*|}{|f^*|} + 1\right) \tag{5.2}$$

The LSRE is the logarithm of one plus the relative error. This is needed to avoid taking the logarithm of zero when dealing with exact estimates of minima.

First, results for the algorithm, as presented in Chapter 3, will be provided with objective function evaluations limited to maximums of 100,000, 500,000, and 1,000,000 evaluations, respectively. Additionally, the algorithm will be tested by varying the number of amoebae in the population using the values 50, 100, 250, and 500 as population sizes. Within those results, the number of neighbors will be varied as a fixed four neighbors, the number of search space dimensions limited to a maximum of 10 neighbors, 2 times the number of search space dimensions with no limit, and the square of the search space dimensions. Furthermore, selected population sizes of 50 and 500 will be tested using the original algorithm using a maximum of 500,000 evaluations while allowing the number of pseudopods to vary from 2 to 10 in steps of two. Results from these runs will be graphed to show the effect of varying population size and objective function evaluation limits on each set of algorithm parameters. The reason for such testing is to evaluate the effect of varying parameters so that the number of function evaluations needed to optimize the various objective functions explained above [Price et al. 2005, Monismith and Mayfield 2008].

The next portion of the testing procedures involves comparison of the slime mold algorithm□s results against those of the Hooke Jeeves Pattern Search, DE, PSO, and RCGA. Each of the four algorithms will be tested on all the functions presented in the Objective Function Appendix. This testing will include limitations of 100,000, 500,000, and 1,000,000 objective function evaluations, respectively. The specific versions of the Evoluationary Algorithms planned for use are the DE current-to-rand algorithm with fixed values for the F and K parameters, the standard PSO algorithm, and an RCGA algorithm with a 90% crossover rate and a 0.5% mutation rate [Price et al. 2005, Kennedy and Eberhart 1995, Herrera et al. 1998]. These EAs will have population sizes of 200 (DE), 100 (PSO), and 500 (RCGA). Such sizes were used because of their effectiveness on the Objective Function Appendix. Code for the EAs was written by the author. Results from the Hooke Jeeves algorithm will be provided using starting step sizes of 10% of the distance across the bounds of the objective functions, and the step size reduction factor will be set to 0.2. Additionally, each trial of the Hooke Jeeves Pattern Search used 100 randomly chosen starting locations from which the algorithm was allowed to start. The best result out of the 100 was used as the result for each trial of the algorithm. This implementation was used as a way to simulate having a population like an EA. Code for this algorithm was provided by John Chandler and updated by the author for use in this work. Results from these algorithms using similar limits on function evaluations should provide a reasonable basis for comparison to the Slime Mold Optimization Algorithm.

The final portion of the testing procedures includes testing the variants of the Slime Mold Optimization Algorithm. There are four of these variants to be tested, and each will be tested using the same parameters as the Original Algorithm where applicable. This includes limitations of 100,000, 500,000 and 1,000,000 objective function evaluations, amoeba population sizes of 50, 100, 250, and 500, and the same four neighbor settings as listed above. The variants to be tested are Slime Mold Optimization Algorithms (SMOAs) with 1) a vegetative state that makes use of the Downhill Simplex Algorithm (Simplex SMOA), 2) a vegetative state that makes use of the Razor Search Algorithm (Razor SMOA), 3) a slug state that makes use of the DE + Followers algorithm (HTDE-SMOA), and 4) both a vegetative state using the Razor Search Algorithm and a slug state using the DE + Followers Algorithm (HTDER-SMOA). Results as explained above will be explained in the following sections and their graphs are provided in the appendices.

Section 5.2 Original Algorithm Results

In this section results from the version of the Slime Mold Optimization Algorithm as presented in Chapter 3 are presented. This algorithm will also be referred to as the □Original Algorithm□ or □SMOA□ in this section and thereafter. Results for the Original Algorithm are presented as tables in Appendix B1. Likewise similar tables are presented in Appendices B2 and B3 for the standard deviations of the results and the runtimes of each test. Results are shown for 57 objective functions, all of which are presented in the Objective Function Appendix (Appendix A). For each objective function, 48 results are presented. These results are divided into three groups of 16 representing the tests of the SMOA with limits of 100,000, 500,000, and 1 million objective function evaluations, respectively. Each set of 16 is further divided into sets of four using population sizes of 50, 100, 250, and 500 amoebae (denoted as A50, A100, A250, and A500 in graphs and tables), respectively. Each of these sets of four uses one of the four neighbor strategies as numbered here: N1) four neighbors, N2) the number of decision variables limited to a maximum of ten neighbors, N3) two times the number of decision variables with no limit, and N4) the square of the number of decision variables. As an example, one point might represent 100,000 objective function evaluations with a population size of 250 (A250) and use neighbor strategy N1) four neighbors.

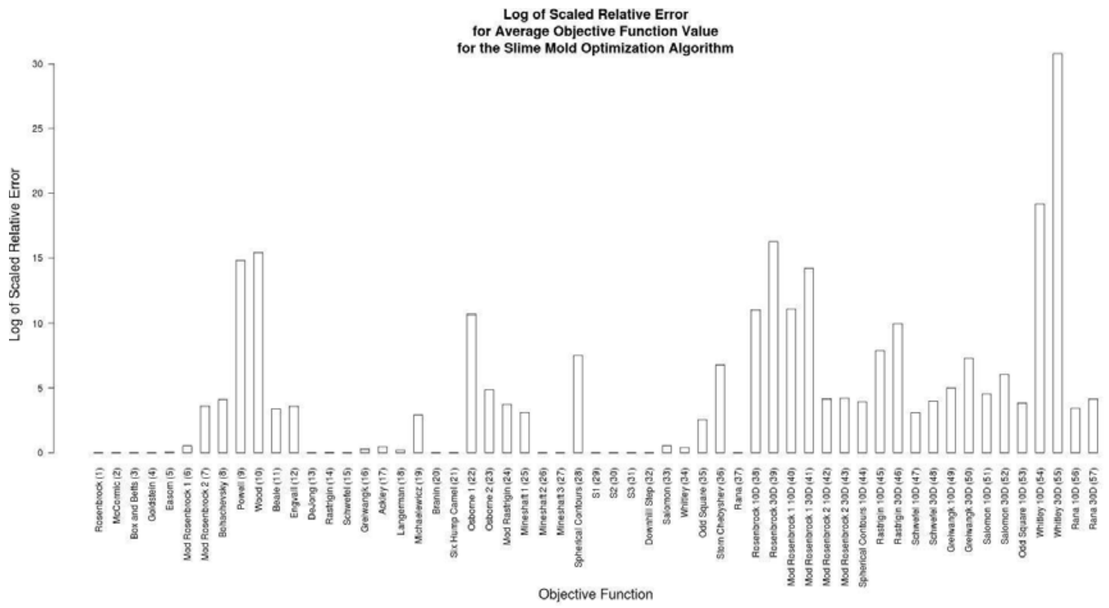


Figure 5.1: Log of Scaled Relative Error for Original SMOA using the best of the average results across parameter variations.
Refer to Table 5.1 for names corresponding to function numbers.

Before comparing results between parameter variations of the original algorithm, the overall performance of the algorithm is considered. That is, assuming the user of the algorithm had knowledge of appropriate parameters, how would said user□s results appear. A first look at the best of our average results shows mediocre to good performance on low dimensional functions. Among the functions where the algorithm performed well are Rosenbrock (1), Rastrigin (14), Griewangk (15), Schwefel (16), Mineshaft 3 (27), and many other functions. In particular, the algorithm performs well on any function that is not of very high dimensionality or of very high difficulty as shown in Figure 5.1. The algorithm□s performance on more difficulty functions such as the Powell (9), Wood (10), Osborne (22, 23), Mineshaft 1 (25), and Modified Rastrigin (24) functions is particularly poor. Many of the results appear to be approaching the optima, but the algorithm needs more objective function evaluations to reach the optima. For example, in the appendices, one can see progress being made toward the minima for the 32D Spherical Contours (28), Storn Chebyshev (36), and Odd Square (35) functions. It appears as if many more evaluations are needed to reach optima on these functions.

Next, the algorithm's performance across the various evaluation limits is discussed. Such performance is as expected. The SMOA shows its best results at the 1,000,000 evaluation limit, mid-range results are at the 500,000 evaluation limit, and the worst results show up at the 100,000 evaluation limit. An example of this can be seen for Rosenbrock's function in Figure 5.2. Moreover, results become more consistent according to their standard deviation as evaluations are increased, but the time cost of the algorithm significantly increases as the evaluation limit is increased. What is odd is that improvement between the 100,000 and 500,000 limits and between the 500,000 and 1,000,000 limits is not always as strong as should be expected. This indicates the need for modification to the algorithm as currently designed. One possible change that could be made to the SMOA is to force the slug stage to retain the current global best within one of its members. This would effectively force all amoebae in the slug to move toward the current global best.

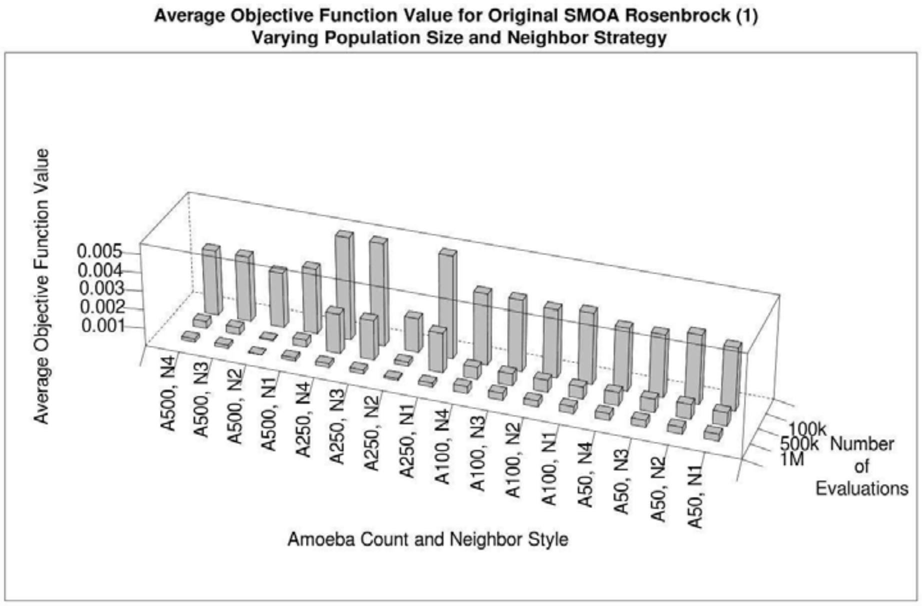


Figure 5.2: Original SMOA results from Rosenbrock's function ($f^* = 0$) across evaluations, population sizes, and neighbor strategies.

Another interesting parameter of the SMOA is the number of amoebae used in algorithm. This parameter has strong effects on both results and runtimes. For objective functions of many dimensions, runtime costs increased as the number of amoebae were increased. The opposite was often true for objective functions of fewer dimensions. This occurred because the time cost in using the slug state with an objective function of few dimensions was quite low because of the small number of neighbors used, even in comparison to the cost associated with the vegetative state. In contrast, with a high dimensional function, using many amoebae causes the slug state to become costly in terms of CPU usage because of the large number of links between neighbors.

Performance changes across by varying population size are quite noticeable across all evaluation limits. Of additional interest is that functions most affected (i.e. requiring more CPU time) were those that are difficult to optimize and/or of high dimension (5+). Lower population sizes improved results and standard deviations for the following functions: Goldstein, Powell, Wood, Langerman, Michaelewicz, Osborne 1 & 2, Modified Rastrigin, Mineshaft 1 & 2, Spherical Contours 10D & 32D, Storn Chebyshev (9D), Rana, Rosenbrock 10D & 30D and its modifications, Griewangk 10D & 30D, Rastrigin 10D & 30D, Schwefel 10D & 30D, Salomon 10D & 30D, Odd Square 10D & 30D, and Whitley 10D & 30D. An example of this for the 10D Spherical Contours function is provided in Figure 5.3. Note that all of the aforementioned

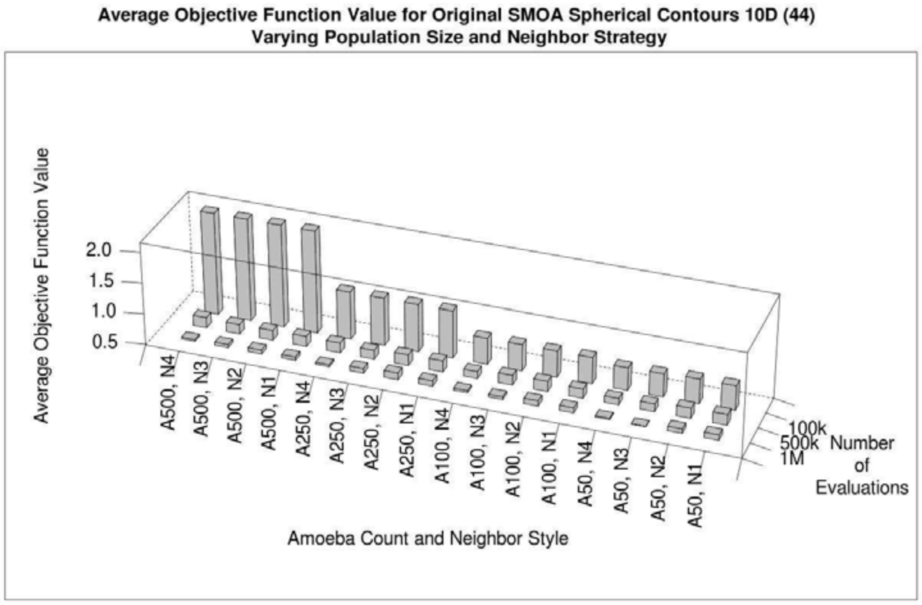


Figure 5.3: Original SMOA results from Spherical Contours Function 10D (f* = 0) across evaluations, population sizes, and neighbor strategies

functions listed may present considerable difficulty to optimization algorithms based on their dimensionality and/or multiple minima. Occasionally, one particular population size was best. This tendency can be seen in the Beale and Engvall functions. Additionally, there is a tendency for results to flatten across parameter variations with higher number of objective function evaluations (500k and 1M). This is to be expected because as results improve in many optimization algorithms, they tend to stabilize as they near optima. Such tendency can be seen in Figure 5.2 for Rosenbrock's function. Results for the Wood and Powell functions reversed their performance with respect to population size at the 100,000 and 1,000,000 evaluation limits. This is, however, not worth much merit since an optimum was not reached, and both results and standard deviations for these functions improved as population size was increased. Lastly, many objective functions that would be considered "easy" to optimize were relatively unaffected by change in population size, especially at higher evaluation limits. This is to be expected because in many cases the number of evaluations was more than sufficient to produce reasonable results.

Objective function values provide much insight into the performance of the Slime Mold Optimization Algorithm. There are, however, limits to how well performance can be judged based upon this one indicator. To better gauge performance in functions where there are many local minima, it is helpful to look at the distance between the decision space values obtained from an optimization algorithm and the decision space values of the actual minima. This will be referred to as the error in x. In Figure 5.4, the error in x is presented for the Griewangk function. From the box plots presented, it is easy to see that the Original SMOA falls between 20 and 70 units away from the actual minimum.

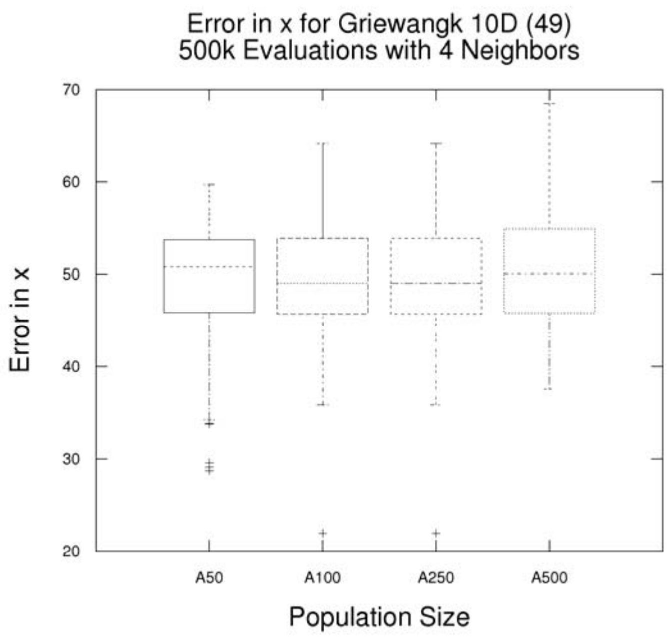


Figure 5.4: Error in x for Griewangk 10D Function (49) using 4 neighbors and 500,000 evaluations.

Looking at Figure 5.5 in conjunction with Figure 5.4, it is clear that the objective function values produced by the Original SMOA are nearing the actual minima of zero at decision space location (0, 0). Since it is known that the Griewangk function has many local minima, one can assume that the Original SMOA was caught in an area of local minima near the true minimum

Next, performance across neighborhood strategies is discussed briefly. Performance from varying neighbor strategies is more straightforward than that of varying population size. Simply put, increasing the number of neighbors has a tendency to improve performance (result and standard deviation) as the number of evaluations is increased and with higher dimensionality and difficulty of the objective function. Such improvement comes with a cost of increased runtime as the dimensionality of the objective function is increased. This should not come as a surprise since more neighbors will provide more information when attempting to optimize functions of higher dimensions.

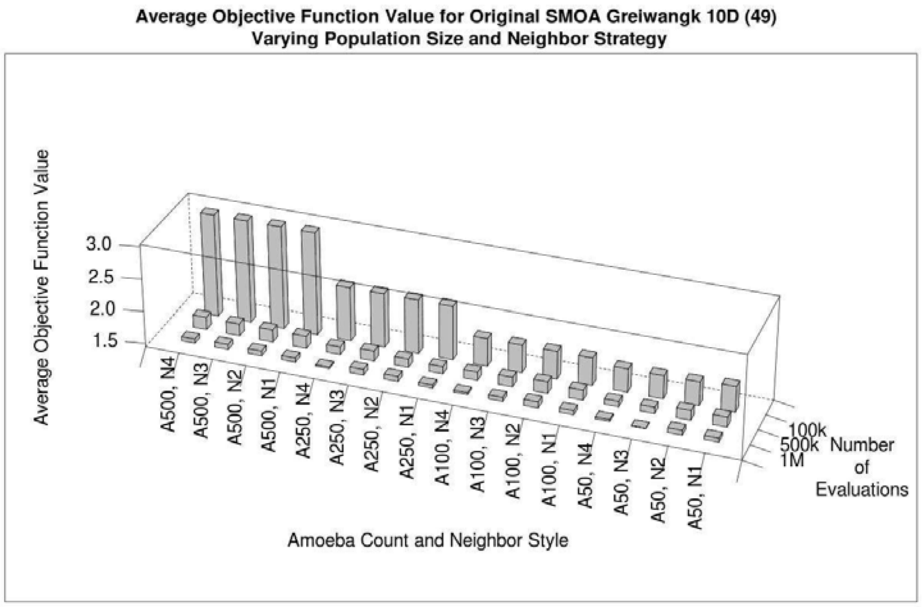


Figure 5.5: Original SMOA results from Griewangk Function 10D (f* = 0) across evaluations, population sizes, and neighbor strategies

Another of the parameters that was varied to ascertain performance was the number of pseudopods. For this set of parameters, the algorithm was fixed at a limit of 500,000 evaluations and was tested using each of the four neighbor strategies with population sizes of 50 and 500 amoebae. Performance from modifying number of pseudopods shows little variation. Perhaps slight preference is indicated for very few (2) or many (10+) pseudopods. Results, standard deviations, and runtimes for varying the number of pseudopods may be seen in Appendices C1, C2, and C3, respectively. Of more interest is that the results, regardless of the number of pseudopods show a definite preference for a smaller population size when optimizing high dimensional functions using a 500,000 evaluation limit.

The last of the data considered for the Original algorithm is its runtime. Runtimes for SMOA are provided in Appendix B3. Note that these runtimes are averaged over the 100 trials that were used for each objective function. The algorithm was executed as a 9 thread process with one server thread and each of a number of client threads running one instance of the SMOA with a particular parameter set. This program ran on a 1U Dell PowerEdge 1950 III with dual quad-core Intel E5430 processors. This was one node of the OSU Supercomputer called Pistol Pete. Run times ranged from less than 0.08sec for a 100,000 evaluation run of SMOA on function S1 to just over 6.5min for a 1,000,000 evaluation run of SMOA on the Storn Chebyshev (9D) function. The high cost associated with the Chebyshev function is due to a high amount of recursion and iteration required for its evaluation. Most runs of SMOA cost between 0.1sec and 10sec for functions of low dimensionality and between 10sec and 6.5min for functions of high dimensionality (e.g. 9D – 32D).

Section 5.3 Comparisons between the Original Algorithm, HJ, DE, RCGA, and PSO

In this section, comparisons between the Hooke Jeeves, DE, RCGA, and PSO algorithms and the best of the average results from the original SMOA are discussed. This is done to get a baseline for the performance of the SMOA versus existing EAs. One might wonder why comparisons are not made against existing derivative-based classical algorithms (e.g. Steepest Descent). For such algorithms, it is not possible to test the entire function set to classical algorithms because many of them lack derivatives (e.g. Storn Chebyshev, Odd Square, Modified Rosenbrock 1, etc.). Such algorithms typically offer a better cost to performance ratio on differentiable functions as well. One direct search algorithm, Hooke Jeeves Pattern search is tested against the SMOA. Since this algorithm is different from EAs in that it does not have a population, a population-based heuristic is used whereby many Hooke Jeeves trials are used with starting points scattered randomly about the decision space. This was done to ensure fairness against EAs, because direct search algorithms using single starting points may become trapped in local minima. Even with such a population-based heuristic, direct search algorithms are typically not very costly in terms of run time. EAs also offer the possibility of global optimization, but this is often at the cost of hundreds of thousands or millions of objective function evaluations. Therefore, it is prudent to compare such algorithms based on fixed limits on evaluations.

Comparison of the algorithms begins with a look at the average performance from each of the algorithms. Such comparisons can be made easily by comparing the best of the average results from Appendix B1 against those of Appendix H1 at the 1,000,000 evaluation limits. These comparisons are also provided in a graph below using LSRE. Hooke-Jeeves performs surprisingly well on the function suite. It outshines the EAs on all but a few functions: Easom, Griewangk, Modified Rastrigin, Odd Square, Salomon, and Rana. Hooke-Jeeves, just like many of the EAs seems to have the most difficulty in areas where the minimum objective function value is hidden along a line or curve having a narrow opening angle. DE shows the best performance of the EAs on most functions in the entire suite, but even it fails to optimize several objective functions including the Michaelewicz, Mineshaft1, Odd Square 2D and 10D, Modified Rosenbrock 1 10D and 30D, Rastrigin 10D and 30D, Schwefel 10D and 30D, Whitley 10D and 30D, and Rana 30D functions. In fact, out of the aforementioned functions the optimum of only one (Michaelewicz) is found by one of the EAs – PSO. PSO, RCGA, and SMOA all have worse performance than DE, but they perform in a similar fashion, each finding minima for about half the functions in the suite. All methods need more objective function evaluations to take on many of the high dimensional functions. There are, however, slight differences between the minima the algorithms find. SMOA has more obvious difficulty with high dimensional functions than any other algorithm. It even has the poorest performance on the 10D Spherical Contours function. PSO seems to have more problems with functions with minima "hidden" on flat planes. This problem has to do with its design as PSO relies on velocity to move about. RCGA doesn’t seem to have any overall problems other than that it seems to be taking longer to reach optima, especially as the search space gets larger. Again this is simply due to the algorithm’s design. RCGA is actually a semi-random search, and with a larger search area, the search time will be increased.

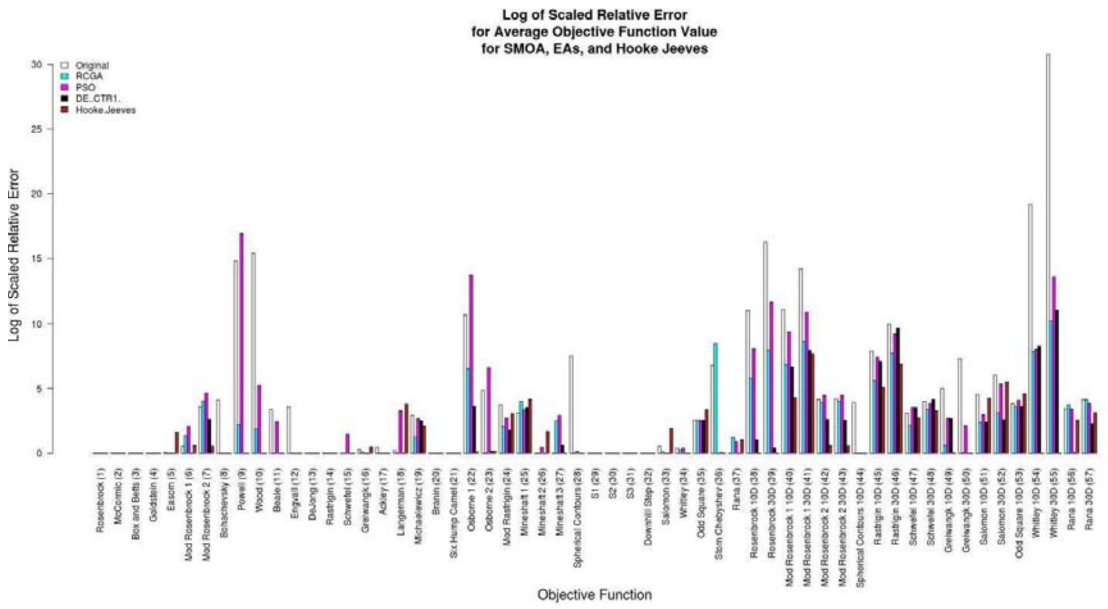


Figure 5.6: LSRE for Original SMOA, EAs, and Hooke Jeeves for Average Objective Function Values.

Given the comparisons in performance, it is also prudent to compare standard deviations and runtimes. The standard deviations of results were excellent for most results of EAs and Hooke-Jeeves, i.e. they were near zero for results near minima. SMOA also showed reasonable results standard deviations, but those standard deviations for results near minima were not as close to zero as those produced by the other EAs. For the entirety of the results considered in this section, standard deviations for poorer results were quite large. Such standard deviations are actually good because they indicate all of the algorithms have not converged on any location – the algorithms were still searching for minima when an evaluation limit was reached. Next runtimes for these algorithms are considered. These are not easily comparable as Hooke-Jeeves, PSO, and RCGA all ran as single processes on 1U on 1 core of 1 processor on the OSU Supercomputer with no context switching, SMOA ran on the same equipment as noted in the previous section, and DE results were produced as part of a process having 40 threads on the author’s home computer, which has 1 processor with 2 cores. Obviously comparing these runtimes against each other could lead to false assumptions because of the overhead associated with context switching.

Section 5.4 Results from Modifying the Slime Mold Algorithm

As noted in previous sections, four major variants of the SMOA were created. These are first, two algorithms that replace the vegetative state with the Downhill Simplex (Simplex SMOA) and Razor Search (Razor SMOA) algorithms, respectively, and two other algorithms that make use of a new slug state, those being the DE+Followers (HTDE-SMOA) and DE+Followers with Razor Search Vegetative State (HTDER-SMOA) algorithms. All of these algorithms provide at least some benefit over the SMOA; however, in some cases they may perform worse. In this section, the performance of these algorithms is explained.

First, the Simplex SMOA is analyzed. On first look, its performance appears to be quite good on many objective functions such as the Modified Rosenbrock 1 function, but occasionally the results are quite poor even for some easier objective functions such as the 2D Rosenbrock function. On closer analysis it becomes clear that the Simplex SMOA is highly dependent on population size and neighborhood strategy. With more difficult objective functions often a smaller population size with a reasonable neighbor strategy works well. Occasionally, with simpler high dimensional functions, a larger population size is more beneficial as with the 10D Spherical Contours function. The method is significantly faster than any of the other SMOA methods, but it is also the most sensitive to changes in population size and neighborhood strategy.

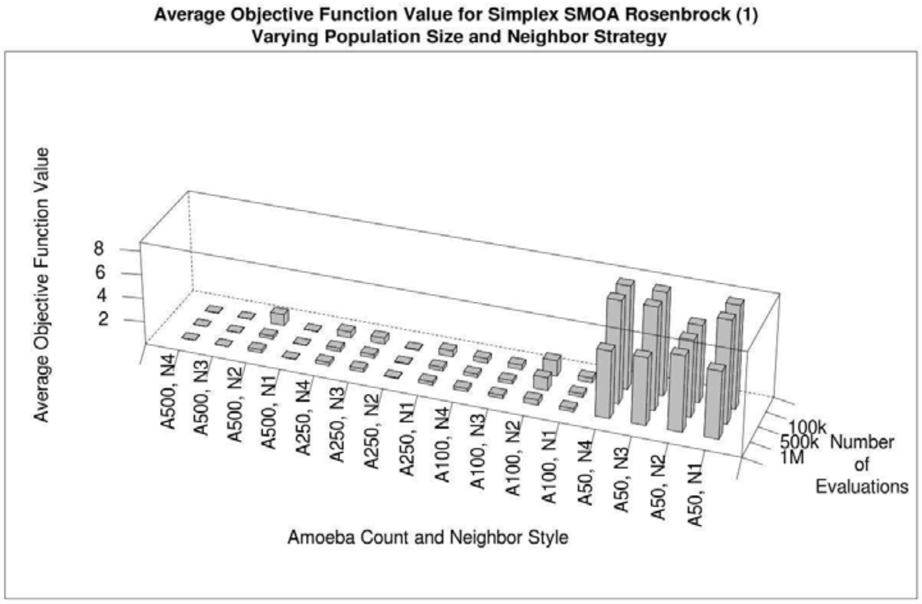


Figure 5.7: Simplex SMOA results from Rosenbrock's function (f* = 0) across evaluations, population sizes, and neighbor strategies.

The HTDE-SMOA method seems to be quite stable. It is fairly consistent across most parameters changes, though there are slight variations that occur from parameter changes. The algorithm reacts better to having more neighbors with objective functions with higher dimensionality. Note the performance on the Storn Chebyshev function in Figure 5.9. For simpler functions, especially those with lower dimensionality, a smaller population size seems to improve results. In comparison to the Original SMOA, many similarities are present. Varying evaluation limits often produces similar improvements and standard deviations are also quite similar, though improved.

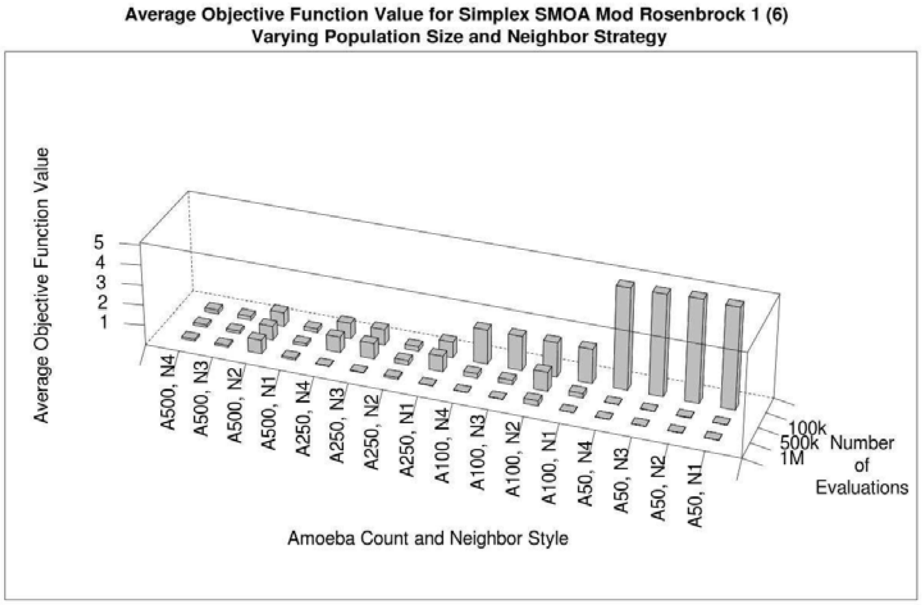


Figure 5.8: Simplex SMOA results from Modified Rosenbrock 1 function (f* = 0) across evaluations, population sizes, and neighbor strategies.

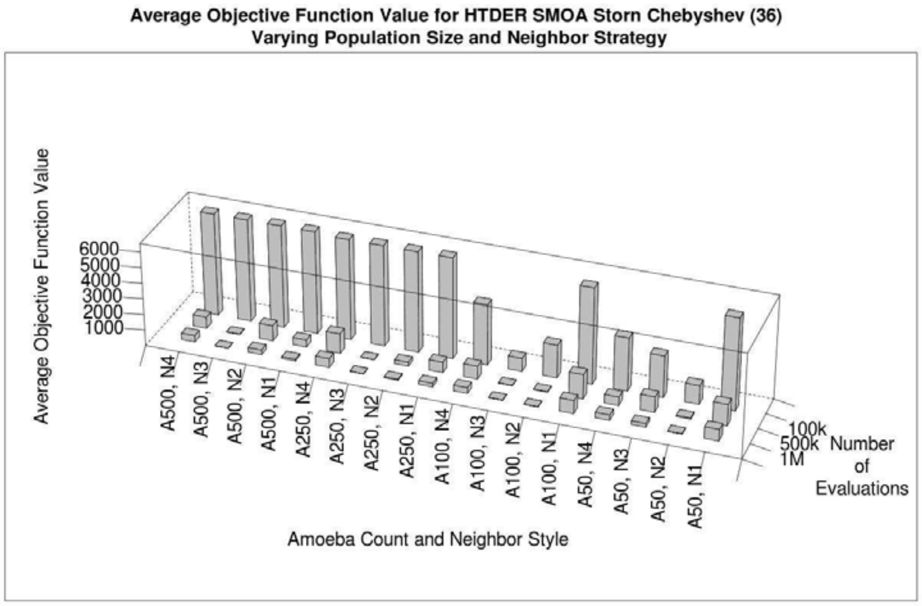


Figure 5.9: HTDER SMOA results from Storn's Chebyshev function (9D, f* = 0) across evaluations, population sizes, and neighbor strategies.

Improvement to this algorithm is seen when the Razor Search is added in place of the vegetative search defined in Chapter 3. The Razor SMOA produces results similar to those of the Original SMOA. It seems offer little performance boost over the Original algorithm on its own, but when added to the HTDE-SMOA significant improvements to results are visible. With this change to the vegetative state, the new algorithm is referred to as HTDER-SMOA. Results from this algorithm are better overall with a larger population size for objective functions of low dimensionality with a generous number of neighbors (i.e. neighbor strategy 3 or 4). Interestingly in many of the same situations, using very few neighbors and a small population (e.g. neighbor strategy 2 with 50 amoebae) also work well for simple functions of low dimensionality. For objective functions of many dimensions, results improve when using few neighbors and a moderate population size (e.g. neighbor strategy 2 with 100 or 250 amoebae). The HTDER-SMOA generally produces quality results with reasonable standard deviations for functions of dimension less than ten and is even able to near the optimum on the Storn Chebyshev (9D) function. More objective function evaluations would be necessary to improve its performance on the difficult, high dimensional functions in the suite.

Section 5.5 Comparisons to the Original Algorithm and other EAs

To simplify this section, the best of the averages at the 1,000,000 evaluation limit from the Original Algorithm, HTDE, HTDE-Razor, Razor, and Simplex algorithms were compared against each other and against the methods mentioned in Section 5.3. Initial observations are made from Figure 5.10. First, comparing the SMOA algorithms against themselves, it is obvious that the HTDE-Razor and Simplex SMOAs provide the best overall quality. The Original SMOA, HTDE SMOA, and Razor SMOA provide a slightly lower level of quality with slight variations between results. None of the algorithms work particularly well on the higher dimensional functions, but the HTDE and HTDE-Razor algorithms do tend to perform consistently and are better on the Storn Chebyshev (9D), Osborne 1 and 2, and many of the high dimensional functions. The Simplex SMOA tends to have varying performance that limits it, especially on some of the easier functions such as the 2D Rosenbrock function, but occasionally has excellent performance on objective functions with high dimensionality such as the 10D and 30D Griewangk functions and those with high difficulty like the 2D Modified Rosenbrock functions.

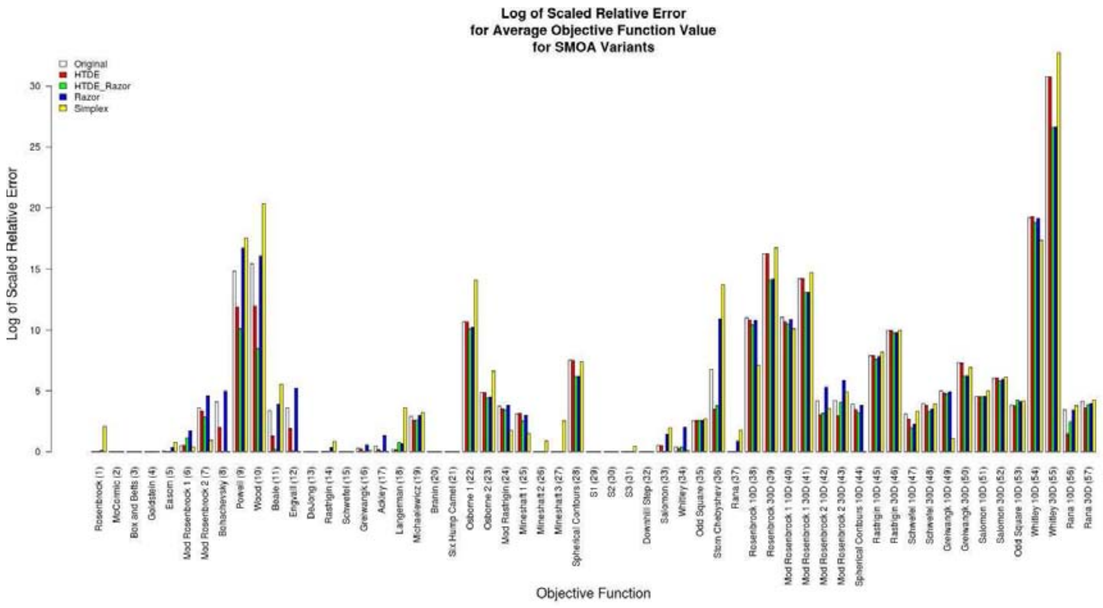


Figure 5.10: LSRE for all SMOA methods across all objective functions.

Next, comparisons are made of the best average results at the 1,000,000 evaluations limit to the EAs covered in Section 5.2 and to the Hooke Jeeves Pattern Search (HJ). Such comparison is made through Figure 5.10. The results show two obvious winners based upon average result: DE and Hooke Jeeves. Aside from this, the

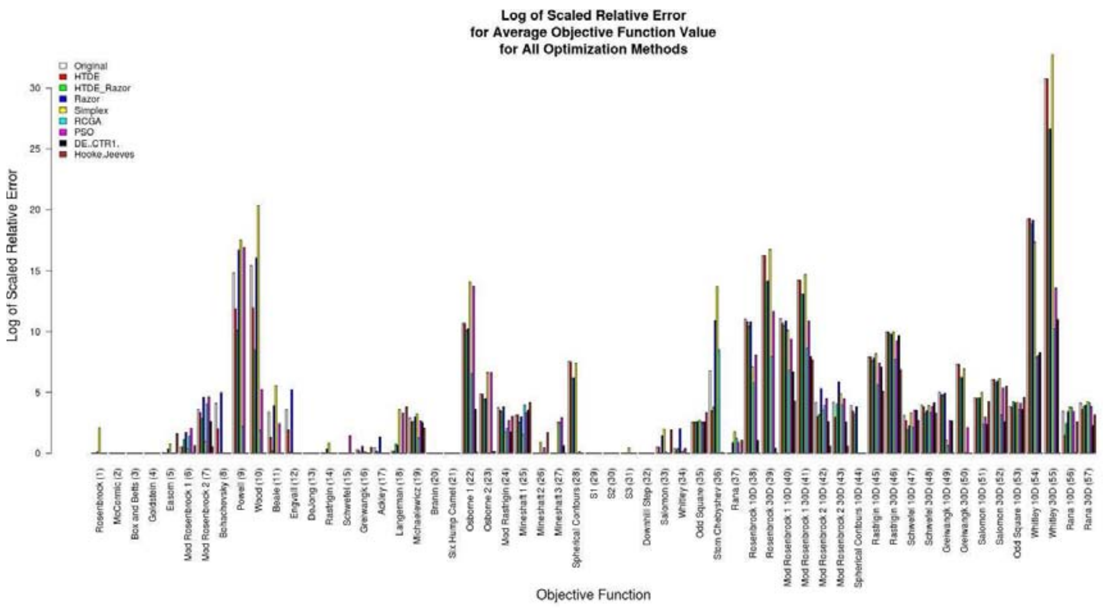


Figure 5.11: LSRE for all optimization methods across all objective functions.

next best quality in results where the algorithms work well is provided by RCGA, PSO, HTDE-SMOA, HTDER-SMOA, and the Original SMOA. Poorer performance is seen in all of these algorithms in functions of both higher dimensionality (esp. those of 30+ dimensions) and high difficulty. Time performance for Slime Mold algorithms may be a problem in comparison to other EAs. Unless context switching is having a significant effect on the time results of the various SMOAs, they appear to utilize as much as 5 to 10 times more CPU time than RCGA or PSO.

CHAPTER VI

VI. CONCLUSION

Section 6.1 Concluding Remarks

In the previous chapters, Slime Mold was taken from biology to simulation to an optimization algorithm. Review of existing Evolutionary Algorithms and Direct Search was provided as was review of the biology of *Dictyostelium discoideum* and its simulation. Educational simulation of the Slime Mold and several additional topics including Cellular Automata and Approximate Nearest Neighbors were reviewed as well. Portions of educational simulation, biological simulation, existing EAs, and existing Direct Search methods were combined to form the Slime Mold Optimization Algorithm. This algorithm was discussed in detail with special attention paid to its relation to the lifecycle of Slime Molds. The Slime Mold Optimization Algorithm was divided into states with each one being related to part of the Slime Mold lifecycle. Thereafter, variations on the algorithm□s vegetative, mound, and slug states were introduced. The vegetative state modifications were based upon two Direct Search methods □Downhill Simplex and Razor Search. The modification to the mound and slug states was based upon biology and the Differential Evolution algorithm.

Using the many variations of the Slime Mold Optimization Algorithm (SMOA), results were generated. Results from each algorithm were provided for a variety of parameters including limits on objective function evaluations, various population sizes, different numbers of nearest neighbors, and various numbers of pseudopods for the Original algorithm. For Original SMOA, results improved when using more objective function evaluations, and they varied depending on the population size and number of nearest neighbors. Generally, better results were produced for more difficult objective functions with smaller population sizes (e.g. 50 or 100) and a generous number of nearest neighbors (e.g. two times the dimension of the objective function). Easier objective functions often yielded good results regardless of parameter choice. Results for objective functions with many dimensions were poor, though they improved as the limit on evaluations was increased. When comparing the Original algorithm to RCGA, PSO, and DE, results from RCGA and PSO were similar to those of the Original SMOA, whereas DE yielded much better results. Unfortunately, the SMOA seems to have much greater time requirements than DE, RCGA, or PSO. It is expected that further refinement of the Original SMOA to include a slug state that always uses the global best as a pacemaker will improve results.

Results from the variants of the SMOA were quite interesting. Overall, adding the DE+Followers (HTDE) strategy for the Slug State improvement over the Original algorithm as did the SMOA using the Downhill Simplex for the Vegetative State (Simplex SMOA). The Simplex SMOA, did however, perform quite poorly on some of the easier objective functions, such as Rosenbrock's function. The Razor Search for the Vegetative State (Razor SMOA) provided about the same level of performance as the Original SMOA; however, when combined with DE+Followers (referred to as HTDER-SMOA), significant improvements were seen. All of these algorithms were quite costly in terms of CPU usage, but they did provide similar, and sometimes better in the case of HTDER-SMOA and Simplex SMOA, performance to PSO and RCGA.

Section 6.2 Future Work

Section 6.2.1 Further Variants on the Vegetative State

Many further variations on the vegetative state, aside from those presented in Chapter 4, are possible. The current vegetative and aggregative state equations are similar to the work of Erban and Othmer [2007]. The discretization of their functions suggests a function similar to the Particle Swarm Optimization functions with a random component to allow for incorrect movements, which is currently implemented in the Slime Mold Optimization Algorithm. A more interesting modification to the algorithm would be to replace the equations and data structure of the vegetative and aggregative states with a structure similar to that of the Glazier and Graner model [1993]. To implement this model multiple data points would be used to represent a single amoeba. The structure used should be similar to that used in the Downhill Simplex, but it would be slightly flexible in size and contain more data points to ensure such flexibility. Knowing that the Nelder-Mead Simplex is prone to collapse, the volume of this new data structure must be loosely conserved and the structure must retain data points in all dimensions of the search space, i.e. there must exist a set of coordinates within the data structure that span the entire search space [Torczon 1989]. Movement of this structure should follow that shown in Figure 2.4, where several data points would protrude from the main structure to search in a preferred direction. Were that direction an improvement in the structure's favor, the points would be moved in said direction with the rest of the structure to follow. Movements in flat directions or in a worse direction would follow an annealing schedule. Once implemented, an analysis of this structure will be needed. It should be evaluated alone, as a population, and finally as part of the Slime Mold Optimization Algorithm in the vegetative and aggregative states. Additionally, comparisons between the original algorithm and the modified one will be necessary.

Section 6.2.2: Population dynamics

Variants of GAs and PSO algorithms often allow for the population to vary in size. Such variations are implemented through the use of operators that allow for birth and/or death of individuals [Arabas et al. 1994, Lu and Yen 2003, Yen and Lu 2003]. Birth operators for GAs vary greatly. They include simple crossover operators such as the α-blend operator [Herrera 1998] and more complex ones such as the Unimodal

Normal Distribution Crossover (UNDX) and the Blend Crossover with Principal Components Analysis (BLXPCA) operators of Takahasi [2001]. Hybrid GA/PSO algorithms may also include such operators. As shown in Chapter 2, even DE includes a birth operator to create a fixed population of children [Price et al. 2005]. Recent research has shown that DE has been modified to include a dynamic population with success [Huang et al. 2006]. Death operators for population based EAs allow the population size to be reduced. Existing operators are typically two pronged. Such operators often make use of an aging operator and a likelihood function. The aging operator counts the number of time steps (iterations) for which an individual has existed in the population. After a fixed number of time steps the individual□s continued existence in the population is contingent upon a likelihood function. This function is often based upon the number of iterations spent searching versus the number of updates said individual has made to its personal best or the population□s global best. For many of such death operators, an individual is exempted from the likelihood function test if it is elite (i.e. the best of the population). This exemption is not necessary if an archive is used to record the best objective function values from the population [Arabas et al. 1994, Yen and Lu 2003].

Since GAs, PSO algorithms, and DE algorithms are population based and may allow for creation (procreation) and removal (aging) of individuals from the population and the Dd lifecycle includes birth and death, it follows that addition of birth and death operators to the Slime Mold Optimization Algorithm may be useful. With respect to birth operators, the Dd lifecycle allows for two different types of procreation. The first is an asexual birth referred to as binary fission or mitosis, which is the splitting of one amoeba into two. Procreation of this sort occurs after an amoeba has eaten numerous meals and becomes large enough to divide [Kessin 2001]. An algorithmic representation of this birth operator would be to allow for one amoeba to split into two after obtaining a certain number of new personal bests. The second type of Dd procreation is sexual and may be referred to as meiosis. Meiosis occurs when two Dd amoebae merge to form a macrocyst with a cellulose cell wall. This macrocyst emits cAMP much like the slug. Other amoebae are attracted to the macrocyst, and they are forced to become part of it because of their attraction to cAMP. Once a sufficient number of amoebae join the macrocyst, the contents of those cells are recombined and used to form new amoebae. Thereafter, the cellulose wall of the macrocyst bursts and new amoebae erupt out of it [Kessin 2001]. As of yet, the author has not determined an appropriate use for this construct. Amoeboid death in the slime mold optimization algorithm provides for several possibilities. The first of these is aging, which may be applied during the vegetative state after a fixed number of time steps. A likelihood function may be applied after amoebae have existed for a fixed number of time steps to determine if such amoebae should be removed from the population [Arabas et al. 1994, Monismith and Mayfield 2008]. Toward the end of the aggregative state, those amoebae that do not join a mound may be subjected to additional scrutiny for removal from the population. Additionally, before the dispersive state, Dd amoebae that are part of the tail of the slug die [Kessin 2001]. This may be implemented in the algorithm as well by forcing the 4/5 of the amoebae in the tail of the slug to be removed from the population before dispersal [Arabas et al. 1994, Kessin 2001, Monismith and Mayfield 2008]. For this portion of future work, reasonable comparisons could be between the base algorithm, the algorithm with the improvements of Sections 4.1 and 4.2, and the above proposed changes.

Section 6.2.3: Theoretical Research of Slime Mold Optimization

Several topics are of interest to the author with respect to theoretical research on Slime Mold Optimization and Evolutionary Algorithms in general. These topics are, however, only of interest as future research and not as part of the dissertation research. The first of these topics is research on the convergence of the Slime Mold Optimization Algorithm. It may prove interesting to investigate if the algorithm meets the criteria necessary to allow for convergence in an Evolutionary Algorithm and then to see if convergence may be proven outright or if it is objective function specific like DE [Rudolph 1996, Zaharie 2002]. Similarly, a study of the relationships between different evolutionary algorithms could be quite interesting. Particle Swarm Optimization and Differential Evolution share many similarities. Additionally, PSO and estimation theory share similarities. We would like to answer two questions in regards to the previous statements. Is DE a generalization of PSO and is PSO a special case of the estimation theory component referred to as a particle filter? Once answers to these questions are available, we would like to address them to the Slime Mold Optimization Algorithm to determine if the algorithm is unique or simply a specialization or generalization of another algorithm.

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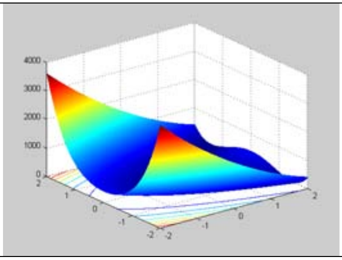
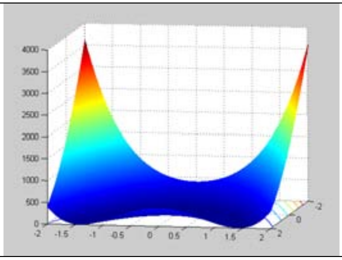
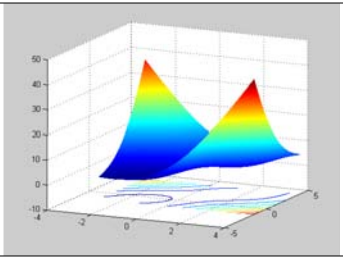
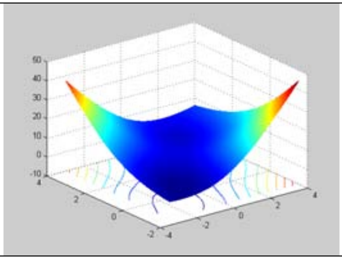
APPENDICES

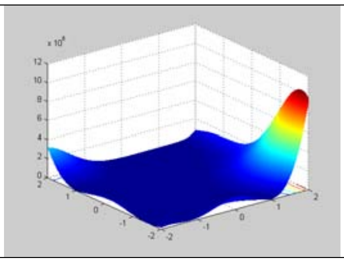
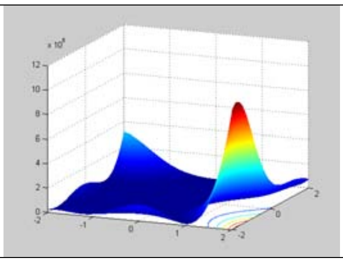
APPENDIX A: OBJECTIVE FUNCTION APPENDIX

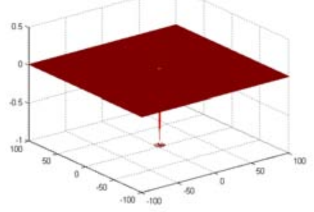
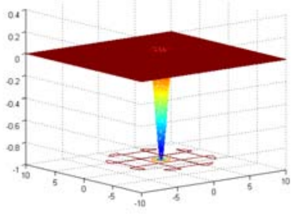
The Razor Search Algorithm, Real-Coded Genetic Algorithm, Particle Swarm Algorithm, Differential Evolution Algorithm, and Slime Mold Optimization Algorithm will be tested on a suite of 36 functions. These functions test different limitations of optimization algorithms. Some of the functions listed below contain plateaus, narrow valleys/peaks, and multiple local minima. Some functions lack derivatives, gradients, or Hessians especially near or at a global minimum. Some contain multiple global minima. Finally, some functions include a disproportionately large search area.

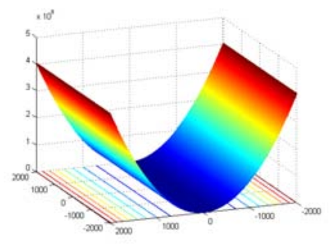
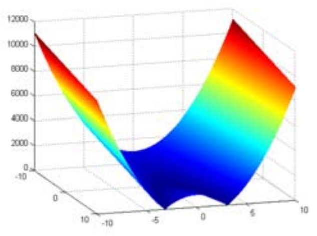
1. Generalized Rosenbrock's Function [Price et al. 2005]	
Objective Function	$f(\mathbf{x}) = \sum_{i=1}^{D-1} (100 \cdot (x_{i+1} - x_i^2)^2 + (x_i - 1)^2)$
Feasible Region	$-30 \le x_i \le 30$
Global Minima	$f(1,...,1) = 0$
Number of Global Minima	1
Function Images	
	

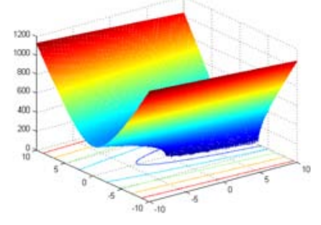
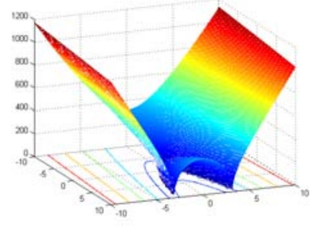
2. McCormic's Function [Madsen 2008]	
Objective Function	$f(x) = \sin(x_1 + x_2) + (x_1 - x_2)^2 - 1.5x_1 + 2.5x_2 + 1$
Feasible Region	$-1.5 \le x_1 \le 4,\ -3 \le x_2 \le 4$
Global Minima	$f(-0.54719, -1.54719) = -1.9133$
Number of Global Minima	1
Function Images	
	

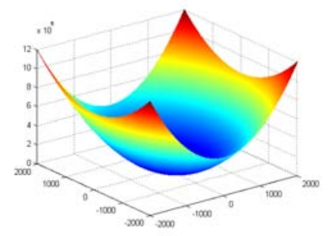
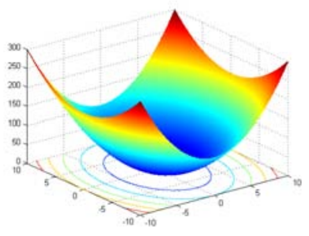
3. Box and Betts Exponential Quadratic Sum Function [Madsen 2008]	
Objective Function	$f(x)=\sum_{i=1}^{10} g(x)^2$ $g(x)=\exp(-0.1i\cdot x_i)-\exp(-0.1i\cdot x_i)-x_3\cdot(\exp(-0.1i)-\exp(-i))$
Feasible Region	$0.9\le x_1,x_3\le 1.2,\ 9\le x_2\le 11.2$
Global Minima	$f(1,10,1)=0$
Number of Global Minima	1
No function images are provided because its graph would be 4-dimensional.	

4. Goldstein and Price Function [GEATbx 2007]	
Objective Function	$f(x)=[1+(x_1+x_2+1)^2\cdot(19-14x_1+3x_1^2-14x_2+6\cdot x_1\cdot x_2+3x_2^2)]\cdot$ $[30+(2x_1-3x_2)^2\cdot(18-32x_1+12x_1^2+48x_2-36\cdot x_1\cdot x_2+27x_2^2)]$
Feasible Region	$x_1,x_2\in[-2,2]$
Global Minima	$f(0,-1)=3$
Number of Global Minima	1
Function Images	
	

5. Easom's Function [GEATbx 2007]	
Objective Function	$f(x)=-\cos(x_1)\cdot\cos(x_2)\cdot\exp(-((x_1-\pi)^2+(x_2-\pi)^2))$
Feasible Region	$-100\le x_1,x_2\le 100$
Global Minima	$f(\pi,\pi)=-1$
Number of Global Minima	1
Function Images	
	

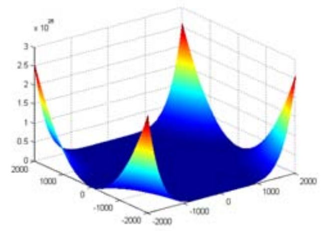
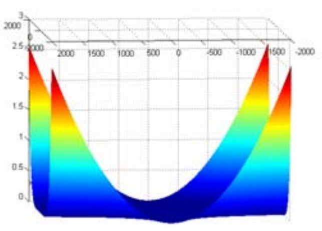
6. Generalized Modified Rosenbrock's Function 1 [Chen 1997] Flat Ground Bent Knife Edge Function	
Objective Function	$f(x)=\sum_{i=1}^{D}(100\cdot\lvert x_{i+1}-x_i^2\rvert+(1-x_i)^2)$
Feasible Region	$-30 \le x_i \le -30$
Global Minima	$f(1,\ldots,1)=0$
Number of Global Minima	1
Function Images	
	

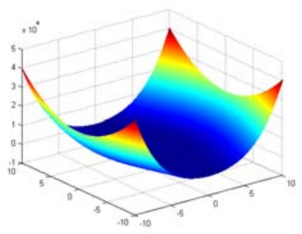
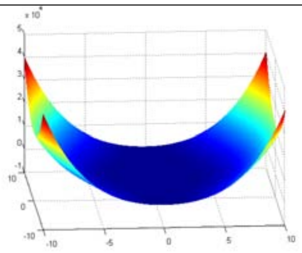
7. Generalized Modified Rosenbrock's Function 2 [Chen 1997] Hollow Ground Bent Knife Edge Function	
Objective Function	$f(x)=\sum_{i=1}^{D}(100\cdot\sqrt{\lvert x_{i+1}-x_i^2\rvert}+(1-x_i)^2)$
Feasible Region	$-30 \le x_i \le 30$
Global Minima	$f(1,\ldots,1)=0$
Number of Global Minima	1
Function Images	
	

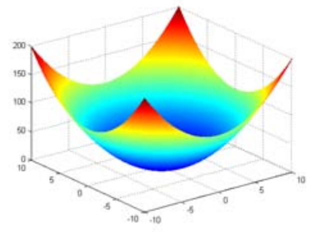
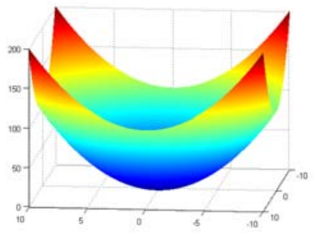
8. Bohachevsky's Function [Chen 1997]	
Objective Function	$f(x) = x_1^2 + 2x_2^2 - 0.3\cos(3\pi x_1) - 0.4\cos(4\pi x_2) + 0.7$
Feasible Region	$-2000 \le x_1, x_2 \le 2000$
Global Minima	$f(0,0) = 0$
Number of Global Minima	1
Function Images	
	

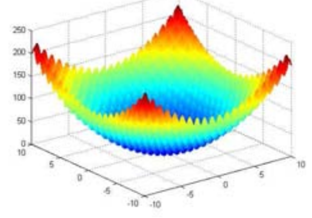
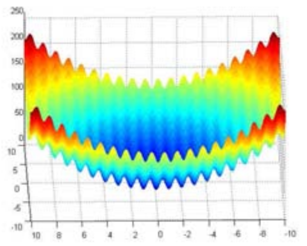
9. Powell's Function [Chen 1997]	
Objective Function	$f(x) = (x_1 + 10x_2)^2 + 5\cdot(x_3 - x_4)^2 + (x_2 - 2x_3)^4 + 10\cdot(x_1 - x_4)^4$
Feasible Region	$-2000 \le x_1, x_2, x_3, x_4 \le 2000$
Global Minima	$f(0,0,0,0) = 0$
Number of Global Minima	1
No function images are provided because its graph would be 5-dimensional.	

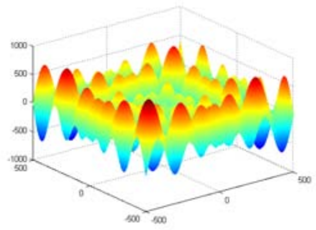
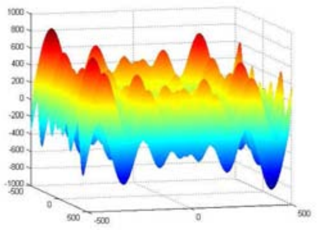
10. Wood's Function [Chen 1997]	
Objective Function	$f(x) = 100\cdot(x_2 - x_1^2)^2 + (1 - x_1)^2 + 90\cdot(x_4 - x_3^2)^2 + (1 - x_3)^2 + 10.1*[(x_2 - 1)^2 + (x_4 - 1)^2] + 19.8\cdot(x_2 - 1)\cdot(x_4 - 1)$
Feasible Region	$-2000 \le x_1, x_2, x_3, x_4 \le 2000$
Global Minima	$f(1,1,1,1) = 0$
Number of Global Minima	1
No function images are provided because its graph would be 5-dimensional.	

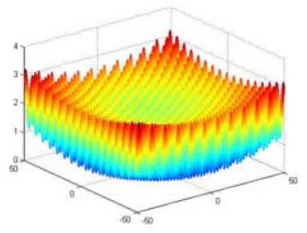
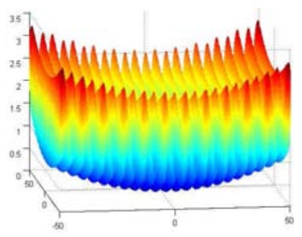
11. Beale's Function [Chen 1997]	
Objective Function	$f(x) = (1.5 - x_1 \cdot (1 - x_2))^2 + (2.25 - x_1 \cdot (1 - x_2^2))^2 + (2.625 - x_1 \cdot (1 - x_2^3))^2$
Feasible Region	$-2000 \le x_1, x_2 \le 2000$
Global Minima	$f(3, 0.5) = 0$
Number of Global Minima	1
Function Images	
	

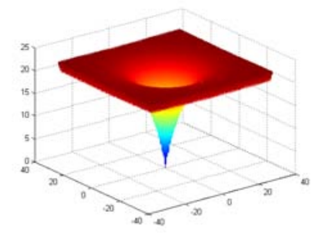
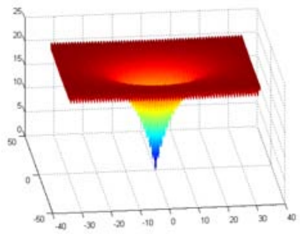
12. Engvall's Function [Chen 1997]	
Objective Function	$f(x) = x_1^4 + x_2^4 + 2x_1^2 \cdot x_2^2 - 4x_1 + 3$
Feasible Region	$-2000 \le x_1, x_2 \le 2000$
Global Minima	$f(1, 0) = 0$
Number of Global Minima	1
Function Images	
	

13. Generalized DeJong's (Spherical Contours) Function [Price et al. 2005]	
Objective Function	$f(x) = \sum_{i=1}^{n} x_i^2$
Feasible Region	$-10 \leq x_1, \ldots, x_n \leq 10$
Global Minima	$f(0, \ldots, 0) = 0$
Number of Global Minima	1
Function Images	
	

14. Generalized Rastrigin's Function [Price et al. 2005]	
Objective Function	$f(\mathbf{x}) = 10n + \sum_{i=1}^{n} (x_i^2 - 10\cos(2\pi x_i))$
Feasible Region	$-10 \leq x_1, \ldots, x_n \leq 10$
Global Minima	$f(0, \ldots, 0) = 0$
Number of Global Minima	1
Function Images	
	

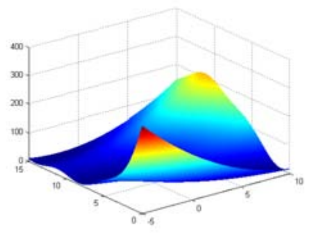
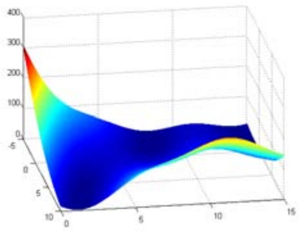
15. Generalized Schwefel's Function [Price et al. 2005]	
Objective Function	$f(\mathbf{x}) = \frac{1}{n}\sum_{i=1}^{n}(-x_i \sin(\sqrt{x_i}))$
Feasible Region	$-500 \le x_1,\dots,x_n \le 500$
Global Minima	$f(-418.983,\dots,-418.983) = 420.968746$
Number of Global Minima	1
Function Images	
	

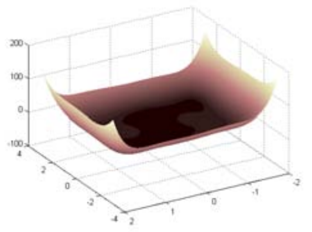
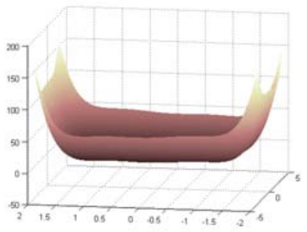
16. Griewangk's Function [GEATbx 2007]	
Objective Function	$f(x) = \sum_{i=1}^{n}\frac{x_i^2}{4000} - \prod_{i=1}^{n}\cos(\frac{x_i}{\sqrt{i}}) + 1$
Feasible Region	$-600 \le x_i \le 600$
Global Minima	$f(0,\dots,0) = 0$
Number of Global Minima	1
Function Images	
	

17. Ackley's Path Function [GEATbx 2007]		
Objective Function	$$f(x) = -20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}\right) - \exp\left(\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)\right) + 20 + e$$ $n = 2$	
Feasible Region	$-32.768 \le x_1, x_2 \le 32.768$	
Global Minima	$f(0,0) = 0$	
Number of Global Minima	1	
Function Images		
		

18. Modified Langermann's Function based on [Chen 1997]	
Objective Function	$$f(x) = -\sum_{i=1}^{m}\left(c_i \cdot \exp\left(-\frac{1}{\pi}\sum_{j=1}^{n}(x_i - A_{i,j})^2\right) \cdot \cos\left(\pi\sum_{j=1}^{n}(x_i - A_{i,j})^2\right)\right)$$ $m = 5, n = 5$ A and c are provided in [Chen 1997].
Feasible Region	$-10 \le x_1, \ldots, x_m \le 10$
Global Minima	$f(???) = -1.5$ (assumed minimum)
Number of Global Minima	1
No function images are provided because its graph would be 6-dimensional.	

19. Michaelewicz's Function [GEATbx 2007]	
Objective Function	$$f(x) = -\sum_{i=1}^{n}\left(\sin(x_i) \cdot \sin\left(i \cdot x_i^{\frac{2}{\pi}}\right)^{2m}\right)$$ $n, m = 10$
Feasible Region	$0 \le x_1, \ldots, x_{10} \le \pi$
Global Minima	$f(???) = -9.66$
Number of Global Minima	1
No function images are provided because its graph would be 11-dimensional.	

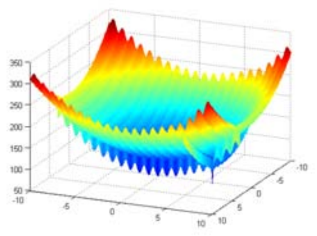
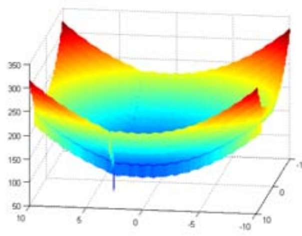
20. Branin's rcos Function [GEATbx 2007]	
Objective Function	$f(x)=a(x_2-bx_1^2+cx_1-d)^2+e(1-f)\cos(x_1)+e$ $a=1,\ b=\frac{5.1}{4\pi^2},\ c=\frac{5}{\pi},\ d=6,\ e=10,\ f=\frac{1}{8\pi}$
Feasible Region	$-5\le x_1\le 10,\ 0\le x_2\le 15$
Global Minima	$f(-\pi,12.275)=0.397887$ $f(\pi,2.275)=0.397887$ $f(9.42478,2.475)=0.397887$
Number of Global Minima	3
Function Images	
	

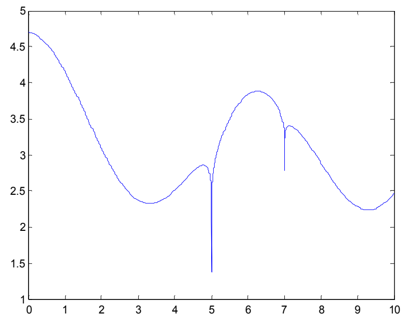
21. Six Hump Camel Back Function [GEATbx 2007]	
Objective Function	$f(x)=(4-2.1x_1^2+\frac{x_1^4}{3})x_1^2+x_1x_2+(-4+4x_2^2)x_2^2$
Feasible Region	$-3\le x_1\le 3, -2\le x_2\le 2$
Global Minima	$f(-0.0898,0.7126)=-1.0316$ $f(0.0898,-0.7126)=-1.0316$
Number of Global Minima	2
Function Images	
	

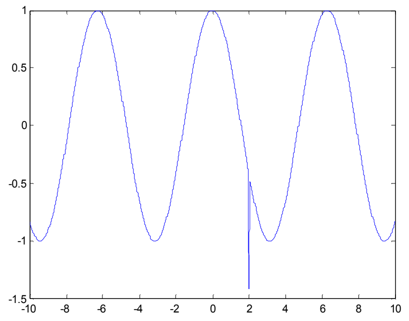
22. Osborne's Function 1 [Chen 1997]	
Objective Function	$f(x)=\sum_{i=1}^{33}((x_1+x_2\exp(-x_4t_i)+x_3\exp(-x_5t_i))-y_i)^2$ $t=10(i-1)$ Values for y are provided in [Chen 1997].
Feasible Region	$0\le x_1,x_2,x_4,x_5\le 3,-3\le x_3\le 0$
Global Minima	$f(0.3753, 1.9358, -1.4647, 0.01287, 0.02212)=5.46e-5$
Number of Global Minima	1

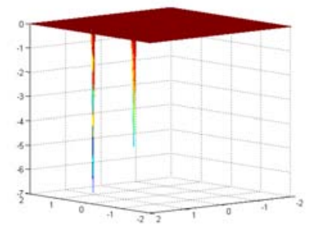
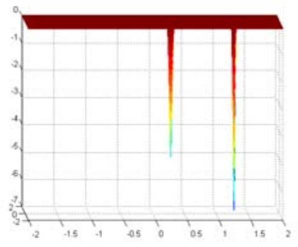
No function images are provided because its graph would be 6-dimensional.

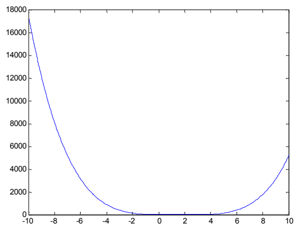
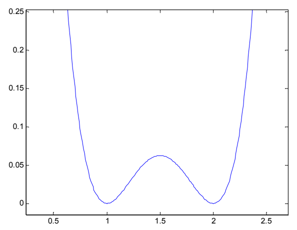
23. Osborne's Function 2 [Chen 1997]	
Objective Function	$f(x)=\sum_{i=1}^{65}(x_1\exp(-x_5 t_i)+x_2\exp(-x_6(t_i-x_9)^2)+ x_3\exp(-x_7(t_i-x_{10})^2 + x_4\exp(-x_8(t_i-x_{11})^2))-y_i)^2$ $t=10(i-1)$ Values for y are provided in [Chen 1997].
Feasible Region	$0\le x_1,\ldots,x_6,x_9\le 3,\ 0\le x_7\le 5,$ $4\le x_8\le 7,\ 2\le x_{10}\le 5,\ 3\le x_{11}\le 6$
Global Minima	$f(1.3100, 0.4315, 0.6336, 0.5993, 0.7539, 0.9056, 1.3651, 4.8248, 2.3988, 4.5689, 5.6754)=0.0402$
Number of Global Minima	1
No function images are provided because its graph would be 12-dimensional.	

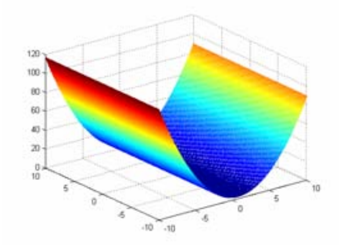
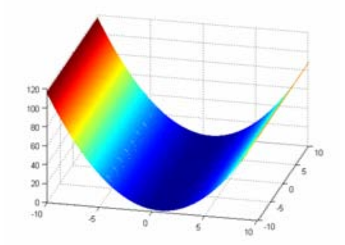
24. Modified Rastrigin's Function Based upon Rastrigin's Function from [Price et al. 2005].	
Objective Function	$f(x)=20+x_1^2+x_2^2-10(\cos(2\pi x_1)+\cos(2\pi x_2))+ 40((7-x_1)^{\frac{2}{15}}+(3-x_2)^{\frac{2}{35}})$
Feasible Region	$-10\le x_1,x_2\le 10$
Global Minima	$f(0.9978,3)=60.79317$
Number of Global Minima	1
Function Images	
	

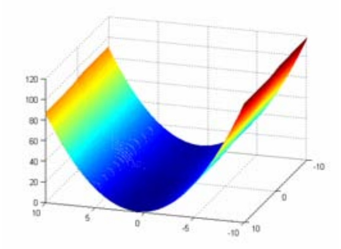
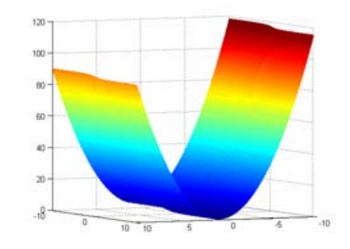
25. Mineshaft Function 1 [Monismith and Mayfield 2008]	
Objective Function	$f(x)=\cos(x)+(7-x)^{\frac{2}{15}}+2(5-x)^{\frac{4}{35}}$
Feasible Region	$0 \le x \le 10$
Global Minima	$f(5)=1.3805$
Number of Global Minima	1
Function Image	
	

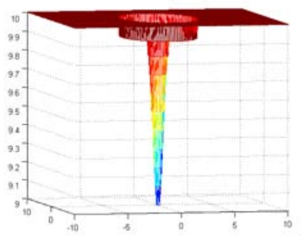
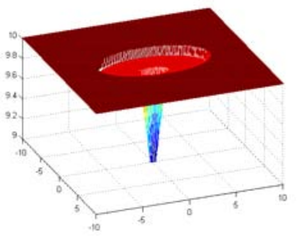
26. Mineshaft Function 2 [Monismith and Mayfield 2008]	
Objective Function	$f(x)=\cos(x)-e^{-1000(x-2)^2}$
Feasible Region	$-10 \le x_1, x_2 \le 10$
Global Minima	$f(2.000454648)=-1.41635352$
Number of Global Minima	1
Function Image	
	

27. Mineshaft Function 3 [Monismith and Mayfield 2008]	
Objective Function	$f(x) = -5 \cdot e^{-1000(x_1-0.5)^2 - 1000(x_2-0.3)^2} - 7 \cdot e^{-2000(x_1-0.8)^2 - 2000(x_2-1.3)^2}$
Feasible Region	$-2 \le x_1, x_2 \le 2$
Global Minima	$f(0.8, 1.3) = -7$
Number of Global Minima	1
Function Images	
	

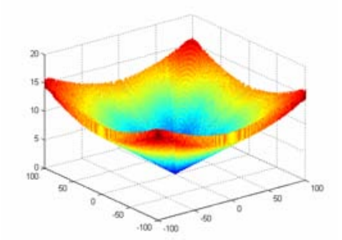
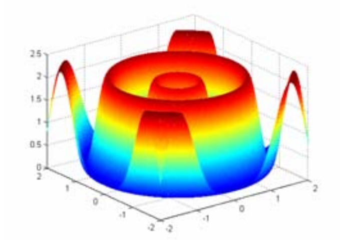
28. S1 [Choi and Mayfield 2009]	
Objective Function	$f(x) = (x-1)^2 \cdot (x-2)^2$
Feasible Region	$-10 \le x \le 10$
Global Minima	$f(1) = 0, f(2) = 0$
Number of Global Minima	2
	

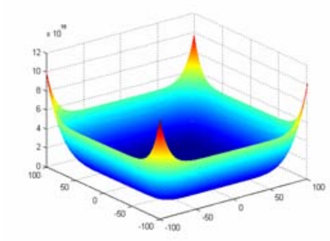
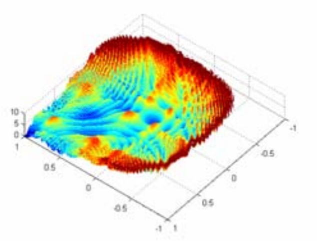
29. S2 [Choi and Mayfield 2009]	
Objective Function	$f(x_1, x_2) = 2.0 + (x_2 - 0.7)^2$
Feasible Region	$-10 \le x_1, x_2 \le 10$
Global Minima	$f(x_1, 0.7) = 2.0$
Number of Global Minima	Infinite
	

30. S3 [Choi and Mayfield 2009]	
Objective Function	$f(x_1, x_2) = 2.0 + (x_2 - 0.7)^2 - \arctan(x_1)$
Feasible Region	$-10 \le x_1, x_2 \le 10$
Global Minima	$f(10, 0.7) = 0.5289$
Number of Global Minima	1
	

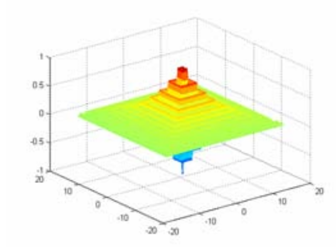
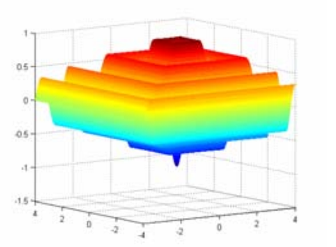
31. Downhill Step Function [Price et al. 2005]	
Objective Function	$f(x_1, x_2) = \dfrac{floor(10(10 - \exp(-x_1^2 - 3x_2^2)))}{10}$
Feasible Region	$-10 \le x_1, x_2 \le 10$
Global Minima	$f(0, 0) = 9$
Number of Global Minima	1
	

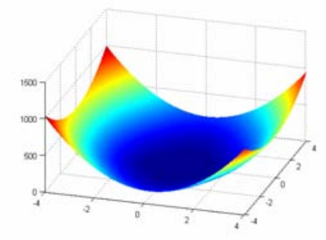
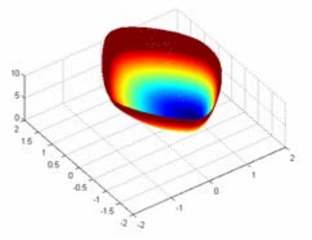
32. Salomon's Function [Price et al. 2005]	
Objective Function	$f(\mathbf{x}) = -\cos(2\pi \lVert \mathbf{x} \rVert) + 0.1 \lVert \mathbf{x} \rVert + 1$ $\lVert \mathbf{x} \rVert = \sqrt{\sum_{j=0}^{N-1} x_j^2}$
Feasible Region	$-100 \le x_j \le 100$
Global Minima	$f(0, \ldots, 0) = 0$
Number of Global Minima	1

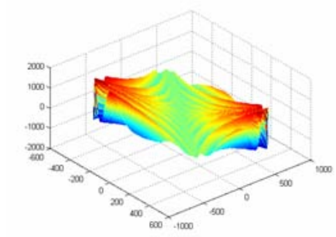
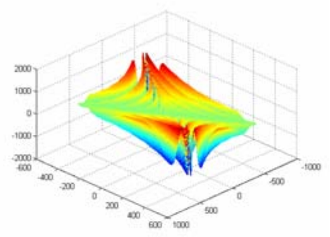
 

33. Whitley Function [Price et al. 2005]	
Objective Function	$f(\mathbf{x}) = \sum_{k=0}^{D-1}\sum_{j=0}^{D-1}(\frac{y_{j,k}^2}{4000} - \cos(y_{j,k}) + 1)$ $y_{j,k} = 100\cdot(x_k - x_j^2)^2 + (1 - x_j)^2$
Feasible Region	$-100 \le x_j \le 100$
Global Minima	$f(1,...,1) = 0$
Number of Global Minima	1
Function Images	
	

34. Odd Square Function [Price et al. 2005]	
Objective Function	$f(x) = -\exp\left(\frac{-d}{2\pi}\right)\cdot\cos(d\pi)\cdot\left(1 + \frac{0.02\cdot h}{d + 0.01}\right)$ $d = \sqrt{D\cdot\max_j((x_j - b_j)^2)}$ $h = \sqrt{\sum_{j=0}^{D-1}(x_j - b_j)^2}$
Feasible Region	$-5\pi \le x_j \le 5\pi,\ j = 0,1,...,D-1,\ D \le 20,\ \varepsilon = 0.01$
Global Minima	$f(\mathbf{x}^*) = -1.14383$, $\mathbf{x}^*$ = many solutions near **b** **b** = [1.0, 1.3, 0.8, -0.4, -1.3, 1.6, -0.2, -0.6, 0.5, 1.4, 1.0, 1.3, 0.8, -0.4, -1.3, 1.6, -0.2, -0.6, 0.5, 1.4]
Number of Global Minima	Many minima near **b**
Function Images	

35. Storn's Chebyshev Function [Price et al. 2005]	
Objective Function	$f(\mathbf{x}) = p_1 + p_2 + p_3$ $p_1 = \begin{cases} (u-d)^2 & \text{if } u < d \\ 0 & \text{otherwise} \end{cases}, \quad u = \sum_{j=0}^{D-1} x_j \cdot (1.2)^{D-1-j},$ $p_2 = \begin{cases} (v-d)^2 & \text{if } v < d \\ 0 & \text{otherwise} \end{cases}, \quad v = \sum_{j=0}^{D-1} x_j \cdot (-1.2)^{D-1-j},$ $p_k = \begin{cases} (w_k-1)^2 & \text{if } w_k > 1 \\ (w_k+1)^2 & \text{if } w_k < -1, \\ 0 & \text{otherwise} \end{cases} \quad w_k = \sum_{j=0}^{D-1} x_j \cdot \left(\frac{2k}{m} - 1\right)^{D-1-j},$ $p_3 = \sum_{k=0}^{m} p_k, \quad k = 0,1,\ldots,m, \quad m = 32 \cdot D,$ $d = T_{D-1}(1.2) \approx \begin{cases} 72.661 & \text{for } D = 9 \\ 10558.145 & \text{for } D = 17 \end{cases}$ $T_{D+1}(z) = 2z \cdot T_D(z) - T_{D-1}(z),\ D > 0 \text{ and odd},$ $T_0(z) = 1,\ T_1(z) = z$
Feasible Region	$-2^D \le x_j \le 2^D, j = 0,1,\ldots,D-1, D > 1$ and odd
Global Minima	$f(x^*) = 0$ $x^* = \begin{cases} [128,0,-256,0,160,0,-32,0,1] \text{ for } D = 9 \\ [32768,0,-131072,0,212992,0,-180224, \\ 0,84480,0,-21504,0,2688,0,-128,0,1] \text{ for } D = 17. \end{cases}$
Number of Global Minima	1
Function Images	
	

36. Rana Function [Price et al. 2005]	
Objective Function	$f(\mathbf{x}) = \sum_{j=0}^{D-1} x_j \cdot \sin(\alpha) \cdot \cos(\beta) + x_{(j+1) \bmod D} \cdot \cos(\alpha) \cdot \sin(\beta)$, $\alpha = \sqrt{\lvert x_{(j+1) \bmod D} + 1 - x_j \rvert}$ $\beta = \sqrt{\lvert x_{(j+1) \bmod D} + 1 + x_j \rvert}$
Feasible Region	$-512 \le x_j \le 512$ $j = 0,1,\ldots, D-1$ $D > 1$
Global Minima	$f(\mathbf{x}^*) = -511.708$, $x_j{}^* = -512$
Number of Global Minima	1
Function Images	
	

APPENDIX B1: SMOA AVERAGE RESULTS

Average Result (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.000402	0.000403	0.000402	0.000402	0.000411	0.000364	0.000411	0.000411	0.000246	0.00014	0.000246	0.000246	0.000209	3.42E-05	0.000209	0.000209	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.9131	-1.91322	-1.91322	-1.9133
Box and Betts (3)	3.26E-08	8.61E-09	5.38E-08	3.15E-08	4.08E-09	3.53E-08	1.02E-08	2.35E-08	3.82E-08	5.25E-07	4.02E-08	5.80E-08	1.05E-06	1.56E-06	1.05E-07	8.84E-07	0
Goldstein (4)	3.000012	3.000004	3.000012	3.000012	3.000005	3.000001	3.000005	3.000005	3.000001	3	3.000001	3.000001	3	3.102064	3	3	3
Easom (5)	-0.99928	-0.99929	-0.99928	-0.99928	-0.99931	-0.99932	-0.99931	-0.99931	-0.99946	-0.99947	-0.99946	-0.99946	-0.99938	-0.99929	-0.99938	-0.99938	-1
Mod Rosenbrock 1 (6)	0.023993	0.027311	0.023993	0.023993	0.023509	0.024999	0.023509	0.023509	0.019007	0.013473	0.019007	0.019007	0.016141	0.006796	0.016141	0.016141	0
Mod Rosenbrock 2 (7)	0.734808	0.723164	0.734808	0.734808	0.761322	0.763334	0.761322	0.761322	0.757242	0.526094	0.757242	0.757242	0.614314	0.352272	0.614314	0.614314	0
Bohachevsky (8)	0.664362	0.600983	0.664362	0.664362	0.615824	0.650657	0.615824	0.615824	0.654595	0.649527	0.654595	0.654595	0.621058	0.585051	0.621058	0.621058	0
Powell (9)	74968.98	74968.98	66287.46	26915.97	56253.28	56253.28	58178.43	54765.92	39263.99	39263.99	61337.53	70041.14	59794.52	59794.52	50184.7	69223.46	0
Wood (10)	188420.1	188420.1	196599.2	49440.49	172541.4	172541.4	181359.4	148724.2	89300.97	89300.97	162123.3	171348.2	160656	160656	139371.1	174150	0
Beale (11)	0.294941	0.320249	0.294941	0.294941	0.287754	0.310209	0.287754	0.287754	0.306603	0.324092	0.306603	0.306603	0.296109	0.281629	0.296109	0.296109	0
Engvall (12)	0.350287	0.366319	0.350287	0.350287	0.357156	0.396479	0.357156	0.357156	0.412141	0.354753	0.412141	0.412141	0.379334	0.359928	0.379334	0.379334	0
DeJong (13)	2.28E-06	2.06E-06	2.28E-06	2.28E-06	2.67E-06	5.64E-07	2.67E-06	2.67E-06	6.01E-07	9.20E-08	6.01E-07	6.01E-07	1.61E-07	2.76E-08	1.61E-07	1.61E-07	0
Rastrigin (14)	0.000933	0.000802	0.000933	0.000933	0.000865	0.000374	0.000865	0.000865	0.000205	0.222181	0.000205	0.000205	0.002028	0.149112	0.002028	0.002028	0
Schwefel (15)	-837.96	-837.959	-837.96	-837.96	-837.961	-837.961	-837.961	-837.961	-837.962	-837.96	-837.962	-837.962	-837.958	-837.958	-837.958	-837.958	-837.9658
Griewangk (16)	0.003196	0.003327	0.003196	0.003196	0.003271	0.003605	0.003271	0.003271	0.003026	0.003575	0.003026	0.003026	0.003465	0.003437	0.003465	0.003465	0
Ackley (17)	0.015715	0.016462	0.015715	0.015715	0.016004	0.015323	0.016004	0.016004	0.016371	0.010282	0.016371	0.016371	0.012684	0.005761	0.012684	0.012684	0
Langerman (18)	-1.49631	-1.49657	-1.49677	-1.49663	-1.49657	-1.49655	-1.49622	-1.49669	-1.49538	-1.49621	-1.49621	-1.49623	-1.49541	-1.49518	-1.49546	-1.49563	-1.5
Michaelewicz (19)	-7.18443	-7.79553	-7.55871	-7.55673	-7.15215	-7.73195	-7.93769	-7.61325	-7.14992	-7.80073	-7.99342	-7.52611	-7.0883	-7.75347	-7.97286	-7.44125	-9.66
Branin (20)	0.397891	0.397889	0.397891	0.397891	0.39789	0.397888	0.39789	0.39789	0.397888	0.397887	0.397888	0.397888	0.397888	0.398608	0.397888	0.397888	0.397887
Six Hump Camel (21)	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.032072	0.032141	0.029817	0.023293	0.032379	0.031557	0.03055	0.026124	0.029172	0.031727	0.032343	0.032014	0.036153	0.032989	0.035131	0.034489	5.46E-05
Osborne 2 (23)	0.101629	0.098665	0.100444	0.110289	0.097727	0.096883	0.090923	0.10364	0.106465	0.099139	0.097962	0.108859	0.115187	0.112919	0.105869	0.117234	0.0402
Mod Rastrigin (24)	82.726	82.82728	82.726	82.726	82.66626	82.45838	82.66626	82.66626	81.77041	85.052	81.77041	81.77041	82.41466	83.57794	82.41466	82.41466	58
Mineshaft 1 (25)	1.862575	1.745877	1.802849	1.745877	1.759968	1.672879	1.717754	1.672879	1.700323	1.774683	1.677735	1.774683	1.692209	2.093864	1.749454	2.093864	1.3805
Mineshaft 2 (26)	-1.41635	-1.35777	-1.40982	-1.35777	-1.41635	-1.38155	-1.41635	-1.38155	-1.41635	-1.34686	-1.40589	-1.34686	-1.41426	-1.29466	-1.38186	-1.29466	-1.4163535
Mineshaft 3 (27)	-6.96415	-6.93958	-6.96415	-6.96415	-6.99618	-6.9822	-6.99618	-6.99618	-6.99976	-6.99998	-6.99976	-6.99976	-6.99997	-6.99999	-6.99997	-6.99997	-7
Spherical Contours (28)	24.61982	25.10117	18.13146	18.13146	23.16058	25.55606	18.85589	18.85589	22.05459	24.43165	21.234	21.15729	24.89933	25.26599	25.08722	24.84398	0
S1 (29)	7.67E-14	0.001592	4.79E-15	0.001592	5.01E-15	4.29E-16	9.77E-16	4.29E-16	2.93E-15	3.20E-05	1.32E-05	3.20E-05	4.72E-13	0.000146	2.60E-07	0.000146	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.5289
Downhill Step (32)	9	9	9	9	9	9.004	9	9	9.018	9	9.018	9.018	9	9.007	9	9	9
Salomon (33)	0.0078	0.007338	0.0078	0.0078	0.006976	0.007919	0.006976	0.006976	0.007943	0.007011	0.007943	0.007943	0.006916	0.00831	0.006916	0.006916	0
Whitley (34)	0.006011	0.007563	0.006011	0.006011	0.006169	0.006361	0.006169	0.006169	0.009314	0.004646	0.009314	0.009314	0.004982	0.007719	0.004982	0.004982	0
Odd Square (35)	-1.00801	-1.00805	-1.00801	-1.00801	-1.00812	-1.00817	-1.00812	-1.00812	-1.00818	-1.0077	-1.00818	-1.00818	-1.00824	-0.92956	-1.00824	-1.00824	-1.14383
Storn Chebyshev (36)	17.71872	13.13723	9.98224	11.86194	24.47983	17.53931	11.44342	8.700355	16.86113	15.3333	16.39474	9.786629	15.2948	17.70423	16.49638	19.257	0
Rana (37)	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1012.45	-1023.42	-1012.45	-1012.45	-1023.42	-1023.42	-1023.42	-1023.42	-1023.416
Rosenbrock 10D (38)	766.493	722.4747	596.8125	616.7109	741.1939	784.4724	670.7025	596.2125	745.57	798.971	782.423	688.4744	753.3015	768.6431	734.5859	693.2436	0
Rosenbrock 30D (39)	215631.9	232480.2	114342.5	114342.5	200409.4	244689.1	135527.8	135527.8	175685.7	221299.4	165377.1	169411.9	236060.5	241090.1	222471.8	231971.3	0
Mod Rosenbrock 1 10D (40)	724.2986	731.2287	626.7474	630.2497	712.1917	752.3544	692.0445	632.0441	718.5163	728.5996	689.4775	680.2817	713.0137	717.6882	722.0127	720.3334	0
Mod Rosenbrock 1 30D (41)	19123.99	20040.35	14648.94	14648.94	18607.25	20184.18	15413.29	15413.29	17771.34	19241.05	17136.23	17141.65	19344.33	19201.11	19187.32	19207.04	0
Mod Rosenbrock 2 10D (42)	0.725363	0.68744	0.676156	0.674962	0.776318	0.764941	0.668965	0.672934	0.825972	0.758619	0.721543	0.628544	0.700211	0.712737	0.74573	0.766718	0
Mod Rosenbrock 2 30D (43)	0.731715	0.757984	0.652705	0.652705	0.718551	0.673812	0.689098	0.689098	0.697617	0.699729	0.733775	0.703081	0.707811	0.734572	0.682897	0.745933	0
Spherical Contours 10D (44)	0.573348	0.558785	0.486478	0.507552	0.567511	0.573723	0.529092	0.5223	0.57518	0.59563	0.562523	0.517418	0.541607	0.549564	0.537536	0.514582	0
Rastrigin 10D (45)	32.31205	30.98844	26.59044	27.23783	32.34689	32.66419	29.38652	26.64686	30.50488	32.49175	31.96937	27.5114	32.26534	32.45634	31.20856	29.9219	0
Rastrigin 30D (46)	256.5294	249.8531	215.3654	215.3654	248.0609	260.1439	218.3076	218.3076	235.6382	253.3823	226.7393	220.3587	250.0238	252.5157	247.4995	237.0287	0
Schwefel 10D (47)	-3208.83	-3239.22	-3127.16	-3088.67	-3223.27	-3279.87	-3207.89	-3080.77	-3176.27	-3316.88	-3252.76	-3091.07	-3227.63	-3281.36	-3290.49	-3136.39	-4189.829
Schwefel 30D (48)	-5876.36	-5950.71	-6057.5	-6057.5	-5853.55	-5992.52	-6004.64	-6004.64	-5853.92	-5976.06	-5982.65	-5942.89	-5787.05	-5921.5	-5927.63	-5892.16	-12569.487
Griewangk 10D (49)	1.509354	1.524128	1.448514	1.47859	1.512455	1.542545	1.509559	1.478292	1.494564	1.526658	1.536328	1.470864	1.51269	1.521907	1.526269	1.511917	0
Griewangk 30D (50)	19.08485	20.00746	14.85195	14.85195	18.84433	20.70837	15.65635	15.65635	17.9959	19.66212	17.07569	17.04924	20.10826	20.12751	20.18833	20.16099	0
Salomon 10D (51)	1.034537	1.049764	0.913313	0.935756	1.027938	1.031107	0.980149	0.951042	1.000648	1.048229	1.049635	0.96145	1.014156	1.005805	1.008794	0.989154	0
Salomon 30D (52)	5.007487	5.10426	4.156946	4.156946	4.855488	5.185718	4.387226	4.387226	4.723363	5.033435	4.659243	4.640203	5.002498	5.002485	4.989255	5.037555	0
Odd Square 10D (53)	-0.54328	-0.54396	-0.62469	-0.63161	-0.55357	-0.5457	-0.58388	-0.62522	-0.55674	-0.54566	-0.55425	-0.59082	-0.54798	-0.54992	-0.54252	-0.56376	-1.14383
Whitley 10D (54)	3378659	3585725	2153528	1.14E+08	3841405	4118895	3582727	2981665	3780291	3871799	4214695	2873089	3187899	3348314	3389248	3278458	0
Whitley 30D (55)	7.42E+11	8.66E+11	2.35E+11	2.35E+11	6.09E+11	8.87E+11	2.79E+11	2.79E+11	5.4E+11	8.78E+11	5.16E+11	4.9E+11	9.75E+11	9.29E+11	8.84E+11	8.67E+11	0
Rana 10D (56)	-3444.04	-3422.27	-3580.58	-3582.14	-3482.99	-3481.24	-3523.15	-3523.21	-3464.34	-3484.33	-3511.95	-3487.39	-3438.73	-3485.49	-3516.14	-3476.35	-5117.08
Rana 30D (57)	-5866.22	-5861.71	-5921.52	-5921.52	-5856.79	-5896.75	-5917.28	-5917.28	-5826.04	-5910.2	-5878.41	-5913.51	-5779.03	-5805.81	-5804.47	-5845.17	-15351.24

Average Result (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.000745	0.000823	0.000745	0.000745	0.000679	0.00069	0.000679	0.000679	0.002178	0.000256	0.002178	0.002178	0.000418	0.000101	0.000418	0.000418	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.9131	-1.91322	-1.91322	-1.9133
Box and Betts (3)	4.64E-08	1.37E-08	7.31E-08	4.94E-08	2.45E-06	1.10E-07	2.24E-08	3.60E-08	3.23E-07	1.50E-06	3.47E-07	7.52E-08	1.70E-06	2.89E-06	1.46E-07	1.04E-06	0
Goldstein (4)	3.000027	3.000007	3.000027	3.000027	3.000011	3.000002	3.000011	3.000011	3.000003	3.000001	3.000003	3.000003	3.000002	3.117788	3.000002	3.000002	3
Easom (5)	-0.99867	-0.99855	-0.99867	-0.99867	-0.9986	-0.99858	-0.9986	-0.9986	-0.99893	-0.99869	-0.99893	-0.99893	-0.99854	-0.99872	-0.99854	-0.99854	-1
Mod Rosenbrock 1 (6)	0.046288	0.043351	0.046288	0.046288	0.033985	0.040769	0.033985	0.033985	0.035841	0.021348	0.035841	0.035841	0.026019	0.012862	0.026019	0.026019	0
Mod Rosenbrock 2 (7)	0.966551	0.95775	0.966551	0.966551	0.988927	1.002509	0.988927	0.988927	1.043309	0.672968	1.043309	1.043309	0.815156	0.508521	0.815156	0.815156	0
Bohachevsky (8)	0.932698	0.836561	0.932698	0.932698	0.872745	0.896879	0.872745	0.872745	0.950082	0.846325	0.950082	0.950082	0.84069	0.808998	0.84069	0.84069	0
Powell (9)	123734.8	123734.8	106795.9	51130.24	88441.81	88441.81	94282.28	95432.51	81372.17	81372.17	99658.67	123353.3	94000.45	94000.45	107395.5	116428.6	0
Wood (10)	305435.2	305435.2	275829.2	130548.7	298982.1	298982.1	304392.3	267746.4	242041.4	242041.4	276099.5	337349.6	344476.2	344476.2	368885.7	332842.5	0
Beale (11)	0.466947	0.465862	0.466947	0.466947	0.44259	0.487837	0.44259	0.44259	0.43689	0.577581	0.43689	0.43689	0.483392	0.504124	0.483392	0.483392	0
Engvall (12)	0.614762	0.690427	0.614762	0.614762	0.687831	0.673797	0.687831	0.687831	0.7067	0.677293	0.7067	0.7067	0.684279	0.701363	0.684279	0.684279	0
DeJong (13)	4.16E-06	4.16E-06	4.16E-06	4.16E-06	5.75E-06	1.24E-06	5.75E-06	5.75E-06	1.22E-06	2.19E-07	1.22E-06	1.22E-06	3.86E-07	7.94E-08	3.86E-07	3.86E-07	0
Rastrigin (14)	0.002035	0.001537	0.002035	0.002035	0.001674	0.000735	0.001674	0.001674	0.003776	0.222826	0.003776	0.003776	0.01751	0.186775	0.01751	0.01751	0
Schwefel (15)	-837.954	-837.951	-837.954	-837.954	-837.952	-837.954	-837.952	-837.952	-837.955	-837.945	-837.955	-837.955	-837.95	-837.94	-837.95	-837.95	-837.9658
Griewangk (16)	0.004799	0.00489	0.004799	0.004799	0.004969	0.005937	0.004969	0.004969	0.005094	0.005043	0.005094	0.005094	0.005185	0.005365	0.005185	0.005185	0
Ackley (17)	0.02524	0.024851	0.02524	0.02524	0.022721	0.022097	0.022721	0.022721	0.024848	0.015184	0.024848	0.024848	0.018771	0.008703	0.018771	0.018771	0
Langerman (18)	-1.49479	-1.49519	-1.49529	-1.49424	-1.4948	-1.49514	-1.49413	-1.49501	-1.49314	-1.49356	-1.49374	-1.49361	-1.49214	-1.49199	-1.49266	-1.49225	-1.5
Michaelewicz (19)	-6.96067	-7.58925	-7.38397	-7.3754	-6.99608	-7.47353	-7.75255	-7.42253	-6.94956	-7.49117	-7.83666	-7.28165	-6.85144	-7.4703	-7.77271	-7.22034	-9.66
Branin (20)	0.397894	0.397891	0.397894	0.397894	0.397893	0.397888	0.397893	0.397893	0.397888	0.397888	0.397888	0.397888	0.397888	0.398608	0.397888	0.397888	0.397887
Six Hump Camel (21)	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03125	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.036664	0.038446	0.035156	0.029259	0.038637	0.036258	0.03715	0.033871	0.045459	0.041723	0.041195	0.04035	0.060455	0.056869	0.060857	0.049059	5.46E-05
Osborne 2 (23)	0.112276	0.110473	0.117362	0.120988	0.114015	0.111065	0.107227	0.120964	0.131523	0.122737	0.12024	0.127316	0.138465	0.139526	0.140423	0.138048	0.0402
Mod Rastrigin (24)	83.71421	83.47038	83.71421	83.71421	83.38983	83.2711	83.38983	83.38983	83.16322	85.41955	83.16322	83.16322	83.57777	83.8372	83.57777	83.57777	58
Mineshaft 1 (25)	1.901967	1.802648	1.82199	1.802648	1.792269	1.773634	1.751829	1.773634	1.732199	1.991808	1.742106	1.991808	1.753886	2.260338	2.008789	2.260338	1.3805
Mineshaft 2 (26)	-1.41635	-1.32939	-1.40982	-1.32939	-1.41635	-1.35292	-1.41334	-1.35292	-1.41635	-1.28807	-1.38864	-1.28807	-1.4028	-1.26025	-1.3434	-1.26025	-1.4163535
Mineshaft 3 (27)	-6.96111	-6.9395	-6.96111	-6.96111	-6.99591	-6.98214	-6.99591	-6.99591	-6.99969	-6.99994	-6.99969	-6.99969	-6.99984	-6.99995	-6.99984	-6.99984	-7
Spherical Contours (28)	25.51745	25.8638	20.61168	20.61168	24.56786	26.14681	22.34442	22.34442	26.538	26.60038	26.45779	26.49303	32.91937	32.91937	32.91937	32.91937	0
S1 (29)	2.41E-13	0.001801	1.45E-14	0.001801	2.29E-14	5.49E-05	6.21E-15	5.49E-05	3.75E-08	0.000228	1.83E-05	0.000228	1.88E-05	0.00019	6.29E-05	0.00019	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.529251	0.528872	0.528872	0.5289
Downhill Step (32)	9	9	9	9	9	9.004	9	9	9.027	9	9.027	9.027	9.004	9.007	9.004	9.004	9
Salomon (33)	0.014462	0.01441	0.014462	0.014462	0.014246	0.015782	0.014246	0.014246	0.014133	0.014331	0.014133	0.014133	0.014538	0.015343	0.014538	0.014538	0
Whitley (34)	0.020963	0.02279	0.020963	0.020963	0.021603	0.023969	0.021603	0.021603	0.023047	0.018761	0.023047	0.023047	0.014601	0.019334	0.014601	0.014601	0
Odd Square (35)	-1.00773	-1.00788	-1.00773	-1.00773	-1.00791	-1.00806	-1.00791	-1.00791	-1.008	-1.00732	-1.008	-1.008	-1.0079	-0.92433	-1.0079	-1.0079	-1.14383
Storn Chebyshev (36)	41.64896	33.55829	40.69228	35.09064	50.90656	49.90842	30.43146	30.28875	53.65604	43.80285	47.14952	41.57691	68.67818	74.45823	39.29214	76.31025	0
Rana (37)	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1020.7	-1023.42	-1023.42	-1012.45	-1021.6	-1012.45	-1012.45	-1020.17	-1022.62	-1020.17	-1020.17	-1023.416
Rosenbrock 10D (38)	918.4728	908.2958	758.0538	765.7898	926.8289	914.2436	886.499	789.7407	904.4731	930.5988	971.5371	856.5653	966.2472	964.2668	969.6031	963.1501	0
Rosenbrock 30D (39)	243498	257539.1	152364.5	152364.5	228155.9	263284.7	186959.7	186959.7	270013.7	254754.3	273200.1	262852.1	507104.4	507104.4	507104.4	507104.4	0
Mod Rosenbrock 1 10D (40)	815.4511	821.5456	727.4187	732.799	785.9742	817.2771	779.8832	758.9857	806.0771	807.8626	785.4078	777.0842	829.0225	827.0791	824.368	820.5442	0
Mod Rosenbrock 1 30D (41)	20015.51	21010.57	16666.07	16666.07	19702.22	20862.12	17705.85	17705.85	20906.1	20870.23	20813.49	21058.39	25223.52	25223.52	25223.52	25223.52	0
Mod Rosenbrock 2 10D (42)	0.921417	0.974508	0.930034	0.906341	0.983053	1.017578	0.957541	0.905441	1.032695	0.974886	0.99482	0.94324	0.945938	0.959603	1.049785	1.030054	0
Mod Rosenbrock 2 30D (43)	0.964574	0.98448	0.889847	0.889847	0.973541	0.893858	0.965637	0.965637	0.945858	0.997484	1.026055	0.959181	0.955648	0.979206	0.924147	0.972271	0
Spherical Contours 10D (44)	0.659596	0.653158	0.611763	0.592002	0.636379	0.653769	0.64485	0.598461	0.669559	0.661656	0.630738	0.648678	0.652335	0.648402	0.641868	0.653789	0
Rastrigin 10D (45)	35.28173	33.55137	29.6772	29.52423	34.24844	35.0147	31.83387	29.98726	33.18431	35.11251	34.36383	31.89178	35.16693	35.23599	33.94539	34.27501	0
Rastrigin 30D (46)	263.3152	257.1323	226.6286	226.6286	255.686	266.7897	229.1577	229.1577	252.8675	263.12	248.3605	241.5597	284.4632	280.9447	283.6631	282.9993	0
Schwefel 10D (47)	-3145.67	-3176.39	-3060.35	-3028.7	-3142.47	-3204.4	-3110.09	-3009.79	-3093.93	-3229.16	-3142.02	-3026.3	-3086.94	-3135.23	-3126.81	-3034.92	-4189.829
Schwefel 30D (48)	-5744.66	-5802.03	-5823.25	-5823.25	-5707.33	-5824.75	-5854.56	-5854.56	-5659.84	-5722.17	-5735.63	-5723.85	-5624.16	-5645.66	-5682.93	-5682.4	-12569.487
Griewangk 10D (49)	1.600331	1.599541	1.543983	1.532638	1.601363	1.628858	1.597149	1.575338	1.559984	1.578625	1.601977	1.568942	1.636706	1.637095	1.632175	1.638385	0
Griewangk 30D (50)	20.26185	20.80651	17.05823	17.05823	19.86282	21.27859	17.89349	17.89349	21.32721	21.30986	21.2296	21.2191	25.84642	25.84642	25.84642	25.84642	0
Salomon 10D (51)	1.128432	1.113801	1.002543	1.024406	1.098746	1.114447	1.0556	1.032528	1.081792	1.120909	1.121521	1.08796	1.118864	1.122935	1.107598	1.11989	0
Salomon 30D (52)	5.119277	5.239006	4.486788	4.486788	5.005253	5.26033	4.71319	4.71319	5.215414	5.178029	5.217887	5.220615	5.993618	5.994326	5.994326	5.99117	0
Odd Square 10D (53)	-0.5382	-0.54247	-0.57701	-0.58726	-0.54528	-0.53775	-0.55675	-0.5662	-0.54446	-0.53885	-0.54514	-0.55165	-0.53214	-0.53114	-0.53615	-0.53131	-1.14383
Whitley 10D (54)	5669948	6026607	12174393	1.24E+08	6416431	6294631	6118509	6606174	6861868	6398473	6896002	5669553	6592230	6670173	7088700	6734376	0
Whitley 30D (55)	9.99E+11	1.06E+12	4.19E+11	4.19E+11	8.87E+11	1.12E+12	5.45E+11	5.45E+11	1.15E+12	1.19E+12	7.42E+12	1.16E+12	3.66E+12	4.42E+12	3.18E+12	4.98E+12	0
Rana 10D (56)	-3345.69	-3342.71	-3432.06	-3443.29	-3367.92	-3390.47	-3402.17	-3391.63	-3359.03	-3358.19	-3392.48	-3355.66	-3298.69	-3361.15	-3396.93	-3358.6	-5117.08
Rana 30D (57)	-5726.06	-5719.84	-5763.07	-5763.07	-5677.15	-5717.46	-5709.77	-5709.77	-5633.5	-5638.21	-5700.16	-5698.6	-5565.47	-5620.87	-5642.25	-5655.73	-15351.24

Average Result (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.003418	0.00375	0.003418	0.003418	0.003874	0.003704	0.003874	0.003874	0.005569	0.001873	0.005569	0.005569	0.003549	0.00299	0.003549	0.003549	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91293	-1.91322	-1.91322	-1.91322	-1.90166	-1.91322	-1.91322	-1.9133
Box and Betts (3)	1.08E-06	1.44E-06	2.45E-06	2.85E-07	2.79E-06	1.34E-06	3.43E-07	1.70E-06	1.88E-06	6.28E-06	2.11E-06	8.08E-07	1.92E-05	2.37E-05	1.00E-05	4.92E-06	0
Goldstein (4)	3.000162	3.000052	3.000162	3.000162	3.000108	3.504945	3.000108	3.000108	3.00018	3.490538	3.00018	3.00018	3.206975	5.156892	3.206975	3.206975	3
Easom (5)	-0.99388	-0.99287	-0.99388	-0.99388	-0.99422	-0.99326	-0.99422	-0.99422	-0.99286	-0.99082	-0.99286	-0.99286	-0.98535	-0.98674	-0.98535	-0.98535	-1
Mod Rosenbrock 1 (6)	0.117143	0.132933	0.117143	0.117143	0.127353	0.123022	0.127353	0.127353	0.117361	0.075912	0.117361	0.117361	0.114336	0.113085	0.114336	0.114336	0
Mod Rosenbrock 2 (7)	1.925014	1.843068	1.925014	1.925014	1.949319	1.95971	1.949319	1.949319	2.02516	1.5959	2.02516	2.02516	1.982055	2.128889	1.982055	1.982055	0
Bohachevsky (8)	2.362853	2.139394	2.362853	2.362853	2.308586	2.278195	2.308586	2.308586	2.160335	2.160901	2.160335	2.160335	2.539755	2.539755	2.539755	2.539755	0
Powell (9)	321099.9	321099.9	342257.4	285808.4	370835.7	370835.7	349614.9	341095.5	542617.3	542617.3	541450.1	551199.2	640170.7	640170.7	640170.7	640170.7	0
Wood (10)	1031810	1031810	1022525	893972.8	1348176	1348176	1467580	1239298	1744189	1744189	1687454	1674930	1905506	1905506	1905506	1905506	0
Beale (11)	3.202994	3.344441	3.202994	3.202994	2.846708	3.860345	2.846708	2.846708	83.19249	83.34356	83.19249	83.19249	6.577071	6.607884	6.577071	6.577071	0
Engvall (12)	3.39726	3.57187	3.39726	3.39726	3.805493	3.068819	3.805493	3.805493	3.228039	3.228039	3.228039	3.228039	3.864261	3.864261	3.864261	3.864261	0
DeJong (13)	2.20E-05	2.25E-05	2.20E-05	2.20E-05	2.59E-05	5.80E-06	2.59E-05	2.59E-05	8.96E-06	2.16E-06	8.96E-06	8.96E-06	9.86E-06	1.53E-05	9.86E-06	9.86E-06	0
Rastrigin (14)	0.010188	0.007594	0.010188	0.010188	0.008792	0.005693	0.008792	0.008792	0.049246	0.646625	0.049246	0.049246	0.525366	0.570336	0.525366	0.525366	0
Schwefel (15)	-835.977	-837.816	-835.977	-835.977	-837.466	-836.927	-837.466	-837.466	-837.578	-837.582	-837.578	-837.578	-837.728	-837.731	-837.728	-837.728	-837.9658
Griewangk (16)	0.011368	0.010784	0.011368	0.011368	0.012219	0.012107	0.012219	0.012219	0.011858	0.011828	0.011858	0.011858	0.012939	0.012939	0.012939	0.012939	0
Ackley (17)	0.054652	0.065456	0.054652	0.054652	0.056902	0.059589	0.056902	0.056902	0.061934	0.043707	0.061934	0.061934	0.068379	0.05407	0.068379	0.068379	0
Langerman (18)	-1.48583	-1.48565	-1.4866	-1.48254	-1.47924	-1.47307	-1.48269	-1.47944	-1.46679	-1.46686	-1.46703	-1.46688	-1.4146	-1.4146	-1.4146	-1.4146	-1.5
Michaelewicz (19)	-6.45532	-7.02583	-6.89872	-6.85788	-6.49994	-7.00235	-7.17848	-6.77879	-6.27718	-6.6968	-7.06501	-6.42042	-5.89349	-5.91413	-6.01987	-5.86381	-9.66
Branin (20)	0.397919	0.397909	0.397919	0.397919	0.397916	0.397892	0.397916	0.397916	0.397894	0.39789	0.397894	0.397894	0.397896	0.39869	0.397896	0.397896	0.397887
Six Hump Camel (21)	-1.03162	-1.03163	-1.03162	-1.03162	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03076	-1.03163	-1.03163	-1.03034	-1.02	-1.03034	-1.03034	-1.0316
Osborne 1 (22)	0.070462	0.072647	0.064281	0.076142	0.083553	0.0942	0.088172	0.090236	0.121577	0.123638	0.120982	0.126099	0.169715	0.169715	0.169715	0.169715	5.46E-05
Osborne 2 (23)	0.1707	0.171416	0.168446	0.170297	0.20026	0.199039	0.196523	0.197037	0.258132	0.258132	0.258132	0.258132	0.413102	0.413102	0.413102	0.413102	0.0402
Mod Rastrigin (24)	85.98206	85.53362	85.98206	85.98206	85.77255	85.61497	85.77255	85.77255	86.69847	88.33066	86.69847	86.69847	88.49238	87.35721	88.49238	88.49238	58
Mineshaft 1 (25)	1.98312	2.034469	1.931517	2.034469	1.908812	2.068563	1.870167	2.068563	1.909791	2.292694	2.016063	2.292694	2.088104	2.323913	2.280424	2.323913	1.3805
Mineshaft 2 (26)	-1.41632	-1.23484	-1.3958	-1.23484	-1.41628	-1.16824	-1.37341	-1.16824	-1.37094	-1.16112	-1.26266	-1.16112	-1.33076	-1.22513	-1.24187	-1.22513	-1.4163535
Mineshaft 3 (27)	-6.94709	-6.93782	-6.94709	-6.94709	-6.97568	-6.96861	-6.97568	-6.97568	-6.87013	-6.91304	-6.87013	-6.87013	-6.99583	-6.24073	-6.99583	-6.99583	-7
Spherical Contours (28)	30.99403	31.06097	31.02947	31.02947	37.52425	37.52425	37.52425	37.52425	62.52586	62.52586	62.52586	62.52586	121.1291	121.1291	121.1291	121.1291	0
S1 (29)	7.24E-12	0.009982	2.63E-12	0.009982	6.11E-12	0.002726	3.96E-05	0.002726	3.75E-08	0.000587	0.000236	0.000587	8.72E-05	0.000211	0.00019	0.000211	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.529576	0.528872	0.528872	0.528923	0.529906	0.528923	0.528923	0.5289
Downhill Step (32)	9	9	9	9	9	9.019	9	9	9.053	9.122	9.053	9.053	9.046	9.088	9.046	9.046	9
Salomon (33)	0.056832	0.053261	0.056832	0.056832	0.054837	0.05279	0.054837	0.054837	0.06167	0.060308	0.06167	0.06167	0.063272	0.064354	0.063272	0.063272	0
Whitley (34)	0.174713	0.138318	0.174713	0.174713	0.19517	0.157596	0.19517	0.19517	0.170948	0.167026	0.170948	0.170948	0.177664	0.176455	0.177664	0.177664	0
Odd Square (35)	-1.00674	-1.00663	-1.00674	-1.00674	-1.00658	-1.00714	-1.00658	-1.00658	-1.00679	-0.93958	-1.00679	-1.00679	-0.99046	-0.87511	-0.99046	-0.99046	-1.14383
Storn Chebyshev (36)	250.9332	274.8116	295.4744	295.6616	276.4222	311.6956	324.9644	291.9985	749.6529	747.3291	741.7043	748.7942	824.3291	824.3291	824.3291	824.3291	0
Rana (37)	-1021.79	-1019.28	-1021.79	-1021.79	-997.202	-991.325	-997.202	-997.202	-1011.72	-1011.72	-1011.72	-1011.72	-1019.38	-1019.38	-1019.38	-1019.38	-1023.416
Rosenbrock 10D (38)	1563.792	1545.567	1449.556	42566.99	1635.92	1643.243	1643.643	1643.153	2784.536	2784.536	2784.536	2784.536	4656.455	4656.455	4656.455	4656.455	0
Rosenbrock 30D (39)	577817.6	559919.4	576602.6	576602.6	790057.7	794483.5	793980.2	793980.2	4542416	4542416	4542416	4542416	16226260	16226260	16226260	16226260	0
Mod Rosenbrock 1 10D (40)	1061.944	1057.338	1052.975	1045.354	1061.817	1061.623	1061.97	1066.683	1327.069	1327.069	1327.069	1327.069	1877.504	1877.504	1877.504	1877.504	0
Mod Rosenbrock 1 30D (41)	24043.93	24061.64	23998.41	23998.41	29083.57	29083.57	29083.57	29083.57	47748.25	47748.25	47748.25	47748.25	85427.94	85427.94	85427.94	85427.94	0
Mod Rosenbrock 2 10D (42)	1.841706	1.819172	1.815861	1.737896	2.006446	1.794079	1.850401	1.749197	2.067904	1.937021	2.062548	2.008344	2.12604	2.12604	2.093678	2.12604	0
Mod Rosenbrock 2 30D (43)	2.017096	1.832401	2.032138	2.032138	1.988985	1.833079	1.978764	1.978764	2.161157	2.179512	2.119597	2.121219	2.269261	2.252955	2.269261	2.269261	0
Spherical Contours 10D (44)	0.886878	0.887071	0.863926	0.855627	0.917595	0.917595	0.917595	0.916217	1.257534	1.257534	1.257534	1.257534	2.155032	2.155032	2.155032	2.155032	0
Rastrigin 10D (45)	40.42471	40.54943	39.05932	38.96465	40.35519	41.98236	40.94677	42.12614	47.72809	46.97278	47.20377	47.38302	58.40093	58.41485	58.38915	58.41485	0
Rastrigin 30D (46)	283.6613	280.9129	266.4985	266.4985	310.1035	305.8013	310.5954	310.5954	368.1069	367.837	365.0247	363.1743	427.9819	426.4318	424.0659	421.1312	0
Schwefel 10D (47)	-2903.92	-2943.96	-2858.16	-2856.06	-2886.14	-2901.9	-2893.51	-2827.3	-2843.6	-2850.52	-2859.4	-2842.82	-2845.17	-2840.39	-2842.32	-2844.18	-4189.829
Schwefel 30D (48)	-5294.78	-5326.71	-5364.84	-5364.84	-5230.92	-5273.78	-5332.78	-5332.78	-5243.2	-5255.31	-5233.14	-5245.75	-5210.81	-5213.75	-5208.92	-5210.42	-12569.487
Griewangk 10D (49)	1.845243	1.813478	1.807298	1.810896	1.879226	1.879226	1.879226	1.879226	2.277633	2.277633	2.277633	2.277633	3.032524	3.032524	3.032524	3.032524	0
Griewangk 30D (50)	24.10725	24.10574	23.98875	23.98875	30.21411	30.21411	30.21411	30.21411	48.74501	48.74501	48.74501	48.74501	94.43771	94.43771	94.43771	94.43771	0
Salomon 10D (51)	1.299216	1.271779	1.266988	1.283517	1.289911	1.28389	1.285536	1.289516	1.560916	1.560916	1.560916	1.560916	2.104141	2.104141	2.104141	2.104141	0
Salomon 30D (52)	5.727591	5.725141	5.723577	5.723577	6.468741	6.471693	6.477592	6.477592	8.928658	8.928658	8.928658	8.928658	12.49786	12.49786	12.49786	12.49786	0
Odd Square 10D (53)	-0.48934	-0.49473	-0.52007	-0.52145	-0.47589	-0.47295	-0.48063	-0.48587	-0.33977	-0.33967	-0.34325	-0.34413	-0.19559	-0.19677	-0.19765	-0.19744	-1.14383
Whitley 10D (54)	49862269	47780480	1.69E+08	1.68E+08	25795092	25838373	25795092	25795092	54611508	54611508	54611508	54611508	3.21E+08	3.21E+08	3.21E+08	3.21E+08	0
Whitley 30D (55)	5.72E+12	5.85E+12	5.73E+12	5.73E+12	8.84E+12	8.62E+12	8.36E+12	8.36E+12	1.14E+15	1.17E+15	1.18E+15	1.16E+15	7.22E+15	7.59E+15	7.68E+15	7.29E+15	0
Rana 10D (56)	-3077.61	-3093.22	-3100.23	-3077.36	-3069.14	-3086.08	-3084.01	-3025.15	-3037.27	-3041.09	-3089.64	-3026.56	-3045.56	-3043.9	-3052.05	-3046.53	-5117.08
Rana 30D (57)	-5238.57	-5332.72	-5283.77	-5283.77	-5170.55	-5213.09	-5245.44	-5245.44	-5275.11	-5198.33	-5265.99	-5240.03	-5265.87	-5255.48	-5266.78	-5229.82	-15351.24

APPENDIX B2: STANDARD DEVIATION FOR SMOA RESULTS

Results St. Dev. (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.000437	0.000384	0.000437	0.000437	0.000394	0.00039	0.000394	0.000394	0.000249	0.000123	0.000249	0.000249	0.000209	2.94E-05	0.000209	0.000209
McCormic (2)	2.40E-07	4.73E-08	2.40E-07	2.40E-07	9.12E-08	1.15E-08	9.12E-08	9.12E-08	1.45E-08	2.76E-09	1.45E-08	1.45E-08	4.39E-09	0.001188	4.39E-09	4.39E-09
Box and Betts (3)	5.54E-08	9.79E-09	1.21E-07	4.41E-08	3.39E-09	3.28E-07	9.76E-09	3.29E-08	1.65E-07	3.84E-06	3.06E-07	4.16E-07	7.50E-06	1.32E-05	8.26E-07	8.69E-06
Goldstein (4)	1.83E-05	9.55E-06	1.83E-05	1.83E-05	8.81E-06	1.14E-06	8.81E-06	8.81E-06	1.09E-06	1.87E-07	1.09E-06	1.09E-06	5.10E-07	0.994924	5.10E-07	5.10E-07
Easom (5)	0.000806	0.000801	0.000806	0.000806	0.000662	0.000639	0.000662	0.000662	0.000555	0.000564	0.000555	0.000555	0.000704	0.000759	0.000704	0.000704
Mod Rosenbrock 1 (6)	0.019627	0.020172	0.019627	0.019627	0.017049	0.020328	0.017049	0.017049	0.013314	0.009603	0.013314	0.013314	0.010117	0.004473	0.010117	0.010117
Mod Rosenbrock 2 (7)	0.296129	0.359734	0.296129	0.296129	0.348243	0.35423	0.348243	0.348243	0.350425	0.253084	0.350425	0.350425	0.265082	0.145965	0.265082	0.265082
Bohachevsky (8)	0.285133	0.252458	0.285133	0.285133	0.279267	0.299992	0.279267	0.279267	0.325081	0.241853	0.325081	0.325081	0.293778	0.288161	0.293778	0.293778
Powell (9)	51274	51274	46213.26	28629.98	39049.87	39049.87	40525.5	37171.9	26211.45	26211.45	35017.68	51505.63	42564.15	42564.15	36754.73	44358.76
Wood (10)	118376.1	118376.1	136333.2	39984.7	110385.9	110385.9	134552.8	108748.4	72063.37	72063.37	113672	139897.3	94209.75	94209.75	97168.61	138458.7
Beale (11)	0.224691	0.180311	0.224691	0.224691	0.177856	0.180317	0.177856	0.177856	0.176953	0.250809	0.176953	0.176953	0.181161	0.183181	0.181161	0.181161
Engvall (12)	0.317157	0.348493	0.317157	0.317157	0.338649	0.358288	0.338649	0.338649	0.430607	0.380675	0.430607	0.430607	0.31182	0.379645	0.31182	0.31182
DeJong (13)	2.46E-06	2.38E-06	2.46E-06	2.46E-06	2.89E-06	6.55E-07	2.89E-06	2.89E-06	5.76E-07	8.78E-08	5.76E-07	5.76E-07	1.83E-07	3.10E-08	1.83E-07	1.83E-07
Rastrigin (14)	0.001056	0.00084	0.001056	0.001056	0.000976	0.000405	0.000976	0.000976	0.000197	0.357481	0.000197	0.000197	0.003895	0.279006	0.003895	0.003895
Schwefel (15)	0.008088	0.013673	0.008088	0.008088	0.005981	0.008294	0.005981	0.005981	0.005349	0.007341	0.005349	0.005349	0.011325	0.009844	0.011325	0.011325
Griewangk (16)	0.002596	0.002658	0.002596	0.002596	0.002417	0.002768	0.002417	0.002417	0.002447	0.002641	0.002447	0.002447	0.002585	0.002616	0.002585	0.002585
Ackley (17)	0.009658	0.0092	0.009658	0.009658	0.009098	0.008817	0.009098	0.009098	0.008827	0.005175	0.008827	0.008827	0.007094	0.003148	0.007094	0.007094
Langerman (18)	0.001851	0.001622	0.001535	0.001951	0.00182	0.001816	0.001709	0.001602	0.002231	0.001811	0.001824	0.001725	0.002214	0.002697	0.002195	0.002337
Michaelewicz (19)	0.474191	0.524754	0.402005	0.365643	0.448133	0.509249	0.493068	0.315874	0.407008	0.54957	0.434785	0.306978	0.404982	0.607983	0.510282	0.323235
Branin (20)	3.22E-06	2.48E-06	3.22E-06	3.22E-06	2.44E-06	4.26E-07	2.44E-06	2.44E-06	6.38E-07	1.33E-07	6.38E-07	6.38E-07	1.49E-07	0.00717	1.49E-07	1.49E-07
Six Hump Camel (21)	3.87E-07	1.20E-07	3.87E-07	3.87E-07	1.30E-07	1.90E-08	1.30E-07	1.30E-07	1.93E-08	4.85E-09	1.93E-08	1.93E-08	9.36E-09	3.71E-09	9.36E-09	9.36E-09
Osborne 1 (22)	0.009487	0.009125	0.008456	0.007486	0.006825	0.007521	0.008168	0.006668	0.007996	0.007609	0.007722	0.008472	0.014464	0.00829	0.008398	0.00871
Osborne 2 (23)	0.01632	0.017976	0.021021	0.028003	0.015778	0.015753	0.016997	0.016419	0.021619	0.017109	0.01872	0.018597	0.018201	0.017597	0.018772	0.023936
Mod Rastrigin (24)	1.572467	1.435843	1.572467	1.572467	1.644803	1.933083	1.644803	1.644803	1.530131	3.569942	1.530131	1.530131	2.155697	2.809348	2.155697	2.155697
Mineshaft 1 (25)	0.144043	0.221727	0.153595	0.221727	0.075129	0.111186	0.057972	0.111186	0.048994	0.248315	0.045997	0.248315	0.065281	0.306814	0.190038	0.306814
Mineshaft 2 (26)	1.24E-06	0.141511	0.047463	0.141511	2.20E-09	0.110871	2.06E-09	0.110871	1.83E-09	0.150486	0.06008	0.150486	0.020859	0.161753	0.107705	0.161753
Mineshaft 3 (27)	0.140713	0.237416	0.140713	0.140713	0.009779	0.171211	0.009779	0.009779	0.001058	3.05E-05	0.001058	0.001058	4.31E-05	1.32E-05	4.31E-05	4.31E-05
Spherical Contours (28)	2.316279	2.21296	1.739907	1.739907	2.260339	2.357092	1.936913	1.936913	2.176073	2.214299	2.388664	1.992827	2.691502	3.666895	3.418473	3.706135
S1 (29)	1.88E-13	0.008996	1.54E-14	0.008996	1.24E-14	1.12E-15	3.07E-15	1.12E-15	8.15E-15	0.000161	0.000126	0.000161	3.41E-12	0.000478	2.27E-06	0.000478
S2 (30)	1.04E-11	1.76E-11	1.04E-11	1.04E-11	8.24E-12	2.35E-12	8.24E-12	8.24E-12	8.29E-12	2.56E-13	8.29E-12	8.29E-12	8.13E-13	1.31E-13	8.13E-13	8.13E-13
S3 (31)	9.22E-11	4.42E-11	9.22E-11	9.22E-11	1.60E-10	1.51E-11	1.60E-10	1.60E-10	1.46E-11	3.16E-12	1.46E-11	1.46E-11	1.26E-11	4.03E-12	1.26E-11	1.26E-11
Downhill Step (32)	0	0	0	0	0	0.039799	0	0	0.080474	0	0.080474	0.080474	0	0.069649	0	0
Salomon (33)	0.007606	0.006057	0.007606	0.007606	0.006246	0.006845	0.006246	0.006246	0.007374	0.00676	0.007374	0.007374	0.005539	0.008213	0.005539	0.005539
Whitley (34)	0.01264	0.016101	0.01264	0.01264	0.010323	0.010424	0.010323	0.010323	0.017283	0.007378	0.017283	0.017283	0.009104	0.01586	0.009104	0.009104
Odd Square (35)	0.000312	0.000288	0.000312	0.000312	0.000255	0.000203	0.000255	0.000255	0.000207	0.000999	0.000207	0.000207	0.000156	0.09702	0.000156	0.000156
Storn Chebyshev (36)	28.24315	28.23429	17.48724	23.05748	35.47553	24.93495	22.9977	13.90026	26.60562	22.6578	24.2301	17.58457	20.73746	27.16827	27.27811	24.83472
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	34.81094	1.71E-12	34.81094	34.81094	1.71E-12	1.71E-12	1.71E-12	1.71E-12
Rosenbrock 10D (38)	246.5233	224.1263	229.9829	220.6009	231.5705	240.9769	234.5566	202.3305	242.4529	237.388	253.4161	214.4771	227.475	242.7615	246.2663	213.9309
Rosenbrock 30D (39)	39785.29	51585.33	22228.96	22228.96	42220.61	52985.06	28159.6	28159.6	35173	41319.68	35073.88	31873.31	65249.3	47462.12	43556.92	48832.5
Mod Rosenbrock 1 10D (40)	145.373	119.141	113.2651	125.1624	130.8563	117.0223	117.7706	106.3879	127.0476	128.7352	144.6954	112.0421	131.2901	124.8997	118.8296	115.4838
Mod Rosenbrock 1 30D (41)	1665.994	1683.406	1626.561	1626.561	1728.878	1789.799	1691.59	1691.59	1759.453	1979.024	2015.454	1764.422	2302.889	2334.024	2210.516	2132.666
Mod Rosenbrock 2 10D (42)	0.31385	0.295638	0.289289	0.307031	0.362549	0.322219	0.294867	0.328345	0.326697	0.32948	0.334571	0.290418	0.319599	0.260012	0.314772	0.304611
Mod Rosenbrock 2 30D (43)	0.338468	0.307206	0.303298	0.303298	0.308544	0.275699	0.293461	0.293461	0.271014	0.296801	0.333813	0.291186	0.309105	0.306422	0.307735	0.329467
Spherical Contours 10D (44)	0.136262	0.134809	0.104814	0.12017	0.122002	0.139334	0.109729	0.157893	0.128079	0.13563	0.122283	0.119952	0.150376	0.148198	0.141052	0.143295
Rastrigin 10D (45)	4.141033	3.974505	3.921938	4.785566	4.604868	3.848777	3.650288	3.274654	3.894978	3.708108	3.773467	3.751131	4.090306	3.560041	4.142855	3.753849
Rastrigin 30D (46)	12.16197	14.17906	11.33831	11.33831	12.67855	11.55342	11.94253	11.94253	12.49333	14.01134	10.60813	13.02565	13.44401	12.5956	9.915176	12.17534
Schwefel 10D (47)	147.1036	143.6883	261.4816	266.8263	130.1488	161.174	194.5188	232.9836	197.011	153.245	170.7773	159.3375	174.1463	169.8404	183.889	186.9393
Schwefel 30D (48)	350.5116	291.8257	343.4402	343.4402	241.9588	306.9538	364.7234	364.7234	292.9508	354.0479	326.8417	352.0194	264.7467	282.5303	305.0204	287.2805
Griewangk 10D (49)	0.140829	0.1472	0.108843	0.16642	0.118374	0.136513	0.126913	0.11344	0.114045	0.125358	0.130051	0.130643	0.118353	0.11711	0.126248	0.121039
Griewangk 30D (50)	1.757051	1.973438	1.482547	1.482547	1.786566	1.980831	1.845376	1.845376	1.625829	1.838516	1.793248	1.632179	1.761672	1.924008	1.965992	1.763186
Salomon 10D (51)	0.142015	0.117095	0.121526	0.112759	0.128949	0.122799	0.121364	0.107272	0.121296	0.138578	0.132315	0.109014	0.126327	0.134343	0.118612	0.131405
Salomon 30D (52)	0.269172	0.273527	0.23604	0.23604	0.271615	0.282089	0.22359	0.22359	0.24395	0.279696	0.248963	0.235967	0.252238	0.336557	0.32004	0.267942
Odd Square 10D (53)	0.03015	0.035421	0.080246	0.082187	0.05013	0.03659	0.072214	0.082494	0.055103	0.037741	0.052313	0.074461	0.042226	0.044102	0.028034	0.059544
Whitley 10D (54)	2364578	2852781	1806714	1.11E+09	3362401	3361426	2920139	2015292	2992812	3124692	3682742	2324133	2844082	3094068	2650511	2932680
Whitley 30D (55)	2.8E+11	3.43E+11	8.49E+10	8.49E+10	2.98E+11	3.59E+11	1.08E+11	1.08E+11	2.49E+11	3.27E+11	2.42E+11	2.57E+11	8.59E+11	3.55E+11	3.97E+11	3.7E+11
Rana 10D (56)	170.6158	146.2269	251.51	260.6151	168.4203	168.9593	210.964	273.8553	181.6538	196.5141	172.6133	190.035	207.5342	194.6198	181.4916	185.6218
Rana 30D (57)	317.3316	319.0104	307.1353	307.1353	286.2096	264.1111	297.03	297.03	324.2637	296.4792	273.5592	296.6738	309.3221	242.2878	303.8686	295.0624

Results St. Dev. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.000756	0.001021	0.000756	0.000756	0.000535	0.000705	0.000535	0.000535	0.016207	0.000231	0.016207	0.016207	0.000404	0.000108	0.000404	0.000404
McCormic (2)	4.66E-07	8.89E-08	4.66E-07	4.66E-07	1.60E-07	2.45E-08	1.60E-07	1.60E-07	2.75E-08	9.54E-09	2.75E-08	2.75E-08	5.44E-08	0.001188	5.44E-08	5.44E-08
Box and Betts (3)	7.51E-08	1.43E-08	1.32E-07	7.31E-08	1.80E-05	5.46E-07	2.64E-08	3.91E-08	1.69E-06	7.13E-06	2.71E-06	4.15E-07	8.32E-06	1.43E-05	8.57E-07	8.76E-06
Goldstein (4)	3.86E-05	1.08E-05	3.86E-05	3.86E-05	1.71E-05	4.06E-06	1.71E-05	1.71E-05	2.84E-06	5.77E-07	2.84E-06	2.84E-06	1.77E-06	1.005553	1.77E-06	1.77E-06
Easom (5)	0.001258	0.001637	0.001258	0.001258	0.001388	0.001466	0.001388	0.001388	0.001096	0.001436	0.001096	0.001096	0.001751	0.00137	0.001751	0.001751
Mod Rosenbrock 1 (6)	0.033548	0.028089	0.033548	0.033548	0.022928	0.031019	0.022928	0.022928	0.024292	0.014084	0.024292	0.024292	0.018788	0.008379	0.018788	0.018788
Mod Rosenbrock 2 (7)	0.416064	0.426825	0.416064	0.416064	0.401015	0.472495	0.401015	0.401015	0.464774	0.323069	0.464774	0.464774	0.357422	0.237959	0.357422	0.357422
Bohachevsky (8)	0.42704	0.357941	0.42704	0.42704	0.405077	0.395993	0.405077	0.405077	0.510331	0.372534	0.510331	0.510331	0.389954	0.408339	0.389954	0.389954
Powell (9)	91484.43	91484.43	78868.13	45732.83	56293.06	56293.06	60952.05	72448.71	55667.27	55667.27	60997.87	77789.82	65463.17	65463.17	79997.6	70285.27
Wood (10)	201482	201482	184856.5	415946.2	229453.5	229453.5	237640.1	233075.2	287028.3	287028.3	233570.6	225014.8	201674.7	201674.7	273360	284447.3
Beale (11)	0.285671	0.350993	0.285671	0.285671	0.314958	0.456711	0.314958	0.314958	0.259253	0.406529	0.259253	0.259253	0.335294	0.3808	0.335294	0.335294
Engvall (12)	0.549128	0.623921	0.549128	0.549128	0.700467	0.579165	0.700467	0.700467	0.622752	0.662169	0.622752	0.622752	0.767395	0.811597	0.767395	0.767395
DeJong (13)	4.43E-06	4.60E-06	4.43E-06	4.43E-06	5.95E-06	1.31E-06	5.95E-06	5.95E-06	1.41E-06	2.06E-07	1.41E-06	1.41E-06	3.26E-07	7.46E-08	3.26E-07	3.26E-07
Rastrigin (14)	0.002195	0.00149	0.002195	0.002195	0.001606	0.000726	0.001606	0.001606	0.031997	0.357165	0.031997	0.031997	0.12018	0.383604	0.12018	0.12018
Schwefel (15)	0.016682	0.023531	0.016682	0.016682	0.022084	0.021574	0.022084	0.022084	0.015005	0.035108	0.015005	0.015005	0.019167	0.036806	0.019167	0.019167
Griewangk (16)	0.003311	0.003194	0.003311	0.003311	0.002987	0.00322	0.002987	0.002987	0.003372	0.003203	0.003372	0.003372	0.003087	0.003252	0.003087	0.003087
Ackley (17)	0.01416	0.015134	0.01416	0.01416	0.013561	0.011914	0.013561	0.013561	0.013498	0.008106	0.013498	0.013498	0.010653	0.004841	0.010653	0.010653
Langerman (18)	0.002913	0.002456	0.002467	0.012533	0.002772	0.002433	0.003217	0.003059	0.003151	0.00406	0.003185	0.003519	0.003899	0.003867	0.003693	0.004393
Michaelewicz (19)	0.437932	0.555375	0.4145	0.390654	0.455488	0.542117	0.530622	0.398117	0.439742	0.561614	0.47687	0.311271	0.353638	0.620254	0.547244	0.358615
Branin (20)	7.93E-06	4.05E-06	7.93E-06	7.93E-06	5.00E-06	9.32E-07	5.00E-06	5.00E-06	8.76E-07	2.39E-07	8.76E-07	8.76E-07	4.35E-07	0.00717	4.35E-07	4.35E-07
Six Hump Camel (21)	1.10E-06	1.44E-07	1.10E-06	1.10E-06	2.44E-07	5.11E-08	2.44E-07	2.44E-07	7.71E-08	1.35E-08	7.71E-08	7.71E-08	2.65E-08	0.003717	2.65E-08	2.65E-08
Osborne 1 (22)	0.011156	0.010547	0.008841	0.011812	0.01086	0.008713	0.009302	0.008073	0.050026	0.010647	0.009622	0.011819	0.094278	0.09423	0.095241	0.022001
Osborne 2 (23)	0.018444	0.018518	0.03167	0.031689	0.019009	0.019751	0.022039	0.021289	0.028155	0.026556	0.028227	0.027274	0.025696	0.0248	0.025815	0.026482
Mod Rastrigin (24)	1.693458	1.482639	1.693458	1.693458	1.681425	1.831429	1.681425	1.681425	1.992592	3.390501	1.992592	1.992592	2.092007	2.748719	2.092007	2.092007
Mineshaft 1 (25)	0.159467	0.235351	0.143134	0.235351	0.070518	0.198024	0.070405	0.198024	0.045475	0.303635	0.099891	0.303635	0.113537	0.189193	0.283163	0.189193
Mineshaft 2 (26)	1.76E-06	0.165565	0.047463	0.165565	6.93E-09	0.14317	0.029955	0.14317	1.87E-09	0.17782	0.09662	0.17782	0.064847	0.165665	0.146946	0.165665
Mineshaft 3 (27)	0.141163	0.237394	0.141163	0.141163	0.009825	0.171204	0.009825	0.009825	0.001064	9.26E-05	0.001064	0.001064	0.001113	0.000172	0.001113	0.001113
Spherical Contours (28)	2.138468	2.401463	1.945076	1.945076	2.643557	2.489723	2.245526	2.245526	2.479205	2.338717	2.490693	2.392029	3.510566	3.510566	3.510566	3.510566
S1 (29)	4.78E-13	0.009055	3.47E-14	0.009055	6.48E-14	0.0005	9.90E-15	0.0005	3.73E-07	0.000838	0.000136	0.000838	0.000186	0.000497	0.000244	0.000497
S2 (30)	3.18E-11	4.28E-11	3.18E-11	3.18E-11	4.27E-11	9.68E-12	4.27E-11	4.27E-11	9.34E-12	1.55E-12	9.34E-12	9.34E-12	2.81E-12	7.33E-13	2.81E-12	2.81E-12
S3 (31)	2.43E-10	2.85E-10	2.43E-10	2.43E-10	3.13E-10	5.62E-11	3.13E-10	3.13E-10	1.06E-10	8.49E-11	1.06E-10	1.06E-10	1.05E-10	0.003772	1.05E-10	1.05E-10
Downhill Step (32)	0	0	0	0	0	0.039799	0	0	0.102815	0	0.102815	0.102815	0.024166	0.069649	0.024166	0.024166
Salomon (33)	0.015735	0.012631	0.015735	0.015735	0.014919	0.014873	0.014919	0.014919	0.01284	0.012219	0.01284	0.01284	0.01366	0.016193	0.01366	0.01366
Whitley (34)	0.042911	0.037759	0.042911	0.042911	0.026428	0.044325	0.026428	0.026428	0.039414	0.03161	0.039414	0.039414	0.025024	0.029495	0.025024	0.025024
Odd Square (35)	0.000475	0.000405	0.000475	0.000475	0.000409	0.000268	0.000409	0.000409	0.000313	0.001226	0.000313	0.000313	0.000455	0.09857	0.000455	0.000455
Storn Chebyshev (36)	46.44464	52.01753	61.51036	41.67516	55.64257	55.28197	39.27005	44.45229	60.40485	58.56539	51.52476	54.02611	229.7484	235.4666	49.52442	229.6639
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	20.76725	1.71E-12	1.71E-12	34.81094	12.7828	34.81094	34.81094	18.83067	7.867985	18.83067	18.83067
Rosenbrock 10D (38)	283.1568	326.7291	277.5191	303.365	306.6709	296.363	295.4585	297.2113	307.667	303.2965	289.1212	283.7867	316.9756	317.6501	328.489	319.0554
Rosenbrock 30D (39)	49290.32	53501.86	62496.98	62496.98	42361.24	58210.43	36716.7	36716.7	74575.26	47671.3	53746.43	54986.3	134491.9	134491.9	134491.9	134491.9
Mod Rosenbrock 1 10D (40)	172.0327	152.6001	126.9216	131.6014	161.3865	138.7985	127.7054	151.448	142.9299	144.602	160.0957	134.2887	146.625	148.68	150.0513	149.4953
Mod Rosenbrock 1 30D (41)	1872.757	1895.906	2150.75	2150.75	2079.416	1966.351	1892.392	1892.392	1983.623	2064.532	2058.752	2101.691	2485.18	2485.18	2485.18	2485.18
Mod Rosenbrock 2 10D (42)	0.378009	0.441916	0.428236	0.389858	0.435787	0.409904	0.387595	0.438606	0.432662	0.437287	0.452299	0.433493	0.45863	0.410275	0.436822	0.448681
Mod Rosenbrock 2 30D (43)	0.408267	0.409574	0.460398	0.460398	0.419137	0.37593	0.458955	0.458955	0.365964	0.361523	0.412087	0.353928	0.46405	0.445902	0.448234	0.445116
Spherical Contours 10D (44)	0.161016	0.156973	0.125477	0.134335	0.144894	0.160651	0.13077	0.173359	0.14547	0.142937	0.153744	0.130692	0.192281	0.19339	0.191203	0.192029
Rastrigin 10D (45)	4.212124	4.410785	3.93059	4.800373	4.851406	3.993777	4.097455	3.51081	4.441527	3.564374	3.971872	4.293258	4.029398	3.998342	4.1198	4.606105
Rastrigin 30D (46)	14.2301	15.88953	11.06821	11.06821	14.43895	11.69973	9.877303	9.877303	12.64218	13.20751	13.6093	12.32588	16.73687	16.14214	22.57886	16.5837
Schwefel 10D (47)	166.8363	154.4088	263.3138	267.9654	148.5298	159.2169	205.8597	201.043	202.7064	147.0821	169.0713	137.9735	155.8784	165.5839	185.6357	190.0388
Schwefel 30D (48)	332.0435	319.3247	401.8298	401.8298	275.2647	336.4802	402.1975	402.1975	280.6042	280.4425	362.399	293.0126	268.9492	258.3261	323.4649	300.0566
Griewangk 10D (49)	0.155881	0.161348	0.130199	0.168696	0.135724	0.143567	0.150523	0.134	0.146008	0.134822	0.135434	0.144402	0.15083	0.148991	0.145054	0.146857
Griewangk 30D (50)	1.88182	2.093944	2.093175	2.093175	1.962253	1.914879	1.743155	1.743155	2.087682	2.090606	2.049338	1.968108	2.63062	2.63062	2.63062	2.63062
Salomon 10D (51)	0.132549	0.125566	0.138015	0.120635	0.143464	0.136163	0.129774	0.125146	0.125886	0.140453	0.140381	0.10726	0.153391	0.146276	0.151146	0.153905
Salomon 30D (52)	0.293693	0.292423	0.233612	0.233612	0.292823	0.282171	0.240855	0.240855	0.285416	0.294164	0.339419	0.289379	0.470059	0.470668	0.470668	0.470226
Odd Square 10D (53)	0.020814	0.035905	0.067289	0.075562	0.041027	0.021729	0.053348	0.060916	0.040699	0.026784	0.04135	0.052192	0.03386	0.033071	0.020078	0.039486
Whitley 10D (54)	4767272	4824064	77893541	1.11E+09	5293312	4507264	4394149	8870866	6272193	5192743	6172813	4335093	5297034	5377713	5627969	5357754
Whitley 30D (55)	3.9E+11	3.97E+11	2.77E+11	2.77E+11	4.14E+11	4.57E+11	2.78E+11	2.78E+11	6.49E+11	4.58E+11	6.19E+13	5.87E+11	2.41E+12	5.3E+12	1.9E+12	1.49E+13
Rana 10D (56)	178.0522	174.5713	237.4377	252.0443	169.1452	180.4416	228.8966	271.3676	182.2362	185.0465	180.0649	179.3566	175.886	211.2059	210.0231	199.835
Rana 30D (57)	329.4383	305.9996	291.5624	291.5624	322.6741	293.1092	323.5251	323.5251	306.683	301.3668	343.1039	314.3504	312.3976	298.984	309.4131	312.1622

Results St. Dev. (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.002838	0.003349	0.002838	0.002838	0.003682	0.003593	0.003682	0.003682	0.016315	0.001747	0.016315	0.016315	0.003032	0.00302	0.003032	0.003032
McCormic (2)	2.47E-06	6.05E-07	2.47E-06	2.47E-06	7.89E-06	2.31E-07	7.89E-06	7.89E-06	6.67E-07	0.002864	6.67E-07	6.67E-07	4.60E-06	0.025841	4.60E-06	4.60E-06
Box and Betts (3)	3.80E-06	3.31E-06	2.14E-05	7.32E-07	1.80E-05	7.87E-06	1.14E-06	1.17E-05	6.19E-06	1.81E-05	9.11E-06	3.78E-06	3.10E-05	3.00E-05	2.14E-05	1.35E-05
Goldstein (4)	0.000175	0.000149	0.000175	0.000175	0.000269	3.614992	0.000269	0.000269	0.001045	1.788555	0.001045	0.001045	0.840233	2.965234	0.840233	0.840233
Easom (5)	0.006828	0.007084	0.006828	0.006828	0.005417	0.006838	0.005417	0.005417	0.006311	0.008941	0.006311	0.006311	0.018758	0.020274	0.018758	0.018758
Mod Rosenbrock 1 (6)	0.075177	0.093308	0.075177	0.075177	0.083478	0.083126	0.083478	0.083478	0.070926	0.054883	0.070926	0.070926	0.094713	0.068096	0.094713	0.094713
Mod Rosenbrock 2 (7)	0.738723	0.823507	0.738723	0.738723	0.831269	0.859281	0.831269	0.831269	0.821032	0.708311	0.821032	0.821032	0.94403	1.327374	0.94403	0.94403
Bohachevsky (8)	1.530798	1.493051	1.530798	1.530798	1.528111	1.480907	1.528111	1.528111	1.571858	1.591045	1.571858	1.571858	1.850036	1.850036	1.850036	1.850036
Powell (9)	210423	210423	231592.3	214135.1	332881.8	332881.8	257341.6	246307.7	368338.7	368338.7	373490	371418.4	466316.6	466316.6	466316.6	466316.6
Wood (10)	765814	765814	724098.6	1336975	1102980	1102980	1127779	964704.1	1651301	1651301	1625699	1625851	1283857	1283857	1283857	1283857
Beale (11)	4.701599	5.872243	4.701599	4.701599	4.280269	8.116981	4.280269	4.280269	787.8959	787.8783	787.8959	787.8959	14.27274	14.27262	14.27274	14.27274
Engvall (12)	5.970906	4.574465	5.970906	5.970906	6.148214	2.875119	6.148214	6.148214	3.724247	3.724247	3.724247	3.724247	4.342884	4.342884	4.342884	4.342884
DeJong (13)	2.42E-05	2.42E-05	2.42E-05	2.42E-05	2.26E-05	6.19E-06	2.26E-05	2.26E-05	1.31E-05	2.19E-06	1.31E-05	1.31E-05	1.35E-05	3.49E-05	1.35E-05	1.35E-05
Rastrigin (14)	0.009252	0.006957	0.009252	0.009252	0.007517	0.007161	0.007517	0.007517	0.135133	0.727172	0.135133	0.135133	0.492697	0.713365	0.492697	0.492697
Schwefel (15)	13.83863	0.331049	13.83863	13.83863	3.960933	6.206651	3.960933	3.960933	2.455792	2.455261	2.455792	2.455792	0.232482	0.231172	0.232482	0.232482
Griewangk (16)	0.00563	0.00576	0.00563	0.00563	0.006283	0.00668	0.006283	0.006283	0.006465	0.006346	0.006465	0.006465	0.006055	0.006055	0.006055	0.006055
Ackley (17)	0.026917	0.038854	0.026917	0.026917	0.032993	0.039287	0.032993	0.032993	0.039174	0.027588	0.039174	0.039174	0.050048	0.032304	0.050048	0.050048
Langerman (18)	0.009487	0.009412	0.008423	0.02421	0.033961	0.074271	0.011145	0.030766	0.030479	0.030211	0.030512	0.030323	0.07677	0.07677	0.07677	0.07677
Michaelewicz (19)	0.391912	0.597608	0.539895	0.492511	0.47352	0.536186	0.636854	0.500768	0.420983	0.652411	0.667338	0.425107	0.345368	0.417608	0.494556	0.321203
Branin (20)	2.97E-05	2.37E-05	2.97E-05	2.97E-05	2.96E-05	4.98E-06	2.96E-05	2.96E-05	6.94E-06	3.21E-06	6.94E-06	6.94E-06	1.06E-05	0.007201	1.06E-05	1.06E-05
Six Hump Camel (21)	5.15E-06	4.81E-06	5.15E-06	5.15E-06	2.15E-06	1.15E-06	2.15E-06	2.15E-06	1.36E-06	0.00678	1.36E-06	1.36E-06	0.009545	0.02913	0.009545	0.009545
Osborne 1 (22)	0.03322	0.033962	0.026389	0.084138	0.03444	0.057156	0.038263	0.048643	0.069075	0.067863	0.068706	0.080832	0.121728	0.121728	0.121728	0.121728
Osborne 2 (23)	0.034968	0.037203	0.037601	0.03814	0.064717	0.064548	0.0613	0.061092	0.073641	0.073641	0.073641	0.073641	0.268108	0.268108	0.268108	0.268108
Mod Rastrigin (24)	1.761468	1.83463	1.761468	1.761468	1.70829	1.881452	1.70829	1.70829	1.757045	3.165864	1.757045	1.757045	2.428702	3.04489	2.428702	2.428702
Mineshaft 1 (25)	0.142259	0.247955	0.1555	0.247955	0.085692	0.232135	0.131124	0.232135	0.118667	0.109911	0.216083	0.109911	0.195876	0.016904	0.12406	0.016904
Mineshaft 2 (26)	0.0003	0.196887	0.074392	0.196887	0.000752	0.185411	0.106206	0.185411	0.11364	0.171838	0.172527	0.171838	0.14573	0.161448	0.164401	0.161448
Mineshaft 3 (27)	0.168102	0.237116	0.168102	0.168102	0.172973	0.196016	0.172973	0.172973	0.901165	0.701755	0.901165	0.901165	0.022708	1.883814	0.022708	0.022708
Spherical Contours (28)	4.248738	4.292402	4.281148	4.281148	4.687166	4.687166	4.687166	4.687166	8.536318	8.536318	8.536318	8.536318	30.41852	30.41852	30.41852	30.41852
S1 (29)	1.74E-11	0.036352	9.70E-12	0.036352	1.40E-11	0.006812	0.000394	0.006812	3.73E-07	0.00102	0.000854	0.00102	0.000297	0.000494	0.000478	0.000494
S2 (30)	9.96E-10	7.01E-10	9.96E-10	9.96E-10	6.93E-10	3.16E-10	6.93E-10	6.93E-10	3.11E-10	4.54E-10	3.11E-10	3.11E-10	2.63E-10	1.60E-10	2.63E-10	2.63E-10
S3 (31)	4.77E-09	5.02E-08	4.77E-09	4.77E-09	9.36E-09	3.09E-09	9.36E-09	9.36E-09	3.11E-08	0.006519	3.11E-08	3.11E-08	0.000451	0.0044	0.000451	0.000451
Downhill Step (32)	0	0	0	0	0	0.100693	0	0	0.144537	0.23731	0.144537	0.144537	0.113508	0.179042	0.113508	0.113508
Salomon (33)	0.034551	0.033432	0.034551	0.034551	0.036091	0.035974	0.036091	0.036091	0.034964	0.034814	0.034964	0.034964	0.034206	0.036658	0.034206	0.034206
Whitley (34)	0.20766	0.144338	0.20766	0.20766	0.221556	0.168407	0.221556	0.221556	0.197661	0.196573	0.197661	0.197661	0.188254	0.194957	0.188254	0.188254
Odd Square (35)	0.000955	0.001239	0.000955	0.000955	0.001065	0.000818	0.001065	0.001065	0.001039	0.091589	0.001039	0.001039	0.036299	0.107439	0.036299	0.036299
Storn Chebyshev (36)	245.9555	280.3621	323.4736	330.8224	265.6606	313.8676	310.1396	302.1664	2964.053	2964.222	2963.801	2964.081	829.6967	829.6967	829.6967	829.6967
Rana (37)	16.13413	22.19053	16.13413	16.13413	50.759	55.12045	50.759	50.759	35.3259	35.3259	35.3259	35.3259	20.27776	20.27776	20.27776	20.27776
Rosenbrock 10D (38)	544.2668	561.8502	526.9612	408455.5	694.8093	695.9515	696.0262	695.8187	1581.916	1581.916	1581.916	1581.916	1719.795	1719.795	1719.795	1719.795
Rosenbrock 30D (39)	1757717	1756056	1757254	1757254	507159.3	505662.7	505633.6	505633.6	3287020	3287020	3287020	3287020	14520913	14520913	14520913	14520913
Mod Rosenbrock 1 10D (40)	196.7557	199.4282	176.8484	188.2609	199.9633	200.3262	200.2455	200.9121	274.1576	274.1576	274.1576	274.1576	399.4616	399.4616	399.4616	399.4616
Mod Rosenbrock 1 30D (41)	3023.376	2945.106	3062.871	3062.871	5560.662	5560.662	5560.662	5560.662	18166.14	18166.14	18166.14	18166.14	17195.34	17195.34	17195.34	17195.34
Mod Rosenbrock 2 10D (42)	0.828299	0.76647	0.859053	0.760965	0.995211	0.835469	0.892004	0.845518	0.889317	0.810037	0.870069	0.882541	0.807257	0.807257	0.797844	0.807257
Mod Rosenbrock 2 30D (43)	0.86417	0.698242	0.837304	0.837304	0.775481	0.84195	0.875478	0.875478	0.899512	0.864116	0.918118	0.846655	0.933929	0.90409	0.933929	0.933929
Spherical Contours 10D (44)	0.206261	0.211533	0.195081	0.205429	0.27877	0.27877	0.27877	0.27837	0.280287	0.280287	0.280287	0.280287	0.747876	0.747876	0.747876	0.747876
Rastrigin 10D (45)	4.657461	5.750572	4.477706	6.033524	5.116071	5.947132	5.45526	5.335982	5.604763	5.967367	5.58317	5.933979	9.525192	9.528807	9.509499	9.528807
Rastrigin 30D (46)	19.00832	21.76841	17.45189	17.45189	26.1127	20.0227	27.45634	27.45634	29.8035	24.98325	29.9287	27.79002	32.84805	33.11667	31.57321	31.37388
Schwefel 10D (47)	175.1269	188.3229	277.9913	251.028	185.3319	189.2527	185.507	183.1529	135.0754	138.8914	140.2418	141.5972	182.4222	178.3132	176.1503	180.7593
Schwefel 30D (48)	342.123	270.9085	395.064	395.064	305.893	289.5095	329.3383	329.3383	257.2975	271.3189	327.4972	282.3059	257.1318	291.1464	263.7628	260.0343
Griewangk 10D (49)	0.195053	0.204644	0.206788	0.226351	0.233878	0.233878	0.233878	0.233878	1.002004	1.002004	1.002004	1.002004	0.522338	0.522338	0.522338	0.522338
Griewangk 30D (50)	2.843025	2.782216	2.842258	2.842258	5.193139	5.193139	5.193139	5.193139	8.931615	8.931615	8.931615	8.931615	20.86054	20.86054	20.86054	20.86054
Salomon 10D (51)	0.148638	0.161632	0.158974	0.156211	0.19557	0.193449	0.190752	0.192801	0.183994	0.183994	0.183994	0.183994	0.365103	0.365103	0.365103	0.365103
Salomon 30D (52)	0.42615	0.382995	0.347839	0.347839	0.453867	0.449924	0.447747	0.447747	0.973472	0.973472	0.973472	0.973472	1.559823	1.559823	1.559823	1.559823
Odd Square 10D (53)	0.056366	0.047269	0.032975	0.042577	0.06664	0.068216	0.059171	0.061553	0.07039	0.071846	0.073289	0.070483	0.061163	0.061631	0.060678	0.060702
Whitley 10D (54)	2.57E+08	2.57E+08	1.13E+09	1.13E+09	24438408	24421204	24438408	24438408	41082708	41082708	41082708	41082708	4.66E+08	4.66E+08	4.66E+08	4.66E+08
Whitley 30D (55)	3.11E+13	3.1E+13	3.1E+13	3.1E+13	6.68E+12	6.38E+12	6.66E+12	6.66E+12	8.87E+15	8.88E+15	8.87E+15	8.88E+15	1.97E+16	1.99E+16	1.99E+16	1.99E+16
Rana 10D (56)	219.4629	210.6493	234.2912	264.267	170.8333	200.0096	210.3132	173.3398	182.4159	146.5596	192.9161	185.9463	162.3644	164.9743	156.7859	160.7358
Rana 30D (57)	273.8008	400.9219	336.5047	336.5047	291.5367	349.2321	355.2759	355.2759	333.6232	324.99	344.1286	276.8022	332.3308	316.2252	332.4017	322.5892

APPENDIX B3: SMOA AVERAGE RUNTIMES

Avg. Times (s) for 1M	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	6.613799	5.49595	6.435699	6.617881	7.168365	5.811244	7.137756	6.900437	3.911926	2.964109	4.437213	4.106608	2.871358	1.676781	1.719594	2.684132
McCormic (2)	5.136221	4.62518	5.483606	5.486636	4.81723	4.135943	4.804808	5.205449	2.15531	1.690097	2.268756	2.034669	1.266853	1.344813	0.808966	1.188881
Box and Betts (3)	5.460829	5.458053	6.356681	7.634364	5.074716	5.14967	5.734344	7.006119	4.473265	4.543513	4.902794	4.936864	4.159611	4.226633	3.379034	4.021287
Goldstein (4)	5.541464	2.780782	5.745909	5.335175	4.833938	2.348163	4.721985	5.162456	1.895617	1.595133	2.115062	1.854919	1.305383	1.336102	0.776496	1.134252
Easom (5)	7.777109	6.652653	7.354092	7.446798	8.4338	6.178865	7.588223	8.210848	4.195966	3.772714	5.153741	4.2457	4.181604	3.691979	2.503036	3.504172
Mod Rosenbrock 1 (6)	6.197947	5.128724	6.210573	6.902117	7.458576	6.079259	6.812547	6.822179	3.697331	2.889789	4.52591	3.885737	2.970707	2.085272	1.916711	2.838048
Mod Rosenbrock 2 (7)	6.565662	5.562929	6.743263	6.705648	6.513673	5.850297	6.695917	6.731973	3.650638	2.875753	5.180426	3.620262	3.037631	2.135995	1.952557	2.876307
Bohachevsky (8)	6.20147	5.253601	6.290412	5.88978	6.246902	5.405451	6.650297	6.435299	3.555574	3.044902	5.671577	3.663418	3.279648	2.728393	2.05948	3.188522
Powell (9)	9.37899	9.869803	10.70057	19.74689	11.81978	12.49842	12.85912	18.14771	10.99263	11.81676	14.8055	11.00522	8.259035	9.130974	8.668564	10.74338
Wood (10)	9.450192	8.98937	10.92066	19.67777	11.66888	11.94785	13.09628	19.55864	11.93797	12.70397	13.86443	11.29106	8.71669	8.857275	8.464375	12.24588
Beale (11)	6.226214	5.379242	6.374365	6.603832	7.008714	5.436622	6.523419	7.081294	4.29657	3.511109	5.122155	4.535129	4.069157	2.541873	2.191154	3.592822
Engvall (12)	6.710042	5.181598	6.638861	6.225753	6.732934	5.706096	7.078105	6.711382	4.642832	3.75763	5.172134	4.912388	3.980243	2.581707	2.824503	3.524106
DeJong (13)	5.845944	4.896637	5.843662	5.845416	6.585459	4.930278	6.418997	6.063519	3.680166	2.459525	3.87409	3.665644	1.880021	1.295241	1.309034	1.38867
Rastrigin (14)	6.843347	5.432136	6.333666	5.613576	6.64679	5.475763	6.52158	6.091244	3.896641	3.645281	3.931068	3.66902	3.609099	2.157795	2.720401	2.739242
Schwefel (15)	5.91332	5.503268	6.01608	5.237423	6.195102	5.464278	6.210626	5.467653	4.193618	3.660051	4.147627	3.840177	3.935921	2.512095	2.994534	3.118975
Griewangk (16)	6.237736	5.021443	5.881769	4.898218	6.192537	5.187354	6.242104	5.241657	4.031423	3.480578	4.017309	3.797104	3.446245	2.041205	2.733858	2.820209
Ackley (17)	6.298445	5.615238	6.260411	5.307112	5.980042	5.603436	5.755114	5.566278	4.380257	4.23828	3.930249	3.889689	3.394515	2.089896	2.979374	3.015374
Langerman (18)	9.053746	9.533012	12.70499	18.57959	11.75306	13.07433	13.76713	26.47555	16.73708	16.61323	13.52897	17.09049	9.042677	10.34946	12.59851	13.06658
Michaelewicz (19)	15.41709	19.49822	25.52088	22.32035	20.5609	20.60488	32.22305	37.14829	50.2831	29.92322	27.75095	84.94867	40.35396	38.4113	28.82615	137.9104
Branin (20)	4.853524	3.895822	3.983656	2.744145	4.078695	3.747102	3.117013	3.213235	4.210837	2.053533	3.587166	2.905569	1.413285	1.161808	1.352275	2.111315
Six Hump Camel (21)	4.618322	3.59779	3.365831	2.874804	3.704143	3.431274	2.888024	2.984431	3.152532	1.774829	2.962868	2.305126	1.292312	1.287802	1.250538	2.030865
Osborne 1 (22)	11.9013	12.60792	12.81209	19.02798	12.15486	14.54145	13.44417	28.6592	17.80582	15.92244	16.6089	21.41303	11.7348	12.24992	15.69455	20.19783
Osborne 2 (23)	25.31205	29.79228	37.34847	39.1124	29.3323	29.10081	47.02715	44.95047	47.04316	34.62267	39.24165	68.9718	33.60319	32.50383	33.71328	56.12242
Mod Rastrigin (24)	3.854405	3.185074	5.18504	3.899767	4.47068	3.594633	4.552304	2.982378	4.834705	3.758273	4.052987	3.374437	2.958736	2.211008	3.575739	4.170118
Mineshaft 1 (25)	3.052929	1.829156	3.034735	1.814792	2.729508	2.054407	1.890567	1.403523	2.056332	2.106356	2.021906	1.517205	1.482065	1.385776	1.734338	1.930882
Mineshaft 2 (26)	2.408014	1.176503	2.489638	1.152727	2.06787	1.430164	1.27672	0.832746	1.472123	1.492057	1.374126	0.874663	0.855492	0.848125	1.089742	1.304276
Mineshaft 3 (27)	3.55787	2.257521	3.916384	2.603946	3.949401	2.5589	2.726598	2.119989	3.675741	2.271166	4.043714	2.49931	1.588794	1.53854	2.089029	2.442945
Spherical Contours (28)	14.65594	17.45506	30.06239	26.78708	25.16013	18.67419	42.41757	33.41362	53.47157	25.704	66.3132	63.43328	9.292332	9.59881	11.00567	14.14044
S1 (29)	2.74464	1.278939	1.090742	0.52496	1.267437	1.668418	0.533168	0.393471	1.343857	1.038206	1.191474	0.88623	0.868224	0.805737	0.9941	1.308215
S2 (30)	4.527625	2.846829	2.299805	1.758596	3.173434	3.348705	1.786237	1.42663	4.117168	1.986607	3.753858	2.812604	1.615396	1.214495	1.944746	2.551961
S3 (31)	4.327778	2.622023	1.845026	1.726302	2.470814	3.069318	1.475359	1.305552	3.098189	1.549074	3.02238	2.164532	1.068691	1.110238	1.398369	1.835022
Downhill Step (32)	5.213667	4.171348	2.794618	2.962182	3.343152	4.076158	2.275705	1.886503	4.512503	3.96103	4.646868	2.872892	3.488734	3.289395	4.55088	5.980122
Salomon (33)	3.400633	3.295614	2.034608	2.165608	2.592878	2.868967	1.770524	1.43738	3.965074	2.879501	3.894935	2.202532	2.29635	2.094338	2.943308	4.034944
Whitley (34)	3.610844	3.788071	2.291399	2.461321	2.91934	3.012311	1.990306	1.624096	4.141167	3.135588	4.170174	2.511532	2.676757	2.177497	3.356535	4.24893
Odd Square (35)	3.514139	4.220452	2.071062	2.010062	3.043076	3.301851	1.847639	1.504023	3.636955	3.008567	3.823934	2.336913	2.492977	2.301599	2.938261	3.699933
Storn Chebyshev (36)	257.3107	262.1088	264.6655	265.8995	258.6052	260.8877	268.4207	283.6502	304.9592	298.4509	292.9311	338.1849	305.2454	320.2647	321.5281	382.4239
Rana (37)	1.804065	1.356672	2.790592	2.96627	2.446765	2.028768	3.813981	3.972093	2.746285	1.909429	3.283737	4.314399	3.022361	2.717246	3.907185	3.387306
Rosenbrock 10D (38)	4.835952	4.7276	13.67396	16.85444	7.923143	6.749569	21.36749	34.57738	21.36187	9.417116	14.45695	65.04985	18.98434	21.28579	17.77329	50.78444
Rosenbrock 30D (39)	10.70515	11.93533	31.50762	32.68089	19.88814	13.92855	54.99049	55.95695	50.44692	20.30087	64.92129	82.73742	17.45415	18.71518	19.8766	23.06443
Mod Rosenbrock 1 10D (40)	6.246331	7.537624	18.6517	19.85064	11.00123	8.881608	25.0546	33.44079	23.99293	11.52014	15.8806	64.01815	24.62549	24.3973	19.09684	59.70329
Mod Rosenbrock 1 30D (41)	15.56996	17.50936	37.46684	38.58607	28.61598	19.33222	58.14355	52.88407	53.68333	25.47722	63.2544	85.93399	18.17628	18.1822	18.45465	22.02974
Mod Rosenbrock 2 10D (42)	8.505972	10.1862	21.90803	21.62336	15.13028	12.81767	26.46376	33.99495	31.94375	19.92992	26.01409	80.76999	47.95552	46.56152	39.32717	114.8307
Mod Rosenbrock 2 30D (43)	19.2187	23.29465	40.58791	39.21351	30.89376	26.88126	61.36922	65.92637	69.40399	34.42633	129.034	142.548	92.88531	77.00947	140.492	219.5336
Spherical Contours 10D (44)	7.175074	9.590458	17.3302	17.48219	11.99978	10.30335	20.45423	35.86759	26.65451	12.66734	15.39423	57.30563	22.66998	19.79966	15.7419	48.44747
Rastrigin 10D (45)	9.296702	12.05046	17.91621	17.38412	15.68421	13.53643	24.49304	41.77034	36.29206	18.0215	23.05156	64.41852	37.14779	37.33171	27.11403	89.93584
Rastrigin 30D (46)	18.29717	22.20647	32.62054	31.56111	31.6227	25.68512	61.87595	58.33818	74.84546	37.58436	103.3455	118.2431	69.68193	65.16387	74.5571	126.387
Schwefel 10D (47)	9.051621	12.77231	16.37617	17.42819	13.54285	15.32291	33.355	35.99154	43.7817	18.97076	26.98596	84.5265	53.01527	54.36699	36.59824	108.9287
Schwefel 30D (48)	18.47298	22.27376	32.95818	34.13808	25.57886	23.66842	64.42522	62.85452	68.73315	28.65875	119.906	127.0634	86.67116	63.13901	158.5732	287.4022
Griewangk 10D (49)	8.52856	11.77787	18.01842	18.72521	11.78298	11.9753	21.74787	29.98135	28.33653	12.50051	16.79553	45.07344	19.53231	19.724	16.86928	48.1142
Griewangk 30D (50)	18.35084	20.59243	33.91431	35.05044	24.7172	20.59425	52.44084	50.78388	59.79942	26.38252	66.96462	72.23434	13.80977	14.12007	14.74965	16.96713
Salomon 10D (51)	8.542803	10.99882	17.96947	19.77559	9.704704	10.74276	22.43255	26.98225	27.03737	16.1222	17.78091	63.2267	24.63116	21.26964	19.05362	51.03555
Salomon 30D (52)	15.52208	17.81248	34.72458	37.00468	22.64604	18.3696	51.05275	43.99472	60.5074	29.56154	72.3095	79.27928	22.03259	21.97533	21.94736	27.47393
Odd Square 10D (53)	8.560091	10.4168	22.59894	21.54306	10.58045	10.88653	22.48632	25.13823	28.39022	20.26134	18.59065	63.09542	33.78817	32.72888	23.87282	78.76165
Whitley 10D (54)	15.67828	17.62821	28.5092	26.28524	19.00035	17.20272	25.35167	32.48615	33.17289	23.88716	22.62702	67.85829	28.88248	29.27771	22.4801	56.35515
Whitley 30D (55)	80.58036	82.61814	98.8676	98.67086	92.37347	82.95903	108.7623	98.11264	127.5969	94.29347	142.2202	131.2344	90.84466	88.16477	82.01653	98.11311
Rana 10D (56)	10.73233	15.14337	19.7964	21.98575	21.33315	16.82809	20.84455	31.41515	44.31701	29.2959	32.1578	77.2435	57.16989	64.38032	35.14409	120.4979
Rana 30D (57)	23.5888	27.18184	39.76545	38.00323	36.32821	30.43075	47.4308	60.85652	81.82342	43.54872	119.0306	163.6339	103.2024	77.45151	167.5479	232.4896

Average Times (s) for 500k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	1.866472	1.200015	1.49851	1.957597	1.845429	0.997644	1.221174	1.443308	1.350086	0.909935	1.914754	1.667095	1.217978	0.731059	1.113268	0.855224
McCormic (2)	1.596234	0.961292	1.357567	1.515414	1.359706	0.559002	0.910556	1.070292	0.62203	0.572082	0.865812	0.711462	0.747627	0.678562	0.692876	0.536551
Box and Betts (3)	2.702351	2.304609	2.842017	3.463622	2.310411	1.8032	2.141791	2.768426	1.86953	1.837524	2.179342	2.083403	2.193098	2.04799	2.042766	1.922394
Goldstein (4)	1.462965	0.887918	1.321163	1.600123	1.34945	0.523975	0.869426	1.114481	0.566842	0.545916	0.786378	0.731518	0.702933	0.570252	0.707388	0.631842
Easom (5)	2.048381	1.549737	1.930244	2.114166	2.106823	1.09626	1.490545	1.968889	1.577224	1.357714	1.984165	1.969757	2.204238	1.655464	2.12107	1.904868
Mod Rosenbrock 1 (6)	1.771943	1.260578	1.607178	1.74436	1.761748	0.922981	1.278862	1.642224	1.235484	0.964266	1.68308	1.558446	1.349372	0.779348	1.221746	1.058521
Mod Rosenbrock 2 (7)	1.699053	1.271691	1.55895	1.60689	1.809238	0.99377	1.268572	1.536106	1.211107	0.996024	1.50511	1.498312	1.468088	0.795103	1.236214	1.076551
Bohachevsky (8)	1.729944	1.187704	1.624632	1.546737	1.878502	0.986968	1.246557	1.456314	1.263123	1.077128	1.656549	1.542409	1.656688	1.148911	1.343584	1.157157
Powell (9)	2.816654	2.599987	3.283706	5.566516	3.079611	2.546025	2.822769	4.650123	3.553474	4.135641	4.370185	4.975007	3.599892	2.870137	3.928404	3.869669
Wood (10)	2.918105	2.623813	3.183586	5.350118	2.904651	2.380609	2.827485	4.386776	3.485095	4.63051	4.387342	5.005611	3.551427	3.05653	3.710883	3.688892
Beale (11)	1.922951	1.521302	1.723947	1.893873	1.513083	0.989162	1.454965	1.439681	1.516799	1.767902	1.879729	2.005827	1.933689	1.410704	1.56566	1.206201
Engvall (12)	2.038561	1.627902	1.82183	2.045296	1.64008	1.112948	1.562518	1.606913	1.393504	1.830198	1.963782	2.197365	1.801394	1.399268	1.535769	1.214009
DeJong (13)	1.852224	1.462074	1.620104	1.847876	1.447503	0.797663	1.249654	1.329549	0.932167	0.952129	1.222223	1.421182	0.898364	0.800074	0.776168	0.549537
Rastrigin (14)	1.856954	1.546947	1.68879	1.824182	1.457272	0.859524	1.247289	1.242263	1.202021	1.742486	1.411328	1.611329	1.613586	1.253	1.397692	1.021925
Schwefel (15)	1.851948	1.574834	1.649504	1.703114	1.483862	0.939502	1.267183	1.235489	1.453946	1.785326	1.81877	2.094636	2.035494	1.509802	1.710635	1.258073
Griewangk (16)	1.831902	1.463299	1.832168	1.717184	1.404875	0.875416	1.231102	1.225065	1.345607	1.374994	1.925259	2.053893	1.513278	1.08317	1.263027	0.942029
Ackley (17)	2.074645	1.612799	1.938848	1.841945	1.548819	1.058553	1.398775	1.366112	1.598923	1.479143	2.19388	2.169687	1.689622	1.070039	1.433488	1.107503
Langerman (18)	3.285721	3.031784	4.5236	7.244079	3.807914	2.84182	4.003971	8.266056	5.085773	5.221239	6.092171	6.927572	3.405322	2.881198	3.701863	3.751516
Michaelewicz (19)	6.528319	7.477758	10.84495	10.67284	8.036606	5.954549	12.35501	16.03136	21.09016	13.25484	13.16233	32.95431	24.34275	22.03104	16.21707	51.99385
Branin (20)	1.66675	1.325817	1.745884	1.506294	1.625028	0.737243	1.673782	1.140794	1.246705	0.80822	0.930212	0.973304	0.791062	0.724602	0.647053	0.606124
Six Hump Camel (21)	1.662738	1.229061	1.885307	1.320794	1.541959	0.707819	1.522069	1.116017	1.015713	0.834995	0.77411	0.787327	0.850156	0.797754	0.656832	0.618691
Osborne 1 (22)	5.139077	5.507185	6.617978	7.983515	5.611106	4.595186	6.777972	9.683367	7.379697	6.53637	6.082312	7.825125	5.307622	4.990712	5.349751	5.881459
Osborne 2 (23)	12.81662	14.87218	17.329	17.03955	13.45492	11.74299	19.27275	19.45654	15.51538	13.97467	13.4879	16.48342	11.53765	10.96952	11.0238	11.2196
Mod Rastrigin (24)	2.156082	2.008455	2.006819	1.936223	1.929326	1.070034	2.07853	1.820956	1.880481	1.846234	1.476745	1.334062	1.587641	1.178248	1.567706	1.297561
Mineshaft 1 (25)	1.582874	1.113263	1.272046	0.96921	1.135086	0.63664	1.023302	0.841511	0.97233	1.065689	0.754629	0.712322	0.954044	0.768706	0.886109	0.726698
Mineshaft 2 (26)	1.306534	0.767453	0.955167	0.695186	0.80976	0.358042	0.763334	0.547477	0.653465	0.764042	0.47868	0.419332	0.667965	0.449429	0.583834	0.426533
Mineshaft 3 (27)	1.863628	1.401013	1.811045	1.594967	1.372821	0.691747	1.552846	1.337103	1.414318	1.116275	1.095276	0.922996	1.178395	0.775305	1.028181	0.777807
Spherical Contours (28)	7.457137	8.729798	15.20376	13.36499	8.619498	5.97747	19.62779	20.51859	4.240456	4.509433	4.173545	4.07118	4.208201	3.519661	3.733006	4.003786
S1 (29)	1.248998	0.568619	0.595237	0.471888	0.470632	0.300232	0.648033	0.612654	0.708574	0.761977	0.489412	0.367151	0.686281	0.36254	0.398659	0.445651
S2 (30)	2.051035	1.453627	1.574699	1.42619	1.302203	0.732435	1.865214	1.899917	1.6599	1.111525	1.229226	1.005704	0.969056	0.552205	0.614903	0.679266
S3 (31)	1.870059	1.338513	1.557251	1.270508	1.113235	0.666532	1.67292	1.654555	1.095312	0.92028	0.77542	0.661925	0.865843	0.659264	0.581813	0.649839
Downhill Step (32)	2.779203	1.988098	2.31913	1.93951	1.709594	1.145628	2.573628	2.307739	2.273516	2.17645	1.736174	1.463271	2.681227	1.97623	1.907048	2.286498
Salomon (33)	2.059377	1.344842	1.594928	1.517373	1.225728	0.825233	2.120875	1.895777	1.888298	1.336263	1.314519	1.09954	1.416734	1.039696	1.017504	1.145825
Whitley (34)	2.121948	1.510143	1.745077	1.643541	1.323347	0.926911	2.325611	1.864719	2.168698	1.429325	1.464332	1.23304	1.558384	1.078251	1.12195	1.440742
Odd Square (35)	2.042027	1.48037	1.639906	1.582886	1.360702	0.886582	2.124916	1.768737	2.059086	1.415701	1.315895	1.163666	1.325703	1.181088	0.909697	1.092928
Storn Chebyshev (36)	149.5484	148.0012	145.7178	143.6409	140.9542	143.9047	149.1804	148.8429	145.3928	142.0895	143.2094	158.8928	147.4202	146.8542	145.8705	149.6886
Rana (37)	1.894079	1.385812	1.177236	1.359382	1.68574	1.927692	1.660078	1.071245	1.376418	1.382513	1.559805	2.002658	1.236451	1.030245	1.282404	1.131559
Rosenbrock 10D (38)	3.775141	4.25443	6.099252	6.996029	5.120043	5.442837	9.747126	9.758587	7.74636	5.026096	5.507486	17.3031	1.995015	1.934206	2.096942	2.337706
Rosenbrock 30D (39)	7.077858	7.813104	12.2125	13.7591	9.912008	8.181398	20.73341	15.98096	5.42755	5.383848	6.513595	7.575083	3.648009	3.469929	3.533961	4.310684
Mod Rosenbrock 1 10D (40)	4.220996	5.018986	6.786319	8.434911	5.349489	5.3811	8.961126	11.39728	7.499886	5.269892	6.387234	18.44754	2.638152	2.68986	2.992215	3.354531
Mod Rosenbrock 1 30D (41)	8.944801	9.255	13.75256	15.53193	11.6446	9.866821	20.6418	19.20473	6.204762	6.218274	7.223564	8.029398	5.594374	5.353889	5.609272	6.484468
Mod Rosenbrock 2 10D (42)	4.969994	5.720629	7.531246	9.429804	7.274896	6.933736	13.073	14.41444	15.29399	9.825766	12.69412	33.18815	16.11036	16.2393	12.62372	29.43907
Mod Rosenbrock 2 30D (43)	10.33116	11.32027	16.61422	18.41448	14.78789	12.57642	25.83009	28.80516	33.25189	18.55725	54.92019	60.05171	31.47623	27.33768	37.997	71.65585
Spherical Contours 10D (44)	3.375786	3.559563	7.274272	9.082089	5.19048	4.295366	6.722751	13.34269	8.166033	4.615673	6.163501	13.92643	1.513563	1.645276	1.682979	1.967047
Rastrigin 10D (45)	4.394631	4.604692	8.3472	8.839606	7.474275	5.867474	9.106227	15.96735	13.9377	8.448648	10.51292	24.41742	6.910117	7.103625	6.595618	11.73876
Rastrigin 30D (46)	8.752113	8.420405	15.3194	15.84074	13.58365	10.48072	19.41857	27.02475	25.19301	15.73244	28.13434	29.01731	6.931492	6.664629	7.610749	9.483885
Schwefel 10D (47)	4.474078	4.450476	8.519795	9.107939	6.578324	6.056496	8.928395	19.22972	23.08609	12.35372	12.31041	32.1929	19.52548	19.69652	17.5276	45.55407
Schwefel 30D (48)	8.627107	8.2533	16.45135	16.14958	12.63388	9.64569	22.69687	32.14722	35.12336	18.81867	52.45928	61.522	36.90792	30.31274	54.74317	88.37382
Griewangk 10D (49)	3.83207	3.642204	8.441675	7.81883	5.183553	4.183955	5.471354	13.07265	7.633027	5.842897	5.91956	12.47382	2.004901	2.210347	2.361538	1.818534
Griewangk 30D (50)	7.737152	7.191766	15.6841	14.03791	10.48767	7.834512	15.40978	20.8378	5.424911	5.864654	5.57875	5.448476	4.317668	4.57082	4.669967	4.128382
Salomon 10D (51)	3.425243	3.179768	7.936032	7.024398	4.782757	4.374273	6.157582	13.86116	9.591047	6.726597	6.283316	13.74698	2.044432	2.310487	2.367835	2.024813
Salomon 30D (52)	6.37556	6.227361	14.14926	12.30861	9.595618	7.482809	16.29703	20.11792	7.519915	7.43901	7.383379	7.564529	3.263835	3.478636	3.438617	3.268376
Odd Square 10D (53)	3.56123	3.300982	8.11797	7.655828	5.172149	4.595878	7.933715	14.56097	12.58753	8.901847	8.863954	21.69348	9.942316	10.01107	6.405781	10.91007
Whitley 10D (54)	7.053694	6.46223	11.3309	10.80854	8.084467	7.239001	11.06256	16.51056	12.17598	10.13982	8.808062	18.18565	5.368681	6.047074	5.145404	4.804946
Whitley 30D (55)	37.83284	35.72564	45.04472	43.39932	40.26792	37.18512	51.87944	50.32638	39.33665	40.0699	38.98531	40.37489	33.50159	33.93474	34.40299	30.44778
Rana 10D (56)	5.702891	5.99736	8.904395	11.31831	6.898484	9.006144	13.94697	15.11767	20.3387	15.00576	13.50773	31.02577	23.06392	24.67561	25.43714	34.46272
Rana 30D (57)	11.32806	11.62016	17.06733	19.80764	14.09311	14.77221	35.24757	29.36327	33.94885	22.12301	52.21543	69.35506	48.1159	39.15533	63.29109	88.89955

Average Times (s) for 100k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.222491	0.201104	0.192819	0.228276	0.230875	0.176298	0.220454	0.244197	0.162732	0.14506	0.128158	0.116672	0.19898	0.211741	0.107874	0.106403
McCormic (2)	0.189459	0.129639	0.169949	0.193123	0.139565	0.112521	0.128445	0.1594	0.14182	0.134647	0.11275	0.103668	0.188567	0.193098	0.105872	0.110969
Box and Betts (3)	0.396608	0.392602	0.404497	0.454514	0.395042	0.367181	0.401	0.448692	0.423836	0.399271	0.379295	0.386263	0.482505	0.478591	0.37333	0.396833
Goldstein (4)	0.185027	0.11955	0.159276	0.1774	0.129245	0.110077	0.128776	0.159081	0.143909	0.128646	0.1065	0.116201	0.184623	0.213885	0.108065	0.117645
Easom (5)	0.297702	0.248499	0.271761	0.288105	0.332854	0.265189	0.325299	0.399103	0.324184	0.292733	0.288818	0.293842	0.495597	0.509484	0.312464	0.318963
Mod Rosenbrock 1 (6)	0.232959	0.202616	0.251965	0.23236	0.211302	0.186919	0.203745	0.273072	0.166357	0.150607	0.151986	0.15019	0.184429	0.212265	0.119724	0.115155
Mod Rosenbrock 2 (7)	0.252715	0.216117	0.254413	0.230265	0.200744	0.180069	0.209528	0.273711	0.17167	0.153767	0.153289	0.154023	0.194474	0.190532	0.121513	0.117585
Bohachevsky (8)	0.261044	0.206342	0.245862	0.226423	0.202598	0.170597	0.20547	0.260657	0.168052	0.155964	0.147713	0.153595	0.233765	0.184891	0.134412	0.125538
Powell (9)	0.433266	0.414665	0.502055	0.667972	0.438088	0.380519	0.4437	0.664748	0.261687	0.26591	0.267117	0.294747	0.312519	0.269706	0.225486	0.232892
Wood (10)	0.415638	0.398595	0.487715	0.642931	0.426646	0.381263	0.402299	0.600958	0.243301	0.234682	0.240997	0.270179	0.272387	0.242	0.204731	0.216651
Beale (11)	0.27074	0.22238	0.290052	0.236361	0.261289	0.20226	0.272427	0.272308	0.188793	0.164284	0.173545	0.169975	0.235752	0.184946	0.137248	0.130024
Engvall (12)	0.291905	0.247697	0.325502	0.268172	0.276695	0.214834	0.287851	0.271477	0.204776	0.185857	0.187332	0.185794	0.272633	0.220287	0.168146	0.163104
DeJong (13)	0.246746	0.184864	0.279162	0.216485	0.207971	0.127887	0.207933	0.212214	0.146948	0.134188	0.130865	0.131255	0.218495	0.184507	0.123164	0.109176
Rastrigin (14)	0.253596	0.204518	0.292806	0.235358	0.225216	0.155419	0.222171	0.233825	0.157366	0.177472	0.136797	0.137633	0.232191	0.186513	0.134195	0.122353
Schwefel (15)	0.259201	0.228632	0.284904	0.248841	0.273152	0.222195	0.26464	0.276759	0.220668	0.182226	0.191005	0.199201	0.209815	0.201173	0.138384	0.125514
Griewangk (16)	0.242859	0.203111	0.271629	0.22557	0.221644	0.177019	0.221634	0.216998	0.159072	0.155323	0.135266	0.138869	0.17906	0.186117	0.1202	0.11107
Ackley (17)	0.304369	0.230491	0.30423	0.27295	0.261108	0.209035	0.258254	0.265074	0.198802	0.191893	0.169804	0.17015	0.200436	0.235067	0.149613	0.140416
Langerman (18)	0.509685	0.44246	0.606386	0.831586	0.397532	0.427962	0.457405	0.591165	0.281307	0.287665	0.289833	0.343661	0.322642	0.354937	0.274979	0.292967
Michaelewicz (19)	1.150589	1.22192	1.728353	1.703729	1.365984	1.231311	2.11232	2.921276	2.62065	1.943334	2.07414	4.331626	1.983061	2.026133	1.651986	2.071392
Branin (20)	0.270891	0.189211	0.285822	0.236885	0.193822	0.125085	0.219731	0.235116	0.15247	0.133673	0.128613	0.180735	0.19309	0.163224	0.125515	0.116856
Six Hump Camel (21)	0.276634	0.173136	0.285754	0.235408	0.141176	0.124002	0.180613	0.181207	0.154433	0.145685	0.140732	0.19184	0.20081	0.169669	0.135751	0.128082
Osborne 1 (22)	0.92439	0.851322	1.062586	1.173653	0.807504	0.789783	0.951152	1.112055	0.712358	0.72149	0.720278	0.899902	0.783625	0.750327	0.705133	0.716121
Osborne 2 (23)	2.266628	2.193361	2.256234	2.198852	1.99232	1.970888	2.112245	2.15802	2.061622	2.086443	2.040424	2.350036	2.372607	2.441848	2.301595	2.292616
Mod Rastrigin (24)	0.351177	0.259931	0.318462	0.287812	0.255701	0.193795	0.289295	0.293639	0.195151	0.222843	0.189286	0.264612	0.225268	0.219126	0.195349	0.180455
Mineshaft 1 (25)	0.249526	0.165107	0.17637	0.171823	0.165731	0.151257	0.180062	0.172393	0.173723	0.153097	0.162371	0.207697	0.197289	0.203177	0.174982	0.159178
Mineshaft 2 (26)	0.188442	0.098819	0.117439	0.105348	0.107614	0.091375	0.120652	0.110498	0.114302	0.090549	0.103483	0.139108	0.135311	0.149595	0.113117	0.093279
Mineshaft 3 (27)	0.304292	0.190709	0.266518	0.287514	0.233198	0.143159	0.257793	0.240171	0.222903	0.174094	0.222005	0.287101	0.393818	0.396692	0.333792	0.294097
Spherical Contours (28)	0.702349	0.654523	0.664182	0.68271	0.600228	0.596054	0.664645	0.69784	0.748352	0.688035	0.781477	0.958673	1.273577	1.277194	1.248358	1.466116
S1 (29)	0.128247	0.092048	0.104399	0.105558	0.076209	0.077691	0.08837	0.120007	0.100701	0.078992	0.091557	0.158064	0.14446	0.110624	0.097801	0.107882
S2 (30)	0.281931	0.208043	0.272552	0.277795	0.189857	0.132773	0.21959	0.278104	0.128156	0.101903	0.127835	0.203163	0.169383	0.124882	0.123195	0.134658
S3 (31)	0.237158	0.183714	0.217267	0.232367	0.137236	0.112958	0.149246	0.180434	0.121271	0.103096	0.126011	0.163154	0.177722	0.126654	0.134057	0.137211
Downhill Step (32)	0.438855	0.306335	0.388676	0.470179	0.300579	0.261546	0.352296	0.436806	0.343797	0.244693	0.353803	0.499993	0.455904	0.338905	0.400131	0.474105
Salomon (33)	0.283071	0.197999	0.249468	0.304029	0.199388	0.178457	0.202099	0.252899	0.130343	0.107395	0.13219	0.220709	0.151629	0.133396	0.123851	0.160468
Whitley (34)	0.298642	0.222844	0.269854	0.321081	0.239043	0.203368	0.23576	0.278	0.159072	0.128469	0.153487	0.244198	0.178381	0.165489	0.15865	0.185194
Odd Square (35)	0.284983	0.228168	0.253864	0.290341	0.247495	0.181557	0.230888	0.261427	0.152913	0.148299	0.147034	0.241458	0.178922	0.16633	0.150249	0.180872
Storn Chebyshev (36)	28.64887	27.66663	28.37439	28.96238	27.48999	28.73381	28.83562	27.73825	27.4583	27.46853	28.04931	28.28452	27.51723	27.57057	28.08283	28.4713
Rana (37)	0.242232	0.267284	0.316319	0.242166	0.232337	0.239082	0.261369	0.223414	0.177948	0.172261	0.240212	0.163064	0.170199	0.21101	0.182827	0.217698
Rosenbrock 10D (38)	0.429355	0.571725	0.801791	0.696626	0.279435	0.324509	0.354418	0.306905	0.305135	0.315044	0.42034	0.36033	0.399905	0.545204	0.516569	0.696634
Rosenbrock 30D (39)	0.689415	0.752973	0.75304	0.734911	0.59169	0.675813	0.71792	0.634994	0.726648	0.736415	0.898818	0.779832	1.171565	1.151093	1.192743	1.553444
Mod Rosenbrock 1 10D (40)	0.550176	0.669298	0.786445	0.842875	0.374755	0.446015	0.481614	0.425141	0.420497	0.450314	0.516198	0.460769	0.609356	0.609211	0.603286	0.729856
Mod Rosenbrock 1 30D (41)	0.999587	1.067305	1.043646	1.075183	0.977044	1.066348	1.073169	0.999236	1.105418	1.124707	1.285553	1.12994	1.550491	1.56914	1.571677	1.726493
Mod Rosenbrock 2 10D (42)	0.719903	1.086623	1.216635	1.391023	0.945455	1.062166	1.402286	1.575179	0.797192	0.835816	1.090263	1.037846	0.73708	0.861088	0.886296	0.889577
Mod Rosenbrock 2 30D (43)	1.688924	2.014203	2.751187	2.765875	2.295481	2.204876	3.344161	3.105403	1.992545	1.916737	2.597138	2.216783	2.071537	2.060698	2.173596	2.246621
Spherical Contours 10D (44)	0.384078	0.448673	0.651807	0.615878	0.279394	0.27398	0.294898	0.282721	0.300886	0.310124	0.445187	0.323735	0.420334	0.465679	0.508281	0.491453
Rastrigin 10D (45)	0.524313	0.702788	1.033462	0.936916	0.6499	0.589841	0.716709	0.712338	0.398133	0.425634	0.561547	0.448881	0.484589	0.560308	0.583799	0.570371
Rastrigin 30D (46)	1.085773	1.324932	1.66582	1.493884	0.921782	0.909952	0.937724	0.864351	0.88863	0.914844	1.045165	0.918822	1.269902	1.312228	1.441186	1.395097
Schwefel 10D (47)	0.680638	0.956613	1.444968	1.315882	1.289847	1.178247	1.657654	2.137872	1.81939	1.769211	2.233594	2.752304	0.980928	1.100561	1.296044	1.230537
Schwefel 30D (48)	1.458247	1.784977	2.803937	2.595493	2.39604	1.978536	4.090254	3.998325	4.089537	2.843404	5.057684	6.269451	2.389878	2.274636	2.970714	3.007148
Griewangk 10D (49)	0.442262	0.521452	0.68065	0.661786	0.367558	0.326809	0.347482	0.359801	0.386354	0.384027	0.483583	0.437042	0.462431	0.520719	0.661004	0.594012
Griewangk 30D (50)	0.770853	0.805646	0.833626	0.821413	0.833714	0.800828	0.775037	0.825206	0.943236	0.938313	1.038321	1.006162	1.273357	1.287598	1.552907	1.447211
Salomon 10D (51)	0.40091	0.50159	0.670255	0.732526	0.329933	0.296924	0.298937	0.338559	0.313935	0.331984	0.3657	0.396822	0.400237	0.481821	0.564435	0.48968
Salomon 30D (52)	0.680484	0.688115	0.726306	0.735217	0.629884	0.594195	0.599383	0.624847	0.726345	0.742766	0.804011	0.818246	1.04474	1.099106	1.202969	1.190089
Odd Square 10D (53)	0.515156	0.614082	0.9003	0.99315	0.692891	0.650115	0.671107	0.916994	0.582477	0.581199	0.649263	0.771546	0.584065	0.655584	0.673138	0.694858
Whitley 10D (54)	1.089554	1.140829	1.302161	1.376157	1.023809	0.99925	0.948251	1.01881	1.019456	1.007377	1.019774	1.102095	1.139339	1.165875	1.146004	1.112171
Whitley 30D (55)	6.646683	6.672179	6.790451	6.635136	6.86819	6.786864	6.454495	6.846869	6.859023	6.892638	6.759579	6.972026	7.317197	7.451221	6.756636	6.785293
Rana 10D (56)	0.906317	1.096823	1.582214	1.476863	1.52975	1.559167	1.630981	2.685022	3.280214	2.81608	2.177672	4.147165	1.78501	2.359101	1.761855	2.155014
Rana 30D (57)	1.976587	2.278849	3.241076	3.140485	3.103375	2.819849	4.573317	4.84334	6.744581	4.455587	6.219114	9.852673	4.976635	4.52803	4.032923	6.054366

APPENDIX C1: SMOA AVG. RESULTS FROM VARYING PSEUDOPODS

	2 Pseudopods								4 Pseudopods							
Results Avgs. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.000746	0.000803	0.000746	0.000746	0.000533	0.000108	0.000533	0.000533	0.000745	0.000823	0.000745	0.000745	0.000418	0.000101	0.000418	0.000418
McCormic (2)	-1.913223	-1.913223	-1.913223	-1.913223	-1.913223	-1.913223	-1.913223	-1.913223	-1.913222	-1.913223	-1.913222	-1.913222	-1.913223	-1.913104	-1.913223	-1.913223
Box and Betts (3)	1.00E-007	8.36E-008	1.14E-007	8.79E-008	2.75E-008	9.58E-008	2.86E-008	4.81E-007	4.64E-008	1.37E-008	7.31E-008	4.94E-008	1.70E-006	2.89E-006	1.46E-007	1.04E-006
Goldstein (4)	3.000031	3.000010	3.000031	3.000031	3.000001	3.000001	3.000001	3.000001	3.000027	3.000007	3.000027	3.000027	3.000002	3.117788	3.000002	3.000002
Easom (5)	-0.998389	-0.998196	-0.998389	-0.998389	-0.998352	-0.998407	-0.998352	-0.998352	-0.998668	-0.998551	-0.998668	-0.998668	-0.998537	-0.998718	-0.998537	-0.998537
Mod Rosenbrock 1 (6)	0.048577	0.045207	0.048577	0.048577	0.037858	0.012755	0.037858	0.037858	0.046288	0.043351	0.046288	0.046288	0.026019	0.012862	0.026019	0.026019
Mod Rosenbrock 2 (7)	1.097358	1.169384	1.097358	1.097358	0.879543	0.560992	0.879543	0.879543	0.966551	0.957750	0.966551	0.966551	0.815156	0.508521	0.815156	0.815156
Bohachevsky (8)	0.976784	1.002071	0.976784	0.976784	1.050037	1.006686	1.050037	1.050037	0.932698	0.836561	0.932698	0.932698	0.840690	0.808998	0.840690	0.840690
Powell (9)	158588.0	158588.0	132723.2	49874.5	128235.4	128235.4	114203.5	134103.0	123734.8	123734.8	106795.9	51130.2	94000.5	94000.5	107395.5	116428.6
Wood (10)	365867	365867	376970	110581	428581	428581	314335	361320	305435	305435	275829	130549	344476	344476	368886	332842
Beale (11)	0.540206	0.532177	0.540206	0.540206	0.484062	0.502112	0.484062	0.484062	0.46695	0.46586	0.46695	0.46695	0.48339	0.50412	0.48339	0.48339
Engvall (12)	0.803660	0.839270	0.803660	0.803660	0.750272	0.695224	0.750272	0.750272	0.614762	0.690427	0.614762	0.614762	0.684279	0.701363	0.684279	0.684279
DeJong (13)	6.06E-006	6.21E-006	6.06E-006	6.06E-006	4.05E-007	8.65E-008	4.05E-007	4.05E-007	4.16E-006	4.16E-006	4.16E-006	4.16E-006	3.86E-007	7.94E-008	3.86E-007	3.86E-007
Rastrigin (14)	0.002215	0.001857	0.002215	0.002215	0.031143	0.240600	0.031143	0.031143	0.002035	0.001537	0.002035	0.002035	0.017510	0.186775	0.017510	0.017510
Schwefel (15)	-837.938	-837.9145	-837.938	-837.938	-837.945	-837.9442	-837.945	-837.945	-837.9542	-837.9514	-837.9542	-837.9542	-837.9501	-837.94	-837.9501	-837.9501
Griewangk (16)	0.005891	0.006565	0.005891	0.005891	0.005458	0.006134	0.005458	0.005458	0.004799	0.004890	0.004799	0.004799	0.005185	0.005365	0.005185	0.005185
Ackley (17)	0.023155	0.023960	0.023155	0.023155	0.020408	0.009098	0.020408	0.020408	0.025240	0.024851	0.025240	0.025240	0.018771	0.008703	0.018771	0.018771
Langerman (18)	-1.492546	-1.492856	-1.493387	-1.494733	-1.490389	-1.491217	-1.491747	-1.49215	-1.494785	-1.495192	-1.495289	-1.494236	-1.492137	-1.491989	-1.492661	-1.492251
Michaelewicz (19)	-7.059541	-7.708027	-7.466392	-7.453501	-6.989918	-7.630765	-7.891652	-7.232019	-6.960669	-7.589251	-7.383973	-7.375397	-6.851436	-7.470301	-7.772708	-7.220339
Branin (20)	0.397892	0.397891	0.397892	0.397892	0.397888	0.397887	0.397888	0.397888	0.397894	0.397891	0.397894	0.397894	0.397888	0.398608	0.397888	0.397888
Six Hump Camel (21)	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.031255	-1.031628	-1.031628
Osborne 1 (22)	0.048009	0.047243	0.044601	0.028059	0.051425	0.050657	0.049735	0.048726	0.036664	0.038446	0.035156	0.029259	0.060455	0.056869	0.060857	0.049059
Osborne 2 (23)	0.125416	0.119760	0.118848	0.128820	0.145431	0.145742	0.127053	0.153083	0.112276	0.110473	0.117362	0.120988	0.138465	0.139526	0.140423	0.138048
Mod Rastrigin (24)	83.96563	83.96497	83.96563	83.96563	83.70780	84.77496	83.70780	83.70780	83.71421	83.47038	83.71421	83.71421	83.57777	83.83720	83.57777	83.57777
Mineshaft 1 (25)	1.905487	1.781436	1.848615	1.781436	1.751920	2.184158	1.898839	2.184158	1.901967	1.802648	1.821990	1.802648	1.753886	2.260338	2.008789	2.260338
Mineshaft 2 (26)	-1.416345	-1.363086	-1.413702	-1.363086	-1.408801	-1.287394	-1.350723	-1.287394	-1.416353	-1.329394	-1.409819	-1.329394	-1.402798	-1.260248	-1.343398	-1.260248
Mineshaft 3 (27)	-6.953914	-6.899922	-6.953914	-6.953914	-6.999935	-6.968199	-6.999935	-6.999935	-6.961112	-6.939497	-6.961112	-6.961112	-6.999838	-6.999953	-6.999838	-6.999838
Spherical Contours (28)	29.07889	29.82400	19.43234	19.43234	29.56055	29.56893	29.67321	29.63210	25.51745	25.86380	20.61168	20.61168	32.91937	32.91937	32.91937	32.91937
S1 (29)	4.6E-013	2.1E-003	4.3E-010	2.1E-003	9.4E-012	1.5E-004	3.8E-005	1.5E-004	2.4E-013	1.8E-003	1.4E-014	1.8E-003	1.9E-005	1.9E-004	6.3E-005	1.9E-004
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.529251	0.528872	0.528872
Downhill Step (32)	9	9	9	9	9	9	9	9	9	9	9	9	9.004	9.007	9.004	9.004
Salomon (33)	0.017542	0.020399	0.017542	0.017542	0.017259	0.016963	0.017259	0.017259	0.014462	0.014410	0.014462	0.014462	0.014538	0.015343	0.014538	0.014538
Whitley (34)	0.024437	0.031039	0.024437	0.024437	0.020170	0.020640	0.020170	0.020170	0.020963	0.022790	0.020963	0.020963	0.014601	0.019334	0.014601	0.014601
Odd Square (35)	-1.007722	-1.007739	-1.007722	-1.007722	-1.007904	-0.892729	-1.007904	-1.007904	-1.007732	-1.007881	-1.007732	-1.007732	-1.007896	-0.924333	-1.007896	-1.007896
Storn Chebyshev (36)	73.58076	50.54949	85.79940	34.28370	81.59889	67.38653	71.57312	72.87019	41.64896	33.55829	40.69228	35.09064	68.67818	74.45823	39.29214	76.31025
Rana (37)	-1023.415	-1023.415	-1023.415	-1023.415	-1022.616	-1023.415	-1022.616	-1022.616	-1023.415	-1023.415	-1023.415	-1023.415	-1020.171	-1022.625	-1020.171	-1020.171
Rosenbrock 10D (38)	1321.147	1252.111	936.219	914.454	1194.791	1127.372	1201.664	1148.586	918.473	908.296	758.054	765.790	966.247	964.267	969.603	963.150
Rosenbrock 30D (39)	492829.9	532270.4	180323.2	180323.2	539264.8	507325.2	232461.1	481169.6	243498.0	257539.1	152364.5	152364.5	507104.4	507104.4	507104.4	507104.4
Mod Rosenbrock 1 10D (40)	942.8080	964.7519	804.2179	790.7743	912.3338	869.8050	879.0835	862.2462	815.4511	821.5456	727.4187	732.7990	829.0225	827.0791	824.3680	820.5442
Mod Rosenbrock 1 30D (41)	21999.17	23340.52	16154.22	16154.22	22891.91	22726.58	21655.45	22888.99	20015.51	21010.57	16666.07	16666.07	25223.52	25223.52	25223.52	25223.52
Mod Rosenbrock 2 10D (42)	0.989492	1.013479	1.045149	1.085769	1.038960	0.987808	1.058465	1.031557	0.921417	0.974508	0.930034	0.906341	0.945938	0.959603	1.049785	1.030054
Mod Rosenbrock 2 30D (43)	1.061295	0.975171	1.020693	1.020693	1.084960	1.029615	0.999817	1.022551	0.964574	0.984480	0.889847	0.889847	0.955648	0.979206	0.924147	0.972271
Spherical Contours 10D (44)	0.797900	0.800119	0.639728	0.644233	0.760882	0.758168	0.723708	0.704292	0.659596	0.653158	0.611763	0.592002	0.652335	0.648402	0.641868	0.653789
Rastrigin 10D (45)	36.5146	35.2733	29.8290	30.4277	35.1926	35.7955	34.8989	33.1628	35.2817	33.5514	29.6772	29.5242	35.1669	35.2360	33.9454	34.2750
Rastrigin 30D (46)	279.7351	265.0001	226.7321	226.7321	270.5668	269.2079	256.9177	247.3701	263.3152	257.1323	226.6286	226.6286	284.4632	280.9447	283.6631	282.9993
Schwefel 10D (47)	-3099.814	-3111.844	-3037.525	-3043.45	-3128.147	-3165.062	-3168.145	-3024.357	-3145.666	-3176.385	-3060.352	-3028.696	-3086.941	-3135.233	-3126.807	-3034.924
Schwefel 30D (48)	-5563.344	-5610.806	-5763.022	-5763.022	-5555.061	-5657.823	-5648.103	-5593.323	-5744.664	-5802.026	-5823.25	-5823.25	-5624.162	-5645.662	-5682.928	-5682.403
Griewangk 10D (49)	1.732396	1.711577	1.579375	1.630563	1.690691	1.696513	1.679318	1.652663	1.600331	1.599541	1.543983	1.532638	1.636706	1.637095	1.632175	1.638385
Griewangk 30D (50)	22.86912	23.64039	16.16083	16.16083	23.49005	23.49154	22.30716	22.74228	20.26185	20.80651	17.05823	17.05823	25.84642	25.84642	25.84642	25.84642
Salomon 10D (51)	1.184472	1.196544	0.994493	1.039233	1.176447	1.132498	1.132432	1.139692	1.128432	1.113801	1.002543	1.024406	1.118864	1.122935	1.107598	1.119890
Salomon 30D (52)	5.850305	5.958257	4.602459	4.602459	5.793019	5.939699	5.087056	5.759671	5.119277	5.239006	4.486788	4.486788	5.993618	5.994326	5.994326	5.991170
Odd Square 10D (53)	-0.46867	-0.51170	-0.56933	-0.57901	-0.48416	-0.49953	-0.52477	-0.54046	-0.53820	-0.54247	-0.57701	-0.58726	-0.53214	-0.53114	-0.53615	-0.53131
Whitley 10D (54)	11249090	10814078	6913993	6367803	9040435	9997516	10122918	9715800	5669948	6026607	12174393	124197945	6592230	6670173	7088700	6734376
Whitley 30D (55)	4.73E+12	5.17E+12	5.38E+11	5.38E+11	8.27E+12	5.77E+12	1.42E+12	4.51E+12	9.99E+11	1.06E+12	4.19E+11	4.19E+11	3.66E+12	4.42E+12	3.18E+12	4.98E+12
Rana 10D (56)	-3311.852	-3276.976	-3414.964	-3369.441	-3270.618	-3338.642	-3368.18	-3268.936	-3345.691	-3342.71	-3432.056	-3443.285	-3298.693	-3361.153	-3396.926	-3358.599
Rana 30D (57)	-5656.143	-5639.391	-5688.901	-5688.901	-5540.291	-5575.206	-5687.771	-5601.711	-5726.055	-5719.839	-5763.075	-5763.075	-5565.468	-5620.874	-5642.249	-5655.733

	6 Pseudopods								8 Pseudopods							
Results Avgs. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.00052	0.000584	0.00052	0.00052	0.00033	9.87E-05	0.00033	0.00033	0.0007	0.000647	0.0007	0.0007	0.000418	0.000101	0.000418	0.000418
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322
Box and Betts (3)	1.71E-08	6.96E-09	3.82E-08	3.14E-08	5.39E-07	5.54E-07	5.73E-08	7.14E-08	9.08E-09	2.77E-08	2.58E-08	2.26E-08	1.31E-06	2.67E-06	5.08E-07	5.36E-07
Goldstein (4)	3.000022	3.000007	3.000022	3.000022	3.000012	3.028328	3.000012	3.000012	3.000023	3.000006	3.000023	3.000023	3.01109	3.146093	3.01109	3.01109
Easom (5)	-0.99869	-0.99879	-0.99869	-0.99869	-0.99838	-0.99885	-0.99838	-0.99838	-0.99881	-0.99888	-0.99881	-0.99881	-0.99912	-0.99877	-0.99912	-0.99912
Mod Rosenbrock 1 (6)	0.036572	0.036833	0.036572	0.036572	0.027617	0.0137	0.027617	0.027617	0.038093	0.03586	0.038093	0.038093	0.032809	0.01333	0.032809	0.032809
Mod Rosenbrock 2 (7)	1.003476	0.925015	1.003476	1.003476	0.740061	0.547084	0.740061	0.740061	0.95881	0.887243	0.95881	0.95881	0.82944	0.53468	0.82944	0.82944
Bohachevsky (8)	0.832892	0.836256	0.832892	0.832892	0.83422	0.810058	0.83422	0.83422	0.814972	0.869549	0.814972	0.814972	0.833451	0.810515	0.833451	0.833451
Powell (9)	97968.86	97968.86	83321.81	65936.5	107239.7	107239.7	115204.1	111136.9	77009.89	77009.89	79818.22	47211.02	141121.7	141121.7	132129.5	123492.6
Wood (10)	267264.2	267264.2	263958.8	94173.49	336466	336466	385478.4	373294.6	221445.7	221445.7	187539.8	111429.8	355593.6	355593.6	366463.8	358783.8
Beale (11)	0.416814	0.426425	0.416814	0.416814	0.500507	3.616479	0.500507	0.500507	0.429547	0.505053	0.429547	0.429547	1.123001	1.126309	1.123001	1.123001
Engvall (12)	0.827544	0.729811	0.827544	0.827544	0.533503	0.600098	0.533503	0.533503	0.815406	0.629086	0.815406	0.815406	0.770021	0.831856	0.770021	0.770021
DeJong (13)	5.37E-06	4.14E-06	5.37E-06	5.37E-06	3.71E-07	1.32E-07	3.71E-07	3.71E-07	5.55E-06	4.33E-06	5.55E-06	5.55E-06	3.89E-07	0.004203	3.89E-07	3.89E-07
Rastrigin (14)	0.001525	0.00129	0.001525	0.001525	0.080145	0.258657	0.080145	0.080145	0.001372	0.001202	0.001372	0.001372	0.148842	0.327283	0.148842	0.148842
Schwefel (15)	-837.957	-837.954	-837.957	-837.957	-837.948	-837.944	-837.948	-837.948	-837.959	-837.956	-837.959	-837.959	-837.936	-837.937	-837.936	-837.936
Griewangk (16)	0.004908	0.00484	0.004908	0.004908	0.004761	0.005172	0.004761	0.004761	0.0051	0.005414	0.0051	0.0051	0.004926	0.004588	0.004926	0.004926
Ackley (17)	0.024437	0.024653	0.024437	0.024437	0.018694	0.009555	0.018694	0.018694	0.022531	0.02287	0.022531	0.022531	0.018769	0.010077	0.018769	0.018769
Langerman (18)	-1.49544	-1.49563	-1.49547	-1.49275	-1.49252	-1.4919	-1.4921	-1.49186	-1.4957	-1.49569	-1.4957	-1.49432	-1.49248	-1.49254	-1.49248	-1.49241
Michaelewicz (19)	-6.98496	-7.46951	-7.46779	-7.44205	-6.84013	-7.17195	-7.57543	-7.10636	-7.0226	-7.40186	-7.38961	-7.39346	-6.81734	-7.10772	-7.57158	-7.00512
Branin (20)	0.397894	0.397891	0.397894	0.397894	0.397888	0.397887	0.397888	0.397888	0.397893	0.397891	0.397893	0.397893	0.397888	0.397888	0.397888	0.397888
Six Hump Camel (21)	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03161	-1.03163	-1.03163
Osborne 1 (22)	0.035599	0.033849	0.032654	0.029671	0.04765	0.046421	0.04665	0.04812	0.032429	0.030702	0.030754	0.028998	0.057328	0.054735	0.055986	0.055183
Osborne 2 (23)	0.107381	0.105048	0.115118	0.146811	0.142157	0.141897	0.141788	0.142091	0.102217	0.100577	0.11539	0.113061	0.139016	0.139016	0.139016	0.139016
Mod Rastrigin (24)	83.49366	83.31685	83.49366	83.49366	84.5416	83.85822	84.5416	84.5416	83.38929	83.15927	83.38929	83.38929	84.92201	84.5887	84.92201	84.92201
Mineshaft 1 (25)	1.879581	1.839534	1.829247	1.839534	1.769375	2.267463	1.996163	2.267463	1.877037	1.860348	1.826955	1.860348	1.804206	2.303124	2.061332	2.303124
Mineshaft 2 (26)	-1.41635	-1.31279	-1.41615	-1.31279	-1.39701	-1.2461	-1.30548	-1.2461	-1.41635	-1.31654	-1.41158	-1.31654	-1.38615	-1.23825	-1.29037	-1.23825
Mineshaft 3 (27)	-6.97305	-6.96076	-6.97305	-6.97305	-6.99992	-6.91806	-6.99992	-6.99992	-6.98213	-6.94559	-6.98213	-6.98213	-6.99987	-6.91423	-6.99987	-6.99987
Spherical Contours (28)	24.73366	24.97351	20.81183	20.81183	34.42596	34.42596	34.42596	34.42596	23.48613	23.58975	20.54741	20.54741	36.12602	36.12602	36.12602	36.12602
S1 (29)	1.9E-13	0.002383	1.42E-14	0.002383	1.97E-05	0.000188	9.02E-05	0.000188	3.54E-13	0.002106	3.22E-14	0.002106	4.57E-12	0.000202	0.000133	0.000202
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872
Downhill Step (32)	9	9	9	9	9.003	9.001	9.003	9.003	9	9	9	9	9.014	9.031	9.014	9.014
Salomon (33)	0.013337	0.013714	0.013337	0.013337	0.011792	0.01369	0.011792	0.011792	0.01229	0.013373	0.01229	0.01229	0.013635	0.013822	0.013635	0.013635
Whitley (34)	0.024521	0.020639	0.024521	0.024521	0.017847	0.019449	0.017847	0.017847	0.020652	0.018401	0.020652	0.020652	0.032669	0.021439	0.032669	0.032669
Odd Square (35)	-1.00778	-1.0079	-1.00778	-1.00778	-1.00757	-0.92339	-1.00757	-1.00757	-1.00795	-1.00792	-1.00795	-1.00795	-1.00774	-0.9201	-1.00774	-1.00774
Storn Chebyshev (36)	36.42944	34.88056	21.70438	93.81863	55.44238	63.19262	77.86615	52.99467	39.20754	35.29816	371.4084	678.0744	50.43014	48.22754	52.15175	49.07183
Rana (37)	-1023.42	-1023.42	-1023.42	-1023.42	-1018.65	-1018.65	-1018.65	-1018.65	-1023.42	-1023.42	-1023.42	-1023.42	-1020.24	-1020.24	-1020.24	-1020.24
Rosenbrock 10D (38)	837.328	875.0127	766.7405	789.5009	1047.726	1047.726	1047.726	1047.726	827.8318	811.1385	773.7085	740.0816	1015.069	1015.069	1015.069	1015.069
Rosenbrock 30D (39)	163406.9	172960.8	134069.7	134069.7	455803.8	455803.8	455803.8	455803.8	143526.6	145293.4	121546.3	121546.3	397981.7	397981.7	397981.7	397981.7
Mod Rosenbrock 1 10D (40)	714.8458	716.438	689.2557	679.2117	789.1436	789.1436	789.1436	789.1436	716.5231	671.0672	667.0397	683.3132	750.9103	750.9103	750.9103	750.9103
Mod Rosenbrock 1 30D (41)	19297.7	19716.22	16631.23	16631.23	26057.84	26057.84	26057.84	26057.84	19089.56	19497.21	17169.7	17169.7	27449.86	27449.86	27449.86	27449.86
Mod Rosenbrock 2 10D (42)	0.933899	0.911117	0.889412	0.948173	0.886908	1.006211	0.991374	0.914106	0.904328	0.810474	0.908214	0.924455	1.021801	1.063872	1.027047	1.055781
Mod Rosenbrock 2 30D (43)	0.964366	0.941883	0.909385	0.909385	0.93866	0.971439	0.984582	1.033932	0.98834	0.892147	0.895235	0.895235	0.916632	0.97493	0.885015	0.960558
Spherical Contours 10D (44)	0.595229	0.585464	0.52675	0.559891	0.616104	0.616104	0.616104	0.616104	0.517872	0.539313	0.507394	0.495694	0.590077	0.590077	0.590077	0.590077
Rastrigin 10D (45)	33.73248	33.27009	29.13231	28.88086	35.85995	35.22537	35.18826	34.89146	32.72753	32.26159	30.51222	30.3931	35.70919	36.26282	35.55772	35.62909
Rastrigin 30D (46)	254.5633	252.0682	223.4216	223.4216	291.4678	293.998	292.668	293.8597	252.4749	249.1816	228.5265	228.5265	298.3384	297.0667	296.3533	297.0902
Schwefel 10D (47)	-3132.08	-3163.41	-3017.42	-3042.68	-3047.43	-3063.31	-3085.98	-3030.49	-3145.27	-3139.33	-2970.17	-3006.08	-3051.67	-3083.37	-3084.27	-3063.72
Schwefel 30D (48)	-5777.05	-5821.31	-5861.64	-5861.64	-5680.04	-5695.96	-5722.45	-5741.11	-5764.9	-5809.33	-5856.98	-5856.98	-5749.1	-5750.25	-5773.83	-5749.43
Griewangk 10D (49)	1.532012	1.535519	1.492024	1.504817	1.58746	1.58746	1.58746	1.58746	1.508687	1.507982	1.478378	1.486784	1.575111	1.575111	1.575111	1.575111
Griewangk 30D (50)	19.56835	20.11405	16.98857	16.98857	26.90051	26.90051	26.90051	26.90051	18.73365	19.09671	17.72758	17.72758	27.99057	27.99057	27.99057	27.99057
Salomon 10D (51)	1.109227	1.069618	1.002211	1.006526	1.141641	1.141641	1.141641	1.141641	1.072069	1.058003	1.031087	1.026598	1.153702	1.153702	1.153702	1.153702
Salomon 30D (52)	4.932784	5.013448	4.492466	4.492466	6.003439	6.003439	6.003439	6.003439	4.765251	4.763544	4.545818	4.545818	6.095562	6.095562	6.095562	6.095562
Odd Square 10D (53)	-0.55321	-0.54811	-0.58535	-0.58389	-0.53527	-0.53113	-0.52998	-0.53323	-0.55971	-0.55413	-0.56825	-0.58758	-0.52681	-0.52986	-0.5309	-0.53482
Whitley 10D (54)	5852138	6397833	5309705	4771349	7206785	7206785	7411196	7370934	6366102	4849191	5385531	5364177	8118920	8118920	8118920	8118920
Whitley 30D (55)	6.5E+11	7.34E+11	3.8E+11	3.8E+11	3.85E+12	3.88E+12	3.87E+12	3.85E+12	6.44E+11	6.54E+11	4.06E+11	4.06E+11	4.68E+12	4.68E+12	4.68E+12	4.65E+12
Rana 10D (56)	-3367.93	-3363.46	-3411.94	-3414.97	-3330.7	-3342.01	-3350	-3343.76	-3390.53	-3388.36	-3413.55	-3395.45	-3351.29	-3355.07	-3365.57	-3361.55
Rana 30D (57)	-5754.2	-5736.36	-5714.54	-5714.54	-5616.85	-5641.12	-5722.63	-5702.61	-5765.99	-5754.83	-5778.15	-5778.15	-5696.72	-5715.05	-5686.48	-5768.91

					10 Pseudopods			
Results Avgs. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.0005173	0.0005796	0.0005173	0.0005173	0.0004784	0.000135	0.0004784	0.0004784
McCormic (2)	-1.913222	-1.913223	-1.913222	-1.913222	-1.913223	-1.913174	-1.913223	-1.913223
Box and Betts (3)	3.02E-007	6.80E-008	2.22E-008	1.82E-008	1.70E-006	2.60E-006	7.19E-007	1.89E-007
Goldstein (4)	3.0000212	3.0000061	3.0000212	3.0000212	3.021183	3.2877212	3.021183	3.021183
Easom (5)	-0.99893	-0.99876	-0.99893	-0.99893	-0.998631	-0.998654	-0.998631	-0.998631
Mod Rosenbrock 1 (6)	0.039484	0.0392951	0.039484	0.039484	0.031345	0.0136327	0.031345	0.031345
Mod Rosenbrock 2 (7)	0.8886352	0.9388832	0.8886352	0.8886352	0.8436484	0.5849233	0.8436484	0.8436484
Bohachevsky (8)	0.8375542	0.8939457	0.8375542	0.8375542	0.8516058	0.8539168	0.8516058	0.8516058
Powell (9)	76567.049	76567.049	71014.659	45928.479	118063.75	118063.75	118474.82	112571.83
Wood (10)	201400.42	201400.42	186187.8	123009.71	403469.86	403469.86	403105.12	396081.04
Beale (11)	0.4042946	0.5063336	0.4042946	0.4042946	0.6446515	0.6277064	0.6446515	0.6446515
Engvall (12)	0.6818518	0.6714933	0.6818518	0.6818518	0.7055988	0.7151354	0.7055988	0.7055988
DeJong (13)	4.92E-006	3.73E-006	4.92E-006	4.92E-006	5.36E-007	2.06E-007	5.36E-007	5.36E-007
Rastrigin (14)	0.0009993	0.0010605	0.0009993	0.0009993	0.1688059	0.3065616	0.1688059	0.1688059
Schwefel (15)	-837.9586	-837.9576	-837.9586	-837.9586	-837.9389	-837.9435	-837.9389	-837.9389
Griewangk (16)	0.0047848	0.0049647	0.0047848	0.0047848	0.0048087	0.0047536	0.0048087	0.0048087
Ackley (17)	0.0210264	0.022563	0.0210264	0.0210264	0.0205172	0.0106471	0.0205172	0.0205172
Langerman (18)	-1.495844	-1.495767	-1.495892	-1.494948	-1.490861	-1.490782	-1.490815	-1.490743
Michaelewicz (19)	-6.951505	-7.37319	-7.400179	-7.371684	-6.716209	-6.836357	-7.204594	-6.815297
Branin (20)	0.3978938	0.3978903	0.3978938	0.3978938	0.3978878	0.3978875	0.3978878	0.3978878
Six Hump Camel (21)	-1.031628	-1.031628	-1.031628	-1.031628	-1.031628	-1.030488	-1.031628	-1.031628
Osborne 1 (22)	0.0308825	0.030226	0.0299776	0.0285964	0.0496613	0.0495464	0.0482054	0.0483372
Osborne 2 (23)	0.1024268	0.1010214	0.1105587	0.1159103	0.1472314	0.1472314	0.1472314	0.1472314
Mod Rastrigin (24)	83.302921	83.469887	83.302921	83.302921	85.058089	84.870976	85.058089	85.058089
Mineshaft 1 (25)	1.87631	1.8518492	1.8378123	1.8518492	1.7850446	2.2976931	2.0899637	2.2976931
Mineshaft 2 (26)	-1.416353	-1.312604	-1.411884	-1.312604	-1.390517	-1.234492	-1.276869	-1.234492
Mineshaft 3 (27)	-6.984874	-6.96863	-6.984874	-6.984874	-6.999941	-6.999941	-6.999941	-6.999941
Spherical Contours (28)	23.297244	23.134779	21.363141	21.363141	37.141543	37.141543	37.141543	37.141543
S1 (29)	3.39E-013	0.0064042	1.41E-014	0.0064042	1.55E-005	0.0002023	0.0001182	0.0002023
S2 (30)	2	2	2	2	2	2	2	2
S3 (31)	0.5288723	0.5288723	0.5288723	0.5288723	0.5288723	0.5288926	0.5288723	0.5288723
Downhill Step (32)	9	9	9	9	9.017	9.028	9.017	9.017
Salomon (33)	0.0111416	0.0135295	0.0111416	0.0111416	0.0131991	0.0130009	0.0131991	0.0131991
Whitley (34)	0.0157282	0.0170988	0.0157282	0.0157282	0.0202845	0.0164709	0.0202845	0.0202845
Odd Square (35)	-1.007856	-1.00791	-1.007856	-1.007856	-1.00767	-0.900818	-1.00767	-1.00767
Storn Chebyshev (36)	43.897955	35.045745	44.983149	52.04174	58.047556	58.192231	58.192231	58.192231
Rana (37)	-1023.415	-1023.415	-1023.415	-1023.415	-1018.69	-1018.69	-1018.69	-1018.69
Rosenbrock 10D (38)	840.52	859.90229	750.36333	787.38753	1000.9787	1000.9787	1000.9787	1000.9787
Rosenbrock 30D (39)	129249.64	134346.69	121367.14	121367.14	382962.88	382962.88	382962.88	382962.88
Mod Rosenbrock 1 10D (40)	690.12406	679.38593	661.12815	674.36462	761.50618	761.50618	761.50618	761.50618
Mod Rosenbrock 1 30D (41)	18365.336	18492.402	17388.935	17388.935	28137.731	28137.731	28137.731	28137.731
Mod Rosenbrock 2 10D (42)	0.9731461	0.928161	0.8815683	0.9139779	0.9046704	0.9303185	0.9236981	0.8991565
Mod Rosenbrock 2 30D (43)	0.9677003	0.8908388	0.9755474	0.9755474	1.0000904	0.9837482	0.9894645	0.9577823
Spherical Contours 10D (44)	0.4942146	0.5066767	0.4882896	0.4885515	0.5836408	0.5836408	0.5836408	0.5836408
Rastrigin 10D (45)	32.706796	32.87367	29.904197	29.641127	37.279442	37.32679	37.376148	37.327742
Rastrigin 30D (46)	250.32011	246.38267	229.28576	229.28576	299.52098	299.72756	299.63223	299.51757
Schwefel 10D (47)	-3150.598	-3157.397	-3033.731	-3025.83	-3028.596	-3044.003	-3053.772	-3031.061
Schwefel 30D (48)	-5808.899	-5856.398	-5871.401	-5871.401	-5781.794	-5718.376	-5728.893	-5730.517
Griewangk 10D (49)	1.4937351	1.4740899	1.4523469	1.477656	1.5515463	1.5515463	1.5515463	1.5515463
Griewangk 30D (50)	18.671223	18.427207	17.301573	17.301573	29.707615	29.707615	29.707615	29.707615
Salomon 10D (51)	1.0631545	1.07975	1.0174733	1.0210911	1.1931783	1.1931783	1.1931783	1.1931783
Salomon 30D (52)	4.7224267	4.7065711	4.5112812	4.5112812	6.3227755	6.3227755	6.3227755	6.3227755
Odd Square 10D (53)	-0.571977	-0.559348	-0.590199	-0.584652	-0.51955	-0.520373	-0.52032	-0.521002
Whitley 10D (54)	5641993.4	5423974.4	4969907.8	5418845.4	7977932.3	7977932.3	7977932.3	7977932.3
Whitley 30D (55)	5.713E+11	6.053E+11	7.09E+11	7.09E+11	7.84E+12	7.84E+12	7.84E+12	7.84E+12
Rana 10D (56)	-3392.982	-3414.131	-3393.954	-3391.886	-3376.711	-3356.652	-3377.814	-3361.737
Rana 30D (57)	-5785.587	-5751.792	-5770.707	-5770.707	-5780.67	-5696.714	-5797.546	-5728.21

APPENDIX C2: SMOA ST. DEV. FROM VARYING PSEUDOPODS

	2 Pseudopods								4 Pseudopods							
Result St. Dev. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.000676	0.000934	0.000676	0.000676	0.000576	9.85E-05	0.000576	0.000576	0.000756	0.001021	0.000756	0.000756	0.000404	0.000108	0.000404	0.000404
McCormic (2)	4.93E-07	1.07E-07	4.93E-07	4.93E-07	2.28E-08	6.56E-09	2.28E-08	2.28E-08	4.66E-07	8.89E-08	4.66E-07	4.66E-07	5.44E-08	0.001188	5.44E-08	5.44E-08
Box and Betts (3)	2.13E-07	2.21E-07	2.4E-07	1.28E-07	7.44E-08	3.62E-07	5.35E-08	3.83E-06	7.51E-08	1.43E-08	1.32E-07	7.31E-08	8.32E-06	1.43E-05	8.57E-07	8.76E-06
Goldstein (4)	3.97E-05	1.48E-05	3.97E-05	3.97E-05	1.49E-06	8.91E-07	1.49E-06	1.49E-06	3.86E-05	1.08E-05	3.86E-05	3.86E-05	1.77E-06	1.005553	1.77E-06	1.77E-06
Easom (5)	0.001749	0.001831	0.001749	0.001749	0.001603	0.001778	0.001603	0.001603	0.001258	0.001637	0.001258	0.001258	0.001751	0.00137	0.001751	0.001751
Mod Rosenbrock 1 (6)	0.031106	0.027639	0.031106	0.031106	0.028678	0.009606	0.028678	0.028678	0.033548	0.028089	0.033548	0.033548	0.018788	0.008379	0.018788	0.018788
Mod Rosenbrock 2 (7)	0.464721	0.463746	0.464721	0.464721	0.378425	0.244553	0.378425	0.378425	0.416064	0.426825	0.416064	0.416064	0.357422	0.237959	0.357422	0.357422
Bohachevsky (8)	0.409327	0.521391	0.409327	0.409327	0.462078	0.531533	0.462078	0.462078	0.42704	0.357941	0.42704	0.42704	0.389954	0.408339	0.389954	0.389954
Powell (9)	109538.6	109538.6	89532.19	37113.15	89736.52	89736.52	86755.39	97564.32	91484.43	91484.43	78868.13	45732.83	65463.17	65463.17	79997.6	70285.27
Wood (10)	286574.2	286574.2	236193.1	89198.32	305294.8	305294.8	249454.3	275587.7	201482	201482	184856.5	415946.2	201674.7	201674.7	273360	284447.3
Beale (11)	0.406413	0.419898	0.406413	0.406413	0.35279	0.334807	0.35279	0.35279	0.285671	0.350993	0.285671	0.285671	0.335294	0.3808	0.335294	0.335294
Engvall (12)	0.904003	0.865229	0.904003	0.904003	0.653837	0.634302	0.653837	0.653837	0.549128	0.623921	0.549128	0.549128	0.767395	0.811597	0.767395	0.767395
DeJong (13)	6.16E-06	7.91E-06	6.16E-06	6.16E-06	3.88E-07	9.12E-08	3.88E-07	3.88E-07	4.43E-06	4.6E-06	4.43E-06	4.43E-06	3.26E-07	7.46E-08	3.26E-07	3.26E-07
Rastrigin (14)	0.002122	0.001737	0.002122	0.002122	0.144413	0.373901	0.144413	0.144413	0.002195	0.00149	0.002195	0.002195	0.12018	0.383604	0.12018	0.12018
Schwefel (15)	0.092446	0.256005	0.092446	0.092446	0.029665	0.030789	0.029665	0.029665	0.016682	0.023531	0.016682	0.016682	0.019167	0.036806	0.019167	0.019167
Griewangk (16)	0.00352	0.003229	0.00352	0.00352	0.003208	0.003797	0.003208	0.003208	0.003311	0.003194	0.003311	0.003311	0.003087	0.003252	0.003087	0.003087
Ackley (17)	0.012889	0.012563	0.012889	0.012889	0.011695	0.00545	0.011695	0.011695	0.01416	0.015134	0.01416	0.01416	0.010653	0.004841	0.010653	0.010653
Langerman (18)	0.004674	0.003939	0.004193	0.005134	0.010764	0.005081	0.004225	0.003956	0.002913	0.002456	0.002467	0.012533	0.003899	0.003867	0.003693	0.004393
Michaelewicz (19)	0.492367	0.467599	0.43502	0.417172	0.53078	0.583361	0.49319	0.316875	0.437932	0.555375	0.4145	0.390654	0.353638	0.620254	0.547244	0.358615
Branin (20)	5.04E-06	4.01E-06	5.04E-06	5.04E-06	3.22E-07	6.97E-08	3.22E-07	3.22E-07	7.93E-06	4.05E-06	7.93E-06	7.93E-06	4.35E-07	0.00717	4.35E-07	4.35E-07
Six Hump Camel (21)	1.12E-06	1.67E-07	1.12E-06	1.12E-06	2.13E-08	6.3E-08	2.13E-08	2.13E-08	1.1E-06	1.44E-07	1.1E-06	1.1E-06	2.65E-08	0.003717	2.65E-08	2.65E-08
Osborne 1 (22)	0.015299	0.017579	0.017967	0.007094	0.013673	0.025481	0.014333	0.01647	0.011156	0.010547	0.008841	0.011812	0.094278	0.09423	0.095241	0.022001
Osborne 2 (23)	0.025836	0.025827	0.025874	0.029693	0.025985	0.043256	0.031859	0.028937	0.018444	0.018518	0.03167	0.031689	0.025696	0.0248	0.025815	0.026482
Mod Rastrigin (24)	1.590035	1.802845	1.590035	1.590035	2.573057	3.107199	2.573057	2.573057	1.693458	1.482639	1.693458	1.693458	2.092007	2.748719	2.092007	2.092007
Mineshaft 1 (25)	0.170673	0.225052	0.153474	0.225052	0.105963	0.255857	0.272843	0.255857	0.159467	0.235351	0.143134	0.235351	0.113537	0.189193	0.283163	0.189193
Mineshaft 2 (26)	5.49E-05	0.137838	0.02638	0.137838	0.047244	0.157746	0.137595	0.157746	1.76E-06	0.165565	0.047463	0.165565	0.064847	0.165665	0.146946	0.165665
Mineshaft 3 (27)	0.119854	0.361295	0.119854	0.119854	8.96E-05	0.222664	8.96E-05	8.96E-05	0.141163	0.237394	0.141163	0.141163	0.001113	0.000172	0.001113	0.001113
Spherical Contours (28)	3.085225	3.211577	1.951988	1.951988	2.585239	3.833221	3.884347	2.842374	2.138468	2.401463	1.945076	1.945076	3.510566	3.510566	3.510566	3.510566
S1 (29)	9.33E-13	0.009938	4.28E-09	0.009938	8.62E-11	0.000466	0.000226	0.000466	4.78E-13	0.009055	3.47E-14	0.009055	0.000186	0.000497	0.000244	0.000497
S2 (30)	6.46E-11	2.74E-11	6.46E-11	6.46E-11	2.6E-12	7.68E-13	2.6E-12	2.6E-12	3.18E-11	4.28E-11	3.18E-11	3.18E-11	2.81E-12	7.33E-13	2.81E-12	2.81E-12
S3 (31)	8.73E-10	9.64E-10	8.73E-10	8.73E-10	8.02E-11	9.41E-11	8.02E-11	8.02E-11	2.43E-10	2.85E-10	2.43E-10	2.43E-10	1.05E-10	0.003772	1.05E-10	1.05E-10
Downhill Step (32)	0	0	0	0	0	0	0	0	0	0	0	0	0.024166	0.069649	0.024166	0.024166
Salomon (33)	0.018708	0.017867	0.018708	0.018708	0.016213	0.013404	0.016213	0.016213	0.015735	0.012631	0.015735	0.015735	0.01366	0.016193	0.01366	0.01366
Whitley (34)	0.036349	0.038786	0.036349	0.036349	0.028776	0.031312	0.028776	0.028776	0.042911	0.037759	0.042911	0.042911	0.025024	0.029495	0.025024	0.025024
Odd Square (35)	0.00053	0.000475	0.00053	0.00053	0.000462	0.114552	0.000462	0.000462	0.000475	0.000405	0.000475	0.000475	0.000455	0.09857	0.000455	0.000455
Storn Chebyshev (36)	93.38422	54.55309	284.8063	86.10771	85.62888	77.9938	77.80163	83.74903	46.44464	52.01753	61.51036	41.67516	229.7484	235.4666	49.52442	229.6639
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	7.954947	1.71E-12	7.954947	7.954947	1.71E-12	1.71E-12	1.71E-12	1.71E-12	18.83067	7.867985	18.83067	18.83067
Rosenbrock 10D (38)	515.1277	440.8547	345.7136	349.036	431.5342	453.5287	385.7465	367.2506	283.1568	326.7291	277.5191	303.365	316.9756	317.6501	328.489	319.0554
Rosenbrock 30D (39)	126351.7	126393.3	39746.12	39746.12	129813.5	122509.3	101087.4	96357.64	49290.32	53501.86	62496.98	62496.98	134491.9	134491.9	134491.9	134491.9
Mod Rosenbrock 1 10D (40)	175.5213	174.1725	158.3237	136.4247	175.6966	180.9816	164.5291	172.1662	172.0327	152.6001	126.9216	131.6014	146.625	148.68	150.0513	149.4953
Mod Rosenbrock 1 30D (41)	2523.447	2652.203	1896.267	1896.267	2149.326	2373.869	3152.417	2297.763	1872.757	1895.906	2150.75	2150.75	2485.18	2485.18	2485.18	2485.18
Mod Rosenbrock 2 10D (42)	0.398094	0.43686	0.513916	0.728649	0.498817	0.458317	0.454953	0.451403	0.378009	0.441916	0.428236	0.389858	0.45863	0.410275	0.436822	0.448681
Mod Rosenbrock 2 30D (43)	0.460521	0.420485	0.459122	0.459122	0.502113	0.405338	0.415119	0.434567	0.408267	0.409574	0.460398	0.460398	0.46405	0.445902	0.448234	0.445116
Spherical Contours 10D (44)	0.191265	0.202644	0.158768	0.15634	0.171902	0.175383	0.183075	0.176693	0.161016	0.156973	0.125477	0.134335	0.192281	0.19339	0.191203	0.192029
Rastrigin 10D (45)	4.605166	4.598585	3.55826	3.823445	5.56356	3.802429	4.1554	4.804282	4.212124	4.410785	3.93059	4.800373	4.029398	3.998342	4.1198	4.606105
Rastrigin 30D (46)	14.54749	17.39869	12.04483	12.04483	16.11625	14.07054	13.13982	15.93621	14.2301	15.88953	11.06821	11.06821	16.73687	16.14214	22.57886	16.5837
Schwefel 10D (47)	171.5034	173.1943	265.7669	241.8503	182.2372	186.7756	188.1842	154.9784	166.8363	154.4088	263.3138	267.9654	155.8784	165.5839	185.6357	190.0388
Schwefel 30D (48)	318.3029	337.168	317.9548	317.9548	308.3505	311.989	396.9133	270.6475	332.0435	319.3247	401.8298	401.8298	268.9492	258.3261	323.4649	300.0566
Griewangk 10D (49)	0.193595	0.163881	0.143445	0.157596	0.16286	0.161107	0.151997	0.153402	0.155881	0.161348	0.130199	0.168696	0.15083	0.148991	0.145054	0.146857
Griewangk 30D (50)	2.248641	2.343898	1.530079	1.530079	2.37969	2.417635	3.112545	2.613705	1.88182	2.093944	2.093175	2.093175	2.63062	2.63062	2.63062	2.63062
Salomon 10D (51)	0.144754	0.137656	0.137023	0.19024	0.13533	0.16727	0.149631	0.137567	0.132549	0.125566	0.138015	0.120635	0.153391	0.146276	0.151146	0.153905
Salomon 30D (52)	0.340667	0.352223	0.364051	0.364051	0.324749	0.323332	0.42872	0.369098	0.293693	0.292423	0.233612	0.233612	0.470059	0.470668	0.470668	0.470226
Odd Square 10D (53)	0.061883	0.037324	0.063683	0.069292	0.054685	0.056188	0.041342	0.037963	0.020814	0.035905	0.067289	0.075562	0.03386	0.033071	0.020078	0.039486
Whitley 10D (54)	9217926	8611525	5094333	9935661	7303094	8651315	7220366	10428174	4767272	4824064	77893541	1.11E+09	5297034	5377713	5627969	5357754
Whitley 30D (55)	2.76E+12	2.7E+12	2.78E+11	2.78E+11	2.12E+13	2.68E+12	1.72E+12	3.01E+12	3.9E+11	3.97E+11	2.77E+11	2.77E+11	2.41E+12	5.3E+12	1.9E+12	1.49E+13
Rana 10D (56)	181.9308	163.804	262.5225	240.1076	209.0901	204.6739	178.199	183.98	178.0522	174.5713	237.4377	252.0443	175.886	211.2059	210.0231	199.835
Rana 30D (57)	298.48	312.049	285.8617	285.8617	296.8297	313.3769	321.4487	291.234	329.4383	305.9996	291.5624	291.5624	312.3976	298.984	309.4131	312.1622

	6 Pseudopods								8 Pseudopods							
Result St. Dev. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.000477	0.000499	0.000477	0.000477	0.000314	9.76E-05	0.000314	0.000314	0.000651	0.000621	0.000651	0.000651	0.000477	8.75E-05	0.000477	0.000477
McCormic (2)	4.01E-07	1.19E-07	4.01E-07	4.01E-07	2.9E-08	4.3E-08	2.9E-08	2.9E-08	5.18E-07	6.8E-08	5.18E-07	5.18E-07	3.22E-08	1.04E-07	3.22E-08	3.22E-08
Box and Betts (3)	1.3E-08	7.55E-09	3.9E-08	2.41E-08	2.78E-06	2.71E-06	2.01E-07	3.71E-07	6.88E-09	1.66E-07	2.11E-08	1.88E-08	1.01E-05	9.14E-06	3.12E-06	4.89E-06
Goldstein (4)	2.93E-05	9.73E-06	2.93E-05	2.93E-05	8.89E-05	0.281832	8.89E-05	8.89E-05	2.86E-05	8.57E-06	2.86E-05	2.86E-05	0.110297	1.030355	0.110297	0.110297
Easom (5)	0.001306	0.001116	0.001306	0.001306	0.001666	0.001066	0.001666	0.001666	0.001141	0.001095	0.001141	0.001141	0.000923	0.001242	0.000923	0.000923
Mod Rosenbrock 1 (6)	0.026058	0.026221	0.026058	0.026058	0.018444	0.008466	0.018444	0.018444	0.0256	0.028709	0.0256	0.0256	0.024769	0.009902	0.024769	0.024769
Mod Rosenbrock 2 (7)	0.383217	0.383061	0.383217	0.383217	0.363881	0.242844	0.363881	0.363881	0.355928	0.361219	0.355928	0.355928	0.380518	0.218694	0.380518	0.380518
Bohachevsky (8)	0.330963	0.498554	0.330963	0.330963	0.426235	0.411378	0.426235	0.426235	0.377457	0.387767	0.377457	0.377457	0.394679	0.389179	0.394679	0.394679
Powell (9)	68642.56	68642.56	57750.06	135362.9	57222.44	57222.44	76022.25	70141.41	51297.62	51297.62	60212.86	38575.75	159551.1	159551.1	156116.8	155442.3
Wood (10)	195626	195626	189620.6	62725.16	286069.5	286069.5	476274	484105.5	175532.8	175532.8	130196.3	106798	259072.5	259072.5	260538	221847.3
Beale (11)	0.254337	0.351579	0.254337	0.254337	0.325323	31.08813	0.325323	0.325323	0.271635	0.348476	0.271635	0.271635	5.815088	5.813925	5.815088	5.815088
Engvall (12)	0.77024	0.751971	0.77024	0.77024	0.472365	0.570896	0.472365	0.472365	0.737057	0.606877	0.737057	0.737057	0.675371	0.722011	0.675371	0.675371
DeJong (13)	5.25E-06	4.04E-06	5.25E-06	5.25E-06	3.95E-07	1.33E-07	3.95E-07	3.95E-07	5.11E-06	3.99E-06	5.11E-06	5.11E-06	3.58E-07	0.041822	3.58E-07	3.58E-07
Rastrigin (14)	0.001439	0.001448	0.001439	0.001439	0.269432	0.4166	0.269432	0.269432	0.001503	0.001104	0.001503	0.001503	0.296292	0.410021	0.296292	0.296292
Schwefel (15)	0.009727	0.018198	0.009727	0.009727	0.018603	0.02214	0.018603	0.018603	0.007806	0.016386	0.007806	0.007806	0.071989	0.072638	0.071989	0.071989
Griewangk (16)	0.002976	0.00306	0.002976	0.002976	0.003066	0.00301	0.003066	0.003066	0.003397	0.003254	0.003397	0.003397	0.003118	0.00311	0.003118	0.003118
Ackley (17)	0.012865	0.013915	0.012865	0.012865	0.011728	0.005007	0.011728	0.011728	0.012042	0.013762	0.012042	0.012042	0.010744	0.005652	0.010744	0.010744
Langerman (18)	0.002371	0.002074	0.00198	0.016625	0.003451	0.004105	0.004098	0.003838	0.001946	0.001922	0.002085	0.004663	0.004056	0.003853	0.003957	0.00407
Michaelewicz (19)	0.386663	0.454494	0.45698	0.371184	0.411908	0.505577	0.469593	0.392169	0.345717	0.481132	0.383931	0.376314	0.416168	0.52143	0.542056	0.422366
Branin (20)	7.21E-06	4.2E-06	7.21E-06	7.21E-06	3.28E-07	1.21E-07	3.28E-07	3.28E-07	6.63E-06	4.36E-06	6.63E-06	6.63E-06	4.03E-07	2.58E-07	4.03E-07	4.03E-07
Six Hump Camel (21)	8.33E-07	1.24E-07	8.33E-07	8.33E-07	2.91E-08	2.21E-08	2.91E-08	2.91E-08	8.03E-07	1.45E-07	8.03E-07	8.03E-07	8.37E-08	0.000144	8.37E-08	8.37E-08
Osborne 1 (22)	0.008368	0.008295	0.007782	0.016863	0.012861	0.013075	0.015774	0.012853	0.008256	0.00749	0.007944	0.009579	0.039012	0.036709	0.03837	0.037613
Osborne 2 (23)	0.015654	0.017142	0.0389	0.263546	0.030277	0.030354	0.030232	0.030205	0.014726	0.017361	0.023631	0.020972	0.025387	0.025387	0.025387	0.025387
Mod Rastrigin (24)	1.482184	1.496115	1.482184	1.482184	2.08543	2.590458	2.08543	2.08543	1.38132	1.548125	1.38132	1.38132	1.821629	3.110957	1.821629	1.821629
Mineshaft 1 (25)	0.12711	0.257795	0.151419	0.257795	0.134149	0.175943	0.279082	0.175943	0.112738	0.259325	0.148753	0.259325	0.168324	0.11076	0.276449	0.11076
Mineshaft 2 (26)	6.12E-07	0.172906	0.001961	0.172906	0.079374	0.165885	0.157246	0.165885	7.57E-06	0.173355	0.03253	0.173355	0.091121	0.16571	0.1655	0.16571
Mineshaft 3 (27)	0.101832	0.231627	0.101832	0.101832	0.000173	0.67388	0.000173	0.000173	0.042346	0.273137	0.042346	0.042346	0.000641	0.710313	0.000641	0.000641
Spherical Contours (28)	2.059187	2.291026	2.612207	2.612207	4.451847	4.451847	4.451847	4.451847	2.124828	2.229298	2.130672	2.130672	3.914744	3.914744	3.914744	3.914744
S1 (29)	3.84E-13	0.010702	3.46E-14	0.010702	0.000196	0.000481	0.000388	0.000481	9.27E-13	0.00932	1.78E-13	0.00932	3.99E-11	0.000495	0.000489	0.000495
S2 (30)	3.63E-11	3.17E-11	3.63E-11	3.63E-11	1.94E-12	1.18E-12	1.94E-12	1.94E-12	1.64E-11	2.18E-11	1.64E-11	1.64E-11	3.54E-12	1.69E-12	3.54E-12	3.54E-12
S3 (31)	2.44E-10	2.34E-10	2.44E-10	2.44E-10	6.12E-10	2.48E-10	6.12E-10	6.12E-10	5.44E-10	8.4E-11	5.44E-10	5.44E-10	2.08E-10	5.8E-10	2.08E-10	2.08E-10
Downhill Step (32)	0	0	0	0	0.02985	0.00995	0.02985	0.02985	0	0	0	0	0.066363	0.13015	0.066363	0.066363
Salomon (33)	0.009768	0.010897	0.009768	0.009768	0.010356	0.014515	0.010356	0.010356	0.010483	0.01151	0.010483	0.010483	0.011806	0.014694	0.011806	0.011806
Whitley (34)	0.035068	0.039705	0.035068	0.035068	0.024662	0.028972	0.024662	0.024662	0.034224	0.0349	0.034224	0.034224	0.104903	0.033382	0.104903	0.104903
Odd Square (35)	0.000409	0.00037	0.000409	0.000409	0.002961	0.104014	0.002961	0.002961	0.000323	0.000349	0.000323	0.000323	0.000653	0.111222	0.000653	0.000653
Storn Chebyshev (36)	50.98642	48.61196	29.5567	558.8741	60.52867	119.2471	125.8908	113.4141	54.49689	46.19512	3429.689	4540.439	60.95829	58.38702	64.00124	58.27107
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	23.05228	23.05228	23.05228	23.05228	1.71E-12	1.71E-12	1.71E-12	1.71E-12	19.43584	19.43584	19.43584	19.43584
Rosenbrock 10D (38)	288.8195	293.8818	271.4301	255.9148	861.1501	861.1501	861.1501	861.1501	304.382	330.2357	312.3893	338.8835	296.0388	296.0388	296.0388	296.0388
Rosenbrock 30D (39)	30980.6	34031.83	29157.56	29157.56	159781.2	159781.2	159781.2	159781.2	30381.64	27742.23	27632.51	27632.51	105485.4	105485.4	105485.4	105485.4
Mod Rosenbrock 1 10D (40)	129.6183	117.3043	136.7653	123.523	142.2414	142.2414	142.2414	142.2414	122.3809	107.2956	119.5945	110.8816	148.6686	148.6686	148.6686	148.6686
Mod Rosenbrock 1 30D (41)	1810.004	1710.047	2266.272	2266.272	2801.432	2801.432	2801.432	2801.432	1753.871	1890.726	1877.441	1877.441	3497.551	3497.551	3497.551	3497.551
Mod Rosenbrock 2 10D (42)	0.442556	0.385151	0.414388	0.438653	0.385006	0.426878	0.397738	0.391033	0.375557	0.365572	0.409534	0.416271	0.415667	0.409772	0.416037	0.39913
Mod Rosenbrock 2 30D (43)	0.423492	0.423003	0.383938	0.383938	0.397022	0.415169	0.409843	0.48637	0.410001	0.374509	0.394813	0.394813	0.423166	0.383593	0.378988	0.407935
Spherical Contours 10D (44)	0.129034	0.142318	0.126448	0.122632	0.169289	0.169289	0.169289	0.169289	0.12816	0.127456	0.113294	0.106398	0.145502	0.145502	0.145502	0.145502
Rastrigin 10D (45)	4.507704	4.234401	4.000986	4.309104	4.189393	4.690121	4.441388	4.754692	4.081303	4.268086	4.329525	4.692818	4.881629	4.772054	4.46905	4.576261
Rastrigin 30D (46)	12.97026	13.27768	12.60938	12.60938	20.03501	20.77978	22.38132	19.98641	11.23109	14.36893	11.03695	11.03695	23.02852	23.94202	23.65142	23.60875
Schwefel 10D (47)	161.8896	165.6454	238.2617	229.5972	134.1966	140.9542	147.8947	122.9543	147.0932	169.8255	251.34	245.8802	133.6169	139.8635	129.7212	140.5738
Schwefel 30D (48)	319.2533	310.5616	412.9138	412.9138	263.2894	233.8696	320.9512	282.5086	309.0499	321.9451	331.4032	331.4032	255.6909	260.3115	320.5529	282.8452
Griewangk 10D (49)	0.132623	0.154188	0.109274	0.12556	0.160803	0.160803	0.160803	0.160803	0.118364	0.113254	0.107795	0.111281	0.130659	0.130659	0.130659	0.130659
Griewangk 30D (50)	2.124338	2.013304	1.555804	1.555804	4.326053	4.326053	4.326053	4.326053	1.771035	1.714039	2.051888	2.051888	3.089392	3.089392	3.089392	3.089392
Salomon 10D (51)	0.128834	0.133065	0.162416	0.129637	0.140682	0.140682	0.140682	0.140682	0.112656	0.110092	0.118289	0.113183	0.138507	0.138507	0.138507	0.138507
Salomon 30D (52)	0.267767	0.270382	0.249255	0.249255	0.320849	0.320849	0.320849	0.320849	0.282069	0.277335	0.306674	0.306674	0.344437	0.344437	0.344437	0.344437
Odd Square 10D (53)	0.04958	0.041355	0.07766	0.07094	0.034471	0.011129	0.02135	0.037854	0.054681	0.049637	0.065189	0.072821	0.02166	0.011181	0.027106	0.026829
Whitley 10D (54)	4807668	4716056	3571662	4292858	5894926	5894926	6068556	5980297	5200292	3638663	3798269	3845555	7522755	7522755	7522755	7522755
Whitley 30D (55)	2.57E+11	2.94E+11	1.94E+11	1.94E+11	2.66E+12	2.64E+12	2.64E+12	2.64E+12	2.46E+11	2.46E+11	1.82E+11	1.82E+11	4.71E+12	4.71E+12	4.71E+12	4.71E+12
Rana 10D (56)	172.8861	194.1819	262.0402	218.7177	197.2557	189.7728	177.2461	168.0939	181.306	194.3324	236.2313	205.5457	176.6516	187.6133	171.3326	155.6038
Rana 30D (57)	292.3238	350.8557	305.3723	305.3723	294.6873	276.1683	289.0724	311.091	303.3703	305.6399	304.1649	304.1649	250.7982	255.2943	260.2904	299.2578

				10 Pseudopods				
Result St. Dev. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.000471	0.000594	0.000471	0.000471	0.000552	0.000172	0.000552	0.000552
McCormic (2)	5.92E-07	6.93E-08	5.92E-07	5.92E-07	3.34E-08	0.000484	3.34E-08	3.34E-08
Box and Betts (3)	2.89E-06	3.45E-07	1.59E-08	1.41E-08	7.62E-06	1.12E-05	3.34E-06	8.07E-07
Goldstein (4)	2.49E-05	5.88E-06	2.49E-05	2.49E-05	0.210725	1.7616	0.210725	0.210725
Easom (5)	0.000934	0.001356	0.000934	0.000934	0.001309	0.001421	0.001309	0.001309
Mod Rosenbrock 1 (6)	0.02586	0.026869	0.02586	0.02586	0.021009	0.008658	0.021009	0.021009
Mod Rosenbrock 2 (7)	0.414455	0.39552	0.414455	0.414455	0.325964	0.300508	0.325964	0.325964
Bohachevsky (8)	0.391537	0.379622	0.391537	0.391537	0.323693	0.325521	0.323693	0.323693
Powell (9)	50785.77	50785.77	50928.29	31757.97	74006.1	74006.1	74021.62	73158.23
Wood (10)	138484.2	138484.2	139250.7	132909.9	389649.1	389649.1	383439.6	384667.3
Beale (11)	0.269944	0.382042	0.269944	0.269944	0.572009	0.504469	0.572009	0.572009
Engvall (12)	0.624774	0.56145	0.624774	0.624774	0.67679	0.67707	0.67679	0.67679
DeJong (13)	4.55E-06	3.64E-06	4.55E-06	4.55E-06	5.09E-07	2E-07	5.09E-07	5.09E-07
Rastrigin (14)	0.000898	0.000938	0.000898	0.000898	0.301363	0.424627	0.301363	0.301363
Schwefel (15)	0.008387	0.008967	0.008387	0.008387	0.048736	0.034437	0.048736	0.048736
Griewangk (16)	0.002945	0.003119	0.002945	0.002945	0.003112	0.003048	0.003112	0.003112
Ackley (17)	0.01286	0.011742	0.01286	0.01286	0.010011	0.005992	0.010011	0.010011
Langerman (18)	0.002194	0.002199	0.001631	0.002983	0.014655	0.014687	0.014646	0.014677
Michaelewicz (19)	0.31883	0.426673	0.445843	0.347047	0.384977	0.497245	0.54146	0.383701
Branin (20)	5.93E-06	3.11E-06	5.93E-06	5.93E-06	4.86E-07	1.8E-07	4.86E-07	4.86E-07
Six Hump Camel (21)	1.06E-06	2.05E-07	1.06E-06	1.06E-06	5.42E-08	0.010464	5.42E-08	5.42E-08
Osborne 1 (22)	0.007457	0.008354	0.007322	0.008166	0.029483	0.029085	0.020044	0.020263
Osborne 2 (23)	0.015037	0.016776	0.021259	0.021745	0.026777	0.026777	0.026777	0.026777
Mod Rastrigin (24)	1.408835	1.463579	1.408835	1.408835	1.765085	2.590538	1.765085	1.765085
Mineshaft 1 (25)	0.12033	0.256444	0.157707	0.256444	0.125875	0.122861	0.267806	0.122861
Mineshaft 2 (26)	6.13E-07	0.174262	0.03765	0.174262	0.089942	0.162722	0.168111	0.162722
Mineshaft 3 (27)	0.043886	0.198855	0.043886	0.043886	6.97E-05	0.000143	6.97E-05	6.97E-05
Spherical Contours (28)	2.216066	2.406677	2.543593	2.543593	3.071966	3.071966	3.071966	3.071966
S1 (29)	9.91E-13	0.033802	2.83E-14	0.033802	0.000131	0.000495	0.000471	0.000495
S2 (30)	2.93E-11	2.97E-11	2.93E-11	2.93E-11	2.23E-12	1.6E-12	2.23E-12	2.23E-12
S3 (31)	2.66E-10	1.11E-10	2.66E-10	2.66E-10	6.67E-10	0.000194	6.67E-10	6.67E-10
Downhill Step (32)	0	0	0	0	0.064892	0.105906	0.064892	0.064892
Salomon (33)	0.009388	0.013461	0.009388	0.009388	0.010129	0.011302	0.010129	0.010129
Whitley (34)	0.030812	0.024382	0.030812	0.030812	0.029209	0.025517	0.029209	0.029209
Odd Square (35)	0.00034	0.000344	0.00034	0.00034	0.000594	0.11311	0.000594	0.000594
Storn Chebyshev (36)	52.69176	47.90423	109.9014	115.5886	85.43672	85.42391	85.42391	85.42391
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	21.44097	21.44097	21.44097	21.44097
Rosenbrock 10D (38)	310.3719	287.5006	275.9039	263.4484	343.4386	343.4386	343.4386	343.4386
Rosenbrock 30D (39)	20436.51	21665.49	29241.37	29241.37	88405.76	88405.76	88405.76	88405.76
Mod Rosenbrock 1 10D (40)	113.4953	105.6971	128.2219	137.0013	148.6025	148.6025	148.6025	148.6025
Mod Rosenbrock 1 30D (41)	2019.024	2009.756	1878.183	1878.183	2906.613	2906.613	2906.613	2906.613
Mod Rosenbrock 2 10D (42)	0.436776	0.338221	0.379541	0.40212	0.400697	0.406313	0.409342	0.400208
Mod Rosenbrock 2 30D (43)	0.3939	0.369174	0.389296	0.389296	0.420238	0.432723	0.419845	0.433057
Spherical Contours 10D (44)	0.126383	0.138639	0.128108	0.140767	0.147573	0.147573	0.147573	0.147573
Rastrigin 10D (45)	3.828726	4.427177	4.019498	4.597968	4.061239	4.115608	4.111863	4.107151
Rastrigin 30D (46)	12.40516	12.54119	11.44259	11.44259	14.28009	14.34087	14.51643	14.19616
Schwefel 10D (47)	198.0844	194.0897	260.5126	259.1012	137.1414	151.3654	149.6903	144.0855
Schwefel 30D (48)	292.0999	291.8634	363.545	363.545	274.9801	230.6737	258.6574	231.1468
Griewangk 10D (49)	0.117618	0.105535	0.106485	0.102087	0.129957	0.129957	0.129957	0.129957
Griewangk 30D (50)	1.799744	1.992991	1.79589	1.79589	3.278212	3.278212	3.278212	3.278212
Salomon 10D (51)	0.124715	0.134333	0.113734	0.13587	0.119309	0.119309	0.119309	0.119309
Salomon 30D (52)	0.249284	0.244432	0.263811	0.263811	0.645282	0.645282	0.645282	0.645282
Odd Square 10D (53)	0.066425	0.052018	0.07686	0.06971	0.04822	0.04673	0.046711	0.046696
Whitley 10D (54)	3848213	4862680	4037592	4712612	6745201	6745201	6745201	6745201
Whitley 30D (55)	3.01E+11	2.32E+11	2.87E+12	2.87E+12	3.44E+13	3.44E+13	3.44E+13	3.44E+13
Rana 10D (56)	177.1926	181.4633	222.3315	249.0385	187.519	173.4844	192.4755	185.3861
Rana 30D (57)	362.3248	302.0619	409.6435	409.6435	332.979	317.4231	317.7074	322.9576

APPENDIX C3: SMOA RUNTIMES FROM VARYING PSEUDOPODS

	2 Pseudopods								4 Pseudopods							
Avg. Times (s) for 500k	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	5.20245	3.960997	5.031517	4.872248	4.903975	2.758121	4.372063	4.973358	1.866472	1.200015	1.49851	1.957597	1.217978	0.731059	1.113268	0.855224
McCormic (2)	3.050171	2.834111	3.300365	3.285669	1.503948	1.828719	1.567208	1.70335	1.596234	0.961292	1.357567	1.515414	0.747627	0.678562	0.692876	0.536551
Box and Betts (3)	4.330867	3.82197	5.334856	6.511325	2.638008	2.851771	2.694788	2.716444	2.702351	2.304609	2.842017	3.463622	2.193098	2.04799	2.042766	1.922394
Goldstein (4)	4.014047	2.473897	3.933652	4.002789	1.355452	1.08192	1.235547	1.401594	1.462965	0.887918	1.321163	1.600123	0.702933	0.570252	0.707388	0.631842
Easom (5)	5.922388	4.983411	5.6607	6.226407	6.124929	4.310349	5.908689	5.654006	2.048381	1.549737	1.930244	2.114166	2.204238	1.655464	2.12107	1.904868
Mod Rosenbrock 1 (6)	5.087222	3.907559	4.594458	4.820351	4.797031	2.690131	4.713909	4.821015	1.771943	1.260578	1.607178	1.74436	1.349372	0.779348	1.221746	1.058521
Mod Rosenbrock 2 (7)	4.837563	4.171961	4.942218	4.883151	4.637554	2.688949	4.358501	4.390661	1.699053	1.271691	1.55895	1.60689	1.468088	0.795103	1.236214	1.076551
Bohachevsky (8)	4.492124	3.927926	4.5055	4.683122	4.691118	3.276034	5.029503	4.616385	1.729944	1.187704	1.624632	1.546737	1.656688	1.148911	1.343584	1.157157
Powell (9)	7.101969	7.358908	9.033829	15.33319	12.06454	11.75792	18.53848	18.35632	2.816654	2.599987	3.283706	5.566516	3.599892	2.870137	3.928404	3.869669
Wood (10)	7.246996	7.216668	9.382266	15.3438	11.74633	12.32285	18.17775	19.02986	2.918105	2.623813	3.183586	5.350118	3.551427	3.05653	3.710883	3.688892
Beale (11)	4.726416	3.934975	5.408944	5.061954	5.250705	3.6927	5.29989	5.270127	1.922951	1.521302	1.723947	1.893873	1.933689	1.410704	1.56566	1.206201
Engvall (12)	4.888281	3.550682	5.091535	4.856754	5.066156	3.711163	4.67787	4.831756	2.038561	1.627902	1.82183	2.045296	1.801394	1.399268	1.535769	1.214009
DeJong (13)	4.817983	3.687671	5.002466	4.880847	2.203064	1.701366	2.198486	2.170625	1.852224	1.462074	1.620104	1.847876	0.898364	0.800074	0.776168	0.549537
Rastrigin (14)	4.907255	4.094633	5.154855	4.816893	5.133976	3.672849	5.312819	5.012999	1.856954	1.546947	1.68879	1.824182	1.613586	1.253	1.397692	1.021925
Schwefel (15)	4.642737	3.750722	4.844448	4.140746	5.385357	4.555561	4.961295	5.364343	1.851948	1.574834	1.649504	1.703114	2.035494	1.509802	1.710635	1.258073
Griewangk (16)	4.650735	3.365567	4.371633	4.399574	4.72735	3.534249	4.308216	4.187692	1.831902	1.463299	1.832168	1.717184	1.513278	1.08317	1.263027	0.942029
Ackley (17)	4.716731	4.074659	4.543295	4.14211	5.087421	3.561147	4.538044	4.574301	2.074645	1.612799	1.938848	1.841945	1.689622	1.070039	1.433488	1.107503
Langerman (18)	7.510887	7.700744	10.87812	15.20686	13.9124	16.44459	19.05693	20.92622	3.285721	3.031784	4.5236	7.244079	3.405322	2.881198	3.701863	3.751516
Michaelewicz (19)	11.93671	14.97084	19.71456	19.08332	56.41422	54.61998	37.52826	118.5602	6.528319	7.477758	10.84495	10.67284	24.34275	22.03104	16.21707	51.99385
Branin (20)	3.874055	3.080177	3.297119	3.547617	1.711111	1.493938	1.721267	0.572759	1.66675	1.325817	1.745884	1.506294	0.791062	0.724602	0.647053	0.606124
Six Hump Camel (21)	3.738432	2.840343	3.196399	3.36224	1.320607	1.517346	1.405283	0.501498	1.662738	1.229061	1.885307	1.320794	0.850156	0.797754	0.656832	0.618691
Osborne 1 (22)	8.50025	9.239131	11.7177	16.45213	12.22394	14.02219	16.26755	8.775248	5.139077	5.507185	6.617978	7.983515	5.307622	4.990712	5.349751	5.881459
Osborne 2 (23)	16.01239	19.96421	26.58179	24.63948	28.94049	31.36679	25.77323	30.9026	12.81662	14.87218	17.329	17.03955	11.53765	10.96952	11.0238	11.2196
Mod Rastrigin (24)	4.175936	3.055548	3.854931	2.592563	3.316135	2.092752	3.227346	1.579019	2.156082	2.008455	2.006819	1.936223	1.587641	1.178248	1.567706	1.297561
Mineshaft 1 (25)	2.784638	1.485196	1.893818	1.041133	1.186401	0.999495	1.091571	0.574563	1.582874	1.113263	1.272046	0.96921	0.954044	0.768706	0.886109	0.726698
Mineshaft 2 (26)	2.427391	1.289414	1.377272	0.766133	0.921859	0.688828	0.813942	0.323923	1.306534	0.767453	0.955167	0.695186	0.667965	0.449429	0.583834	0.426533
Mineshaft 3 (27)	3.21348	2.561198	2.656639	2.172313	1.902954	1.159405	1.845032	0.819486	1.863628	1.401013	1.811045	1.594967	1.178395	0.775305	1.028181	0.777807
Spherical Contours (28)	12.44302	16.3549	23.66679	24.34307	11.6751	11.97533	13.25694	11.79489	7.457137	8.729798	15.20376	13.36499	4.208201	3.519661	3.733006	4.003786
S1 (29)	1.904417	1.144386	0.83804	0.794771	0.652526	0.845133	0.612569	0.298061	1.248998	0.568619	0.595237	0.471888	0.686281	0.36254	0.398659	0.445651
S2 (30)	3.452092	2.840989	2.589975	2.223185	1.466956	1.10632	1.427301	0.71522	2.051035	1.453627	1.574699	1.42619	0.969056	0.552205	0.614903	0.679266
S3 (31)	3.136684	2.462228	2.392343	1.800243	0.912569	0.957841	0.887231	0.464084	1.870059	1.338513	1.557251	1.270508	0.865843	0.659264	0.581813	0.649839
Downhill Step (32)	4.269638	3.341942	3.684011	2.994813	3.332816	3.325331	3.362348	1.803079	2.779203	1.988098	2.31913	1.93951	2.681227	1.97623	1.907048	2.286498
Salomon (33)	2.673339	2.507356	2.564982	2.267318	2.201124	1.898402	2.254826	1.241535	2.059377	1.344842	1.594928	1.517373	1.416734	1.039696	1.017504	1.145825
Whitley (34)	2.649587	2.834026	2.628312	2.328094	2.0782	2.023533	2.199276	1.533541	2.121948	1.510143	1.745077	1.643541	1.558384	1.078251	1.12195	1.440742
Odd Square (35)	2.556175	3.077464	2.582026	2.144564	1.828631	2.133726	1.967559	1.650108	2.042027	1.48037	1.639906	1.582886	1.325703	1.181088	0.909697	1.092928
Storn Chebyshev (36)	125.8444	127.6472	129.4052	129.8261	140.4069	146.7928	137.1756	204.4261	149.5484	148.0012	145.7178	143.6409	147.4202	146.8542	145.8705	149.6886
Rana (37)	1.491546	1.333211	1.615062	2.07091	3.085764	2.03253	2.683682	3.106838	1.894079	1.385812	1.177236	1.359382	1.236451	1.030245	1.282404	1.131559
Rosenbrock 10D (38)	3.719049	4.577713	9.992949	13.19939	25.30212	22.83521	18.52075	55.39606	3.775141	4.25443	6.099252	6.996029	1.995015	1.934206	2.096942	2.337706
Rosenbrock 30D (39)	8.440162	10.64215	24.14735	27.38706	33.7732	30.8115	33.41894	47.60154	7.077858	7.813104	12.2125	13.7591	3.648009	3.469929	3.533961	4.310684
Mod Rosenbrock 1 10D (40)	4.296082	5.877285	15.99929	15.29668	24.262	24.07776	19.00116	52.44394	4.220996	5.018986	6.786319	8.434911	2.638152	2.68986	2.992215	3.354531
Mod Rosenbrock 1 30D (41)	9.687228	11.88014	28.15718	28.73076	17.47712	17.34834	18.99551	22.39654	8.944801	9.255	13.75256	15.53193	5.594374	5.353889	5.609272	6.484468
Mod Rosenbrock 2 10D (42)	5.187563	6.764088	16.35648	15.14009	43.80725	41.81127	33.94884	88.30372	4.969994	5.720629	7.531246	9.429804	16.11036	16.2393	12.62372	29.43907
Mod Rosenbrock 2 30D (43)	11.54066	14.50108	28.8385	29.03149	82.94347	68.96858	128.4887	182.877	10.33116	11.32027	16.61422	18.41448	31.47623	27.33768	37.997	71.65585
Spherical Contours 10D (44)	4.365006	6.104612	13.97874	14.09156	19.50891	17.6693	15.01112	36.41791	3.375786	3.559563	7.274272	9.082089	1.513563	1.645276	1.682979	1.967047
Rastrigin 10D (45)	5.727049	8.67859	14.28662	15.78317	35.52319	33.3275	26.82089	62.60659	4.394631	4.604692	8.3472	8.839606	6.910117	7.103625	6.595618	11.73876
Rastrigin 30D (46)	13.62125	19.61836	27.90638	27.20822	64.30894	64.25873	76.19736	108.7126	8.752113	8.420405	15.3194	15.84074	6.931492	6.664629	7.610749	9.483885
Schwefel 10D (47)	8.222686	10.88503	14.26075	15.04187	40.3165	38.78708	33.57724	57.62579	4.474078	4.450476	8.519795	9.107939	19.52548	19.69652	17.5276	45.55407
Schwefel 30D (48)	14.61417	17.08264	26.93416	25.25533	67.77095	57.60016	110.3341	154.0672	8.627107	8.2533	16.45135	16.14958	36.90792	30.31274	54.74317	88.37382
Griewangk 10D (49)	6.721458	9.02714	12.56489	13.22474	15.24998	15.17809	11.73961	22.95567	3.83207	3.642204	8.441675	7.81883	2.004901	2.210347	2.361538	1.818534
Griewangk 30D (50)	12.73158	16.63217	23.93751	25.06451	11.85565	12.06746	12.70818	12.79809	7.737152	7.191766	15.6841	14.03791	4.317668	4.57082	4.669967	4.128382
Salomon 10D (51)	6.547566	8.513015	12.86918	14.17734	18.17421	17.10547	13.0527	27.34395	3.425243	3.179768	7.936032	7.024398	2.044432	2.310487	2.367835	2.024813
Salomon 30D (52)	12.5981	14.77409	24.48033	24.45225	26.5642	25.27422	26.55522	31.89788	6.37556	6.227361	14.14926	12.30861	3.263835	3.478636	3.438617	3.268376
Odd Square 10D (53)	7.609772	9.191254	14.07827	13.01612	26.35381	28.79768	20.44691	47.45033	3.56123	3.300982	8.11797	7.655828	9.942316	10.01107	6.405781	10.91007
Whitley 10D (54)	9.911	12.24059	16.48408	15.75506	17.79977	18.58262	15.39384	28.37637	7.053694	6.46223	11.3309	10.80854	5.368681	6.047074	5.145404	4.804946
Whitley 30D (55)	45.67305	49.57273	55.73526	56.07422	74.57876	70.4578	79.72578	90.68116	37.83284	35.72564	45.04472	43.39932	33.50159	33.93474	34.40299	30.44778
Rana 10D (56)	9.48504	11.66675	13.81943	15.38356	34.4319	36.47613	25.98769	54.97352	5.702891	5.99736	8.904395	11.31831	23.06392	24.67561	25.43714	34.46272
Rana 30D (57)	18.2488	20.18183	28.53011	26.4138	65.20876	52.76731	94.41902	161.5636	11.32806	11.62016	17.06733	19.80764	48.1159	39.15533	63.29109	88.89955

	6 Pseudopods								8 Pseudopods							
Avg. Times (s) for 500k	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	2.141995	1.905871	2.247172	2.245457	1.507928	1.298733	1.305958	1.507194	2.029403	1.541192	2.030434	1.756307	1.276703	1.044069	1.277816	1.115118
McCormic (2)	1.316901	1.246138	1.264863	1.25653	1.205791	1.10962	1.226103	1.203479	1.030054	1.078112	0.998866	1.133437	1.098728	1.022978	1.02114	1.130481
Box and Betts (3)	2.175868	1.985744	2.456118	2.70981	1.885525	1.922385	1.90346	1.880789	1.946626	1.832997	2.116036	2.278635	1.792538	1.835706	1.793467	1.825902
Goldstein (4)	1.883204	1.199564	2.060729	1.813103	0.815868	0.627809	0.691166	0.809207	1.497144	1.064416	1.746333	1.746111	0.725453	0.549384	0.703154	0.704933
Easom (5)	2.639719	2.16091	2.658804	2.764614	2.516433	1.955414	2.543029	2.583753	2.22313	2.059086	2.254952	1.994989	1.933304	1.582677	1.884891	2.114581
Mod Rosenbrock 1 (6)	2.179337	1.892749	2.106599	2.047244	1.320813	1.329213	1.442905	1.406022	1.710351	1.713502	1.721154	1.588979	1.12133	1.075707	1.122098	1.265054
Mod Rosenbrock 2 (7)	1.933066	1.695935	1.905046	1.889817	1.315534	1.278859	1.315652	1.317718	1.543229	1.506492	1.550917	1.449673	1.161954	1.074709	1.121802	1.121936
Bohachevsky (8)	1.999599	1.561337	1.92914	1.966019	1.276303	1.431196	1.265923	1.24565	1.67048	1.300804	1.671318	1.503571	1.174132	1.22843	1.073856	1.049095
Powell (9)	3.065757	3.016984	3.473192	6.171536	2.04442	2.143341	2.232635	2.674794	2.405529	2.360789	2.82033	4.460571	1.514684	1.517846	1.532985	1.645034
Wood (10)	3.165694	3.037994	3.58254	6.106171	2.015228	2.014268	2.242238	2.616135	2.473874	2.269152	3.017075	4.604261	1.45414	1.421533	1.449119	1.598258
Beale (11)	2.236576	1.90224	2.073276	2.146868	1.646404	1.584261	1.574002	1.56144	1.924973	1.510537	1.72725	1.610288	1.153655	1.183964	1.226478	1.09989
Engvall (12)	2.067061	2.091773	1.926749	2.21855	1.477963	1.352541	1.382845	1.507874	1.740533	1.639663	1.71484	1.737079	1.185246	1.167197	1.218451	1.23956
DeJong (13)	1.876485	1.755031	1.855608	1.886323	1.133813	0.964055	1.029679	1.207777	1.400674	1.305756	1.619355	1.505726	0.950868	0.863994	1.018072	1.066409
Rastrigin (14)	2.015051	1.658154	1.961349	1.795081	1.505357	1.379768	1.522334	1.389666	1.54955	1.121499	1.589981	1.5868	1.236368	1.166726	1.230134	1.239714
Schwefel (15)	1.810224	1.593735	1.786946	1.723725	2.017575	1.628572	1.833866	1.922352	1.590661	1.354962	1.433642	1.434226	1.297852	1.446683	1.336485	1.417266
Griewangk (16)	1.882536	1.56921	1.899682	1.660052	1.265063	1.24138	1.37625	1.150111	1.605152	1.313893	1.437056	1.352621	1.019407	1.023176	1.024013	1.114388
Ackley (17)	1.972737	1.852352	1.949033	1.711406	1.366093	1.505977	1.392292	1.226571	1.540109	1.457171	1.500077	1.424016	1.066716	1.161823	1.088504	1.073646
Langerman (18)	2.939199	3.175163	3.778962	5.873561	1.909888	2.021307	2.204349	2.44975	2.339387	2.527782	2.893785	4.340389	1.531913	1.578905	1.611626	1.783481
Michaelewicz (19)	5.690852	6.651227	8.74174	6.710437	20.18049	19.58044	15.92154	31.86424	4.734102	5.47009	6.56906	5.723281	14.43974	13.90741	11.78886	19.65845
Branin (20)	1.564382	1.304876	0.948747	0.794293	0.642016	0.831699	0.894853	0.65978	1.02168	1.083214	0.696204	0.698435	0.663058	0.761184	0.858375	0.473994
Six Hump Camel (21)	1.430682	1.246672	0.946087	0.813103	0.659922	0.844724	0.938085	0.806652	0.925429	1.067797	0.747115	0.666554	0.686934	0.736653	0.904302	0.507297
Osborne 1 (22)	3.946485	4.619455	4.137867	5.418164	3.45431	3.654805	4.144955	4.219659	3.440115	3.718942	3.578409	4.019997	3.218794	3.313667	3.522693	3.042568
Osborne 2 (23)	10.24463	10.85877	13.02862	14.04092	9.60889	9.58237	9.620855	10.30385	9.442886	9.828461	11.15735	12.06306	9.033298	9.090682	9.17672	9.570645
Mod Rastrigin (24)	1.546161	1.084071	1.649604	1.025154	1.155276	1.12155	0.945738	0.922365	1.138466	0.906394	1.541221	1.315549	0.794886	0.715934	0.598105	1.168503
Mineshaft 1 (25)	1.0496	0.771158	1.07854	0.599176	0.804549	0.950358	0.781034	0.593785	0.778534	0.69536	1.055468	0.770782	0.735645	0.695109	0.571437	0.956695
Mineshaft 2 (26)	0.701587	0.562634	0.845894	0.367855	0.468835	0.50233	0.563318	0.293499	0.429673	0.451184	0.82964	0.427894	0.438599	0.365459	0.345809	0.793402
Mineshaft 3 (27)	0.896005	1.030904	1.28732	0.833529	0.795295	0.804454	1.051334	0.532413	0.668482	0.715527	1.213261	0.789963	0.686385	0.708634	0.6954	1.059201
Spherical Contours (28)	4.850577	5.110121	7.618789	7.260204	3.43444	3.398833	3.600376	3.481541	4.212352	4.155531	5.922377	5.368172	3.266836	3.221251	3.351701	3.764203
S1 (29)	0.969747	0.467007	0.236816	0.21652	0.627905	0.382188	0.327767	0.285838	0.890674	0.622615	0.239548	0.222564	0.563537	0.342454	0.290971	0.290512
S2 (30)	1.436443	1.090884	0.608278	0.543287	0.763287	0.591732	0.43709	0.399726	1.278296	1.083467	0.502753	0.532659	0.786728	0.442173	0.378089	0.407564
S3 (31)	1.029032	1.098998	0.568059	0.566728	0.7731	0.731096	0.477052	0.428829	0.842417	1.137094	0.438812	0.513723	0.758808	0.518146	0.442351	0.369162
Downhill Step (32)	1.293787	1.769717	0.897927	0.685585	2.127386	1.782893	1.926946	1.159115	1.191569	1.409055	0.65987	0.617992	1.97041	1.64443	1.275011	0.791626
Salomon (33)	0.699156	0.999518	0.74765	0.494062	0.764908	1.005374	0.871293	0.44319	0.780443	0.780293	0.511619	0.423044	0.73129	0.829622	0.843533	0.339011
Whitley (34)	0.799482	0.979427	0.870703	0.587388	0.707447	0.935868	1.02249	0.47991	0.720982	0.881448	0.681431	0.512413	0.700327	0.956561	0.917329	0.466561
Odd Square (35)	0.913626	0.917161	0.783802	0.523519	0.676108	0.987849	0.961459	0.486568	0.763351	0.807781	0.606682	0.454113	0.638628	1.001939	0.944664	0.434391
Storn Chebyshev (36)	121.6982	122.5835	124.7231	125.3331	122.5144	123.4491	123.9238	124.0241	121.8527	122.3655	123.2513	123.6694	121.8852	122.3024	122.8898	122.673
Rana (37)	0.861146	0.73763	1.228675	1.374171	0.628573	0.564071	0.475085	0.97708	0.77628	0.612744	0.880341	1.102159	0.527757	0.50705	0.44027	0.596119
Rosenbrock 10D (38)	1.766937	2.204191	5.297529	5.516897	1.118074	1.188207	1.050572	1.800562	1.51076	1.769282	3.59354	3.639323	0.991551	0.985043	1.006231	1.293718
Rosenbrock 30D (39)	3.881749	4.359458	9.328963	9.526069	3.051523	3.064062	3.137942	4.262324	3.376157	3.626791	6.568476	6.702997	2.902237	2.865411	2.849644	3.478102
Mod Rosenbrock 1 10D (40)	2.24648	2.54289	6.135262	6.321769	1.670573	1.727552	1.781224	2.518139	2.225096	2.359403	4.299357	4.41367	1.646334	1.728961	1.782198	2.310198
Mod Rosenbrock 1 30D (41)	6.710757	7.085024	11.01957	11.25551	4.697763	4.678151	4.75873	6.138264	6.02316	6.359014	8.364787	8.696137	4.849084	4.765421	4.820963	5.814358
Mod Rosenbrock 2 10D (42)	3.834876	4.825024	7.334419	7.456684	7.841491	7.854614	6.568553	12.47123	2.974412	3.507338	5.756421	6.062831	4.261653	4.39992	4.264596	5.841148
Mod Rosenbrock 2 30D (43)	8.163299	9.480574	14.51539	14.45707	18.66206	17.00806	20.59745	29.33488	7.094599	8.000415	11.79427	11.76408	10.61547	10.32755	11.41752	14.452
Spherical Contours 10D (44)	2.625382	3.305021	5.478174	5.53766	1.52661	1.607533	1.646338	1.917277	1.825813	2.048506	4.001366	4.270834	1.303261	1.37733	1.420817	1.880973
Rastrigin 10D (45)	3.373256	4.038739	5.985881	6.034549	2.516005	2.814614	2.746805	3.457109	2.17293	2.67561	4.953276	4.87168	1.710406	1.794663	1.867468	2.284147
Rastrigin 30D (46)	6.419714	6.925066	11.11101	10.48213	4.393609	4.396947	4.512751	5.389727	5.489049	6.412599	8.287081	7.810072	4.030233	3.985858	4.068654	4.823282
Schwefel 10D (47)	2.765613	4.734415	5.313819	5.47989	16.51007	18.36846	14.64565	25.76462	3.132611	3.757691	4.194733	4.221278	10.53953	11.27355	9.495263	16.28322
Schwefel 30D (48)	7.136555	8.527506	10.66996	10.16115	26.75096	22.22463	31.99774	55.01806	6.127988	6.689654	8.307401	8.067224	19.33647	16.48469	21.82415	30.93708
Griewangk 10D (49)	3.197838	3.656811	3.9681	4.095149	1.675924	1.895304	1.733054	1.799695	2.339788	2.886429	2.945583	3.01261	1.633725	1.965445	1.727222	1.557572
Griewangk 30D (50)	6.340719	6.908743	8.250185	8.249404	4.259633	4.472683	4.367071	4.595108	5.434664	5.896015	6.187175	6.086767	4.165237	4.384394	4.284003	4.115754
Salomon 10D (51)	2.74587	3.39985	3.595151	4.108449	1.324642	1.46748	1.438656	1.534631	2.310393	2.753504	2.635325	2.756142	1.274809	1.35985	1.368346	1.315607
Salomon 30D (52)	5.232727	5.843735	7.723339	7.59038	3.286823	3.238649	3.329362	3.647953	4.51763	4.468154	5.353098	5.363367	3.188383	3.203212	3.271787	3.163208
Odd Square 10D (53)	2.871593	3.269791	3.968176	4.243307	2.325952	2.535986	2.487197	2.777383	2.259811	2.235277	2.677324	3.04878	1.520111	1.647013	1.601145	1.583802
Whitley 10D (54)	6.379736	6.759664	7.268797	8.187467	4.627962	4.776328	4.582106	4.598376	5.327675	5.532529	5.903962	6.071805	4.463442	4.631756	4.503956	4.663495
Whitley 30D (55)	34.63756	34.16166	38.42748	37.73706	31.86858	31.93162	32.04625	29.92874	32.19461	32.16955	34.87036	34.57592	31.07461	31.10349	31.18246	31.81001
Rana 10D (56)	3.338862	4.17058	4.791211	5.092622	13.61583	15.5099	13.71941	18.04542	2.805274	3.319124	3.606598	4.470556	8.612361	9.697811	8.808671	13.63876
Rana 30D (57)	8.146166	8.965172	10.85688	9.988377	27.21553	23.05851	32.63891	55.39832	7.047758	8.226644	9.677914	9.57394	18.87779	16.54047	21.28005	35.81763

				10 Pseudopods				
Avg. Times (s) for 500k	A50, N1	A50, N2	A50, N3	A50, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	1.652288	1.587666	1.535932	1.761453	1.173716	1.0291	1.021111	1.076757
McCormic (2)	1.038648	0.886199	1.055019	0.964796	0.962621	1.016635	0.978423	1.078228
Box and Betts (3)	1.803487	1.725344	1.879489	2.086168	1.720616	1.733429	1.738566	1.736307
Goldstein (4)	1.38522	1.059978	1.444333	1.339928	0.657716	0.626005	0.599873	0.725015
Easom (5)	1.757823	1.79738	1.966994	1.749493	1.69449	1.520346	1.868192	1.894342
Mod Rosenbrock 1 (6)	1.539082	1.519074	1.481364	1.589231	1.030103	1.049349	1.16148	1.035925
Mod Rosenbrock 2 (7)	1.2921	1.363302	1.270935	1.356308	1.032674	1.127451	1.156738	1.026152
Bohachevsky (8)	1.302745	1.19755	1.261109	1.357058	1.028246	1.133816	1.033285	1.078413
Powell (9)	1.912028	2.004899	2.251261	3.758447	1.28202	1.350753	1.321472	1.427456
Wood (10)	1.978085	2.063296	2.337419	3.622404	1.183233	1.189234	1.297928	1.334043
Beale (11)	1.585145	1.518923	1.554062	1.238227	0.973546	0.936533	1.036729	0.956894
Engvall (12)	1.710441	1.569719	1.597268	1.563894	1.051464	1.032385	1.086317	1.106969
DeJong (13)	1.228539	1.126822	1.196316	1.366721	0.947706	0.85569	0.981246	0.914196
Rastrigin (14)	1.243851	1.021825	1.290064	1.296615	1.087368	1.013657	1.116875	1.00118
Schwefel (15)	1.30683	1.192203	1.279259	1.150578	1.209476	1.195006	1.183879	1.093619
Griewangk (16)	1.306062	1.215995	1.318614	1.077406	0.957866	1.040603	1.017034	0.938479
Ackley (17)	1.331395	1.330738	1.335929	1.138964	1.075142	1.056933	1.019763	0.986119
Langerman (18)	2.043332	2.139164	2.402897	3.446569	1.514444	1.461287	1.570947	1.54874
Michaelewicz (19)	4.136682	4.511612	5.508782	4.676256	9.574647	9.477914	8.541031	12.14914
Branin (20)	0.861535	0.89413	0.631571	0.489407	0.769859	0.718438	0.74721	0.486288
Six Hump Camel (21)	0.758038	0.723627	0.610298	0.520157	0.763109	0.77609	0.80601	0.527355
Osborne 1 (22)	3.124206	3.203295	3.195071	3.566605	3.134367	3.166421	3.213055	2.97439
Osborne 2 (23)	9.055923	9.216701	10.20961	10.80893	8.751568	8.787067	8.850807	9.111796
Mod Rastrigin (24)	0.976321	0.99776	0.924958	1.541459	0.66401	0.61592	0.645653	0.709009
Mineshaft 1 (25)	0.749786	0.601553	0.804371	0.948667	0.629249	0.596756	0.604592	0.64757
Mineshaft 2 (26)	0.508889	0.377105	0.529065	0.663999	0.452521	0.387197	0.418332	0.367811
Mineshaft 3 (27)	0.705868	0.618628	0.964818	0.84876	0.766962	0.784723	0.834348	0.625098
Spherical Contours (28)	3.689709	3.806372	5.496513	4.424187	3.215783	3.205687	3.317483	3.856107
S1 (29)	0.780628	0.54792	0.319763	0.221351	0.485701	0.295815	0.446588	0.730636
S2 (30)	1.326926	1.112979	0.532025	0.401674	0.582743	0.542442	0.586496	0.819599
S3 (31)	1.019849	1.089226	0.43934	0.348883	0.624392	0.58597	0.626	0.760198
Downhill Step (32)	1.139009	1.285637	0.585197	0.513389	1.556228	1.121714	1.483068	1.280398
Salomon (33)	0.70093	0.712194	0.430806	0.374561	0.965429	0.676053	0.969329	0.503805
Whitley (34)	0.819976	0.748592	0.534118	0.470834	0.925157	0.974949	0.995405	0.589907
Odd Square (35)	0.60517	0.719453	0.5487	0.410841	0.810629	1.032147	0.792412	0.545173
Storn Chebyshev (36)	110.0809	110.6102	111.206	111.2438	110.804	111.2777	111.2331	111.0782
Rana (37)	0.765444	0.630744	0.720573	0.790685	0.494651	0.420802	0.508827	0.635352
Rosenbrock 10D (38)	1.439424	1.653632	2.347183	2.602705	0.957757	1.009022	1.010809	1.312977
Rosenbrock 30D (39)	3.097626	3.296654	4.695704	4.826502	2.919139	2.854683	3.040111	3.259971
Mod Rosenbrock 1 10D (40)	2.074299	2.256507	3.206218	3.329658	1.620275	1.706489	1.713863	1.940454
Mod Rosenbrock 1 30D (41)	5.127109	5.372779	6.555227	6.538274	4.762478	4.73372	4.879756	5.269397
Mod Rosenbrock 2 10D (42)	2.572237	3.025688	3.83876	4.52236	2.741213	2.885202	2.972244	3.667177
Mod Rosenbrock 2 30D (43)	6.092649	6.659937	9.762769	9.780447	7.408168	7.440367	7.869666	9.008563
Spherical Contours 10D (44)	1.474762	1.736212	2.969752	3.14926	1.165419	1.215956	1.246293	1.614434
Rastrigin 10D (45)	1.951104	2.533597	3.761043	3.384694	1.456686	1.523017	1.565553	1.968148
Rastrigin 30D (46)	4.830776	5.239043	6.46077	6.402276	3.785	3.767446	4.007235	4.435857
Schwefel 10D (47)	2.366993	2.792176	3.65441	3.708668	5.181255	5.784582	5.50395	8.112269
Schwefel 30D (48)	5.311278	5.99978	7.368573	6.89473	11.66679	10.55872	12.24267	16.40529
Griewangk 10D (49)	2.169859	2.226263	2.299223	2.35343	1.60302	1.716284	1.632784	1.538602
Griewangk 30D (50)	4.511517	4.48062	4.842526	4.881197	4.061791	4.089547	4.190418	3.94982
Salomon 10D (51)	1.589076	1.872191	2.041228	2.111867	1.269741	1.286219	1.349118	1.207056
Salomon 30D (52)	3.368417	3.665413	4.179954	4.027339	3.140949	3.179816	3.182891	3.025329
Odd Square 10D (53)	1.705554	1.873026	2.028919	2.148582	1.398003	1.481314	1.395385	1.355451
Whitley 10D (54)	4.940133	4.809714	5.02324	4.939917	4.455708	4.53181	4.345904	4.323864
Whitley 30D (55)	30.15141	30.20839	32.64665	32.7992	29.81816	29.87458	29.96699	30.84656
Rana 10D (56)	2.33994	3.373608	3.649446	3.686519	6.465626	6.948161	6.730818	9.649686
Rana 30D (57)	7.030908	7.403769	8.525557	8.468066	16.16661	14.18463	17.36994	26.12307

APPENDIX D1: AVG. RESULTS FOR SMOA WITH RAZOR VEG. STATE

Average Results (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.001696	0.001885	0.001696	0.001696	0.001382	0.002072	0.001382	0.001382	0.002343	0.000989	0.002343	0.002343	0.001071	0.000391	0.001071	0.001071	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.9133
Box and Betts (3)	9.87E-09	4.81E-09	1.72E-08	2.70E-08	3.14E-09	1.66E-09	6.22E-09	1.05E-08	6.83E-10	4.53E-10	1.70E-09	3.13E-09	3.53E-10	2.90E-10	7.74E-10	1.13E-09	0
Goldstein (4)	3.000092	3.000038	3.000092	3.000092	3.000041	3.000012	3.000041	3.000041	3.000009	3.000001	3.000009	3.000009	3.000002	3	3.000002	3.000002	3
Easom (5)	-0.99479	-0.99262	-0.99479	-0.99479	-0.99476	-0.99359	-0.99476	-0.99476	-0.99455	-0.99541	-0.99455	-0.99455	-0.99625	-0.9949	-0.99625	-0.99625	-1
Mod Rosenbrock 1 (6)	0.061715	0.083196	0.061715	0.061715	0.067448	0.079917	0.067448	0.067448	0.076539	0.050464	0.076539	0.076539	0.045518	0.021355	0.045518	0.045518	0
Mod Rosenbrock 2 (7)	1.265023	1.399975	1.265023	1.265023	1.185417	1.357179	1.185417	1.185417	1.252908	1.000841	1.252908	1.252908	0.994726	0.804874	0.994726	0.994726	0
Bohachevsky (8)	1.441675	0.222995	1.441675	1.441675	1.368883	0.623431	1.368883	1.368883	1.732728	0.381256	1.732728	1.732728	1.519596	0.294893	1.519596	1.519596	0
Powell (9)	196183.8	196183.8	184121	202438.3	194451.9	194451.9	162214	154686.8	183583.8	183583.8	147646.5	142516.1	190131.6	190131.6	190707.8	178994.8	0
Wood (10)	100304.5	100304.5	91765.11	100084.7	92932.42	92932.42	92661.53	93993.36	95615.51	95615.51	98950.61	93464.56	99567.54	99567.54	99649.17	93199.88	0
Beale (11)	0.481391	0.58859	0.481391	0.481391	0.521178	0.598695	0.521178	0.521178	0.544152	0.563272	0.544152	0.544152	0.552642	0.634401	0.552642	0.552642	0
Engvall (12)	1.986981	1.624779	1.986981	1.986981	1.877412	1.941074	1.877412	1.877412	2.589991	1.713352	2.589991	2.589991	1.840463	1.605247	1.840463	1.840463	0
DeJong (13)	9.40E-06	2.26E-05	9.40E-06	9.40E-06	1.10E-05	5.96E-06	1.10E-05	1.10E-05	6.03E-06	9.82E-07	6.03E-06	6.03E-06	1.47E-06	2.66E-07	1.47E-06	1.47E-06	0
Rastrigin (14)	0.003811	0.004292	0.003811	0.003811	0.003321	0.001132	0.003321	0.003321	0.001008	0.247171	0.001008	0.001008	0.014947	0.445292	0.014947	0.014947	0
Schwefel (15)	-837.954	-837.953	-837.954	-837.954	-837.955	-837.951	-837.955	-837.955	-837.952	-837.953	-837.952	-837.952	-837.955	-837.951	-837.955	-837.955	-837.9658
Griewangk (16)	0.0075	0.001039	0.0075	0.0075	0.008321	0.002335	0.008321	0.008321	0.00925	0.0023	0.00925	0.00925	0.008284	0.001236	0.008284	0.008284	0
Ackley (17)	0.032546	0.042843	0.032546	0.032546	0.033416	0.03873	0.033416	0.033416	0.037904	0.026116	0.037904	0.037904	0.02752	0.014274	0.02752	0.02752	0
Langerman (18)	-1.47482	-1.47813	-1.48335	-1.47389	-1.48003	-1.47588	-1.48064	-1.4755	-1.47157	-1.47656	-1.47929	-1.48605	-1.46967	-1.46979	-1.47413	-1.48682	-1.5
Michaelewicz (19)	-7.71425	-7.88011	-7.74542	-7.69666	-7.71126	-7.90225	-7.90724	-7.78829	-7.72512	-7.88872	-8.11404	-7.75847	-7.78196	-7.87654	-8.1249	-7.83867	-9.66
Branin (20)	0.397898	0.397899	0.397898	0.397898	0.3979	0.397892	0.3979	0.3979	0.397892	0.397888	0.397892	0.397892	0.397888	0.397888	0.397888	0.397888	0.397887
Six Hump Camel (21)	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.015114	0.015854	0.014698	0.013364	0.014105	0.015163	0.014969	0.014282	0.013538	0.015308	0.014389	0.0163	0.015162	0.016106	0.015695	0.01535	5.46E-05
Osborne 2 (23)	0.075296	0.073823	0.07382	0.074811	0.076575	0.076095	0.073224	0.07559	0.075629	0.077372	0.073736	0.076525	0.077211	0.07816	0.075532	0.077232	0.0402
Mod Rastrigin (24)	83.41079	83.87437	83.41079	83.41079	83.15301	82.96398	83.15301	83.15301	83.77353	86.96689	83.77353	83.77353	83.06728	87.02505	83.06728	83.06728	58
Mineshaft 1 (25)	1.956879	1.792251	1.930152	1.792251	1.848077	1.721388	1.813247	1.721388	1.778783	1.608487	1.718993	1.608487	1.709794	1.642697	1.685668	1.642697	1.3805
Mineshaft 2 (26)	-1.39004	-1.40998	-1.41605	-1.40998	-1.41635	-1.40842	-1.41635	-1.40842	-1.41635	-1.41635	-1.41635	-1.41635	-1.41635	-1.41635	-1.41635	-1.41635	-1.4163535
Mineshaft 3 (27)	-6.82396	-6.83613	-6.82396	-6.82396	-6.9476	-6.97622	-6.9476	-6.9476	-6.99852	-6.99934	-6.99852	-6.99852	-6.99966	-6.99988	-6.99966	-6.99966	-7
Spherical Contours (28)	4.96985	5.005228	5.033569	5.033569	5.001982	5.025784	4.975556	4.975556	5.093355	5.090472	5.093651	5.096461	5.068457	5.068457	5.068457	5.068457	0
S1 (29)	3.53E-12	4.47E-15	2.76E-13	4.47E-15	2.79E-13	1.56E-15	2.26E-14	1.56E-15	1.80E-14	1.67E-16	2.10E-15	1.67E-16	3.32E-15	1.25E-15	2.15E-15	1.25E-15	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528874	0.528901	0.528874	0.528874	0.528884	0.528889	0.528884	0.528884	0.528894	0.528878	0.528894	0.528894	0.528881	0.528875	0.528881	0.528881	0.5289
Downhill Step (32)	9	9	9	9	9	9	9	9	9.012	9.014	9.012	9.012	9.005	9.017	9.005	9.005	9
Salomon (33)	0.032677	0.004737	0.032677	0.032677	0.033757	0.012969	0.033757	0.033757	0.033826	0.018724	0.033826	0.033826	0.034436	0.028066	0.034436	0.034436	0
Whitley (34)	0.063944	0.123215	0.063944	0.063944	0.078439	0.127179	0.078439	0.078439	0.123879	0.120891	0.123879	0.123879	0.0738	0.135189	0.0738	0.0738	0
Odd Square (35)	-1.00721	-1.00722	-1.00721	-1.00721	-1.00729	-1.00722	-1.00729	-1.00729	-1.00749	-1.00669	-1.00749	-1.00749	-1.00636	-0.89728	-1.00636	-1.00636	-1.14383
Storn Chebyshev (36)	548.0704	473.9319	373.0537	433.0638	572.264	426.8169	364.354	419.8795	441.264	341.4179	302.7324	585.1456	554.6864	612.7405	427.737	689.02	0
Rana (37)	-1005.33	-1007.71	-1005.33	-1005.33	-1006.07	-1007.74	-1006.07	-1006.07	-1017.48	-1007.9	-1017.48	-1017.48	-1009.37	-1004.35	-1009.37	-1009.37	-1023.416
Rosenbrock 10D (38)	507.6564	454.2154	483.6049	459.3534	469.8455	479.1368	470.3675	465.8449	467.9976	456.6045	450.4529	469.5532	472.5877	466.3241	456.3035	481.0808	0
Rosenbrock 30D (39)	14109.95	13956.16	13799.46	13799.46	13843.73	13556.51	13895.57	13895.57	14192.64	14112.26	14018.93	14118.08	14120.29	14120.29	14120.29	14120.29	0
Mod Rosenbrock 1 10D (40)	518.9648	507.4081	526.6958	517.057	503.3568	511.8162	523.0454	519.8099	511.1372	504.3079	511.3731	526.2199	504.922	515.2365	526.2784	524.8925	0
Mod Rosenbrock 1 30D (41)	4782.417	4753.207	4746.194	4746.194	4832.935	4860.192	4755.945	4755.945	4828.46	4820.413	4815.723	4822.196	4845.711	4845.711	4845.711	4845.711	0
Mod Rosenbrock 2 10D (42)	1.987154	1.929456	2.217332	2.187478	2.03379	1.823429	2.022871	2.373633	1.972626	1.869931	1.893291	2.367416	2.017113	1.8492	1.844894	2.252787	0
Mod Rosenbrock 2 30D (43)	3.522668	3.166208	4.017076	4.017076	3.818592	3.32383	4.092454	4.092454	4.295114	3.923566	4.062262	4.225195	5.551905	5.551905	5.539793	5.551905	0
Spherical Contours 10D (44)	0.432733	0.444978	0.424278	0.426329	0.423859	0.435689	0.44746	0.430478	0.435175	0.420137	0.443509	0.440897	0.445429	0.420977	0.421645	0.436014	0
Rastrigin 10D (45)	26.30071	25.76142	25.3403	25.86263	25.36088	25.66963	24.95008	25.53268	25.3066	24.82052	24.21833	25.57307	24.41513	24.20859	24.46359	24.86082	0
Rastrigin 30D (46)	174.7691	173.4534	172.5575	172.5575	173.4369	176.322	174.8363	174.8363	174.4631	175.3274	175.0354	175.3912	175.9331	175.9331	175.9331	175.9331	0
Schwefel 10D (47)	-3834.49	-3875.38	-3916.82	-3907.36	-3855.02	-3866.23	-3900.99	-3881.22	-3854.14	-3865.24	-3848.92	-3819.65	-3805.5	-3837.57	-3822.98	-3818.03	-4189.829
Schwefel 30D (48)	-8588.13	-8669.79	-8887.29	-8887.29	-8592.44	-8467.82	-8724.87	-8724.87	-8204.62	-8192.53	-8167.53	-8173.6	-7873.76	-7862.1	-7870.13	-7857.53	-12569.487
Griewangk 10D (49)	1.385168	1.392713	1.400105	1.398638	1.396512	1.39427	1.39604	1.386683	1.393197	1.39107	1.393761	1.40511	1.392557	1.371369	1.381934	1.39202	0
Griewangk 30D (50)	5.082036	5.059493	5.121912	5.121912	5.079777	5.049145	5.065691	5.065691	5.089583	5.095229	5.107441	5.090928	5.093065	5.093065	5.093065	5.093065	0
Salomon 10D (51)	0.939959	0.934299	0.948992	0.940824	0.927791	0.944278	0.944275	0.93542	0.945691	0.962344	0.94615	0.932361	0.955006	0.951809	0.953186	0.935743	0
Salomon 30D (52)	3.773245	3.701854	3.345409	3.345409	4.138153	4.145054	4.109498	4.109498	5.35295	5.35295	5.35295	5.35295	6.987675	6.987675	6.987675	6.987675	0
Odd Square 10D (53)	-0.18694	-0.35283	-0.38986	-0.40818	-0.21751	-0.37045	-0.4402	-0.38109	-0.23249	-0.41351	-0.49154	-0.31906	-0.26898	-0.45769	-0.50377	-0.47035	-1.14383
Whitley 10D (54)	2179432	2228757	2342664	2269598	2113607	2209022	2249100	2479878	2149992	2238282	2159644	2046609	2004460	1886040	1940592	2109044	0
Whitley 30D (55)	3.76E+09	3.73E+09	3.65E+09	3.65E+09	3.85E+09	3.86E+09	3.62E+09	3.62E+09	3.87E+09	3.91E+09	3.84E+09	3.86E+09	3.86E+09	3.86E+09	3.86E+09	3.86E+09	0
Rana 10D (56)	-3584.24	-3628.56	-3731.81	-3721.55	-3625.83	-3611.93	-3680.77	-3706.96	-3635.1	-3624.87	-3611.21	-3680.23	-3571.9	-3607.82	-3558.43	-3613.09	-5117.08
Rana 30D (57)	-7171.38	-7197.62	-7528.1	-7528.1	-7170.09	-7167.22	-7547.34	-7547.34	-7211.91	-7098.12	-7281.26	-7522.25	-7195.06	-7193.21	-7256.2	-7482.36	-15351.24

Average Results (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.003103	0.004071	0.003103	0.003103	0.002952	0.003838	0.002952	0.002952	0.004722	0.001991	0.004722	0.004722	0.002433	0.000745	0.002433	0.002433	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.9133
Box and Betts (3)	1.60E-08	7.92E-09	2.74E-08	4.11E-08	5.02E-09	2.65E-09	9.93E-09	1.82E-08	1.42E-09	8.41E-10	2.84E-09	5.04E-09	1.26E-09	7.73E-10	1.55E-09	2.41E-09	0
Goldstein (4)	3.000195	3.000064	3.000195	3.000195	3.00007	3.000017	3.00007	3.00007	3.000018	3.000003	3.000018	3.000018	3.000004	3.000001	3.000004	3.000004	3
Easom (5)	-0.99058	-0.9865	-0.99058	-0.99058	-0.98855	-0.98567	-0.98855	-0.98855	-0.99116	-0.98943	-0.99116	-0.99116	-0.99275	-0.99	-0.99275	-0.99275	-1
Mod Rosenbrock 1 (6)	0.103371	0.118717	0.103371	0.103371	0.101515	0.110827	0.101515	0.101515	0.11264	0.078093	0.11264	0.11264	0.077788	0.034866	0.077788	0.077788	0
Mod Rosenbrock 2 (7)	1.609354	1.865767	1.609354	1.609354	1.548259	1.778427	1.548259	1.548259	1.638526	1.305264	1.638526	1.638526	1.437713	1.040032	1.437713	1.437713	0
Bohachevsky (8)	2.057183	0.845318	2.057183	2.057183	2.36895	1.783636	2.36895	2.36895	2.998851	1.282916	2.998851	2.998851	2.315651	0.979606	2.315651	2.315651	0
Powell (9)	334641.8	334641.8	306086.1	333889.5	346383.9	346383.9	261974.1	252444.9	308141.6	308141.6	264614.3	223232.1	353240.4	353240.4	345437.4	300504.2	0
Wood (10)	152625.6	152625.6	152387.5	177527.2	153299.4	153299.4	136857	144931	148069.9	148069.9	146880.1	149041.8	160016.1	160016.1	157758.1	148177.5	0
Beale (11)	1.010008	1.079002	1.010008	1.010008	1.008326	1.163811	1.008326	1.008326	1.47745	1.187295	1.47745	1.47745	1.127001	1.060431	1.127001	1.127001	0
Engvall (12)	3.812513	3.166476	3.812513	3.812513	4.019079	3.69155	4.019079	4.019079	6.100946	4.14202	6.100946	6.100946	9.596502	3.523968	9.596502	9.596502	0
DeJong (13)	1.90E-05	3.89E-05	1.90E-05	1.90E-05	2.35E-05	1.26E-05	2.35E-05	2.35E-05	1.25E-05	1.74E-06	1.25E-05	1.25E-05	2.79E-06	5.10E-07	2.79E-06	2.79E-06	0
Rastrigin (14)	0.007214	0.007715	0.007214	0.007214	0.005747	0.001919	0.005747	0.005747	0.001979	0.263114	0.001979	0.001979	0.033256	0.446329	0.033256	0.033256	0
Schwefel (15)	-837.944	-837.939	-837.944	-837.944	-837.946	-837.935	-837.946	-837.946	-837.939	-837.941	-837.939	-837.939	-837.935	-837.934	-837.935	-837.935	-837.9658
Griewangk (16)	0.010396	0.004314	0.010396	0.010396	0.011883	0.006948	0.011883	0.011883	0.013662	0.005853	0.013662	0.013662	0.011625	0.004291	0.011625	0.011625	0
Ackley (17)	0.049757	0.065405	0.049757	0.049757	0.049368	0.063679	0.049368	0.049368	0.056512	0.041881	0.056512	0.056512	0.042332	0.021293	0.042332	0.042332	0
Langerman (18)	-1.46197	-1.46531	-1.47468	-1.46122	-1.46881	-1.46592	-1.47131	-1.46393	-1.45315	-1.45616	-1.46594	-1.47876	-1.45029	-1.4489	-1.45361	-1.47825	-1.5
Michaelewicz (19)	-7.56018	-7.70489	-7.62024	-7.5703	-7.57177	-7.73343	-7.76551	-7.64992	-7.58501	-7.75205	-7.93507	-7.64076	-7.57952	-7.66925	-7.86296	-7.69616	-9.66
Branin (20)	0.39791	0.397915	0.39791	0.39791	0.397915	0.397895	0.397915	0.397915	0.397895	0.397889	0.397895	0.397895	0.397889	0.397888	0.397889	0.397889	0.397887
Six Hump Camel (21)	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.018524	0.020291	0.01853	0.017317	0.019361	0.020261	0.018954	0.019677	0.018602	0.019381	0.019283	0.020263	0.020857	0.021244	0.022419	0.021545	5.46E-05
Osborne 2 (23)	0.08072	0.079939	0.080809	0.081126	0.082568	0.080747	0.078748	0.083507	0.084647	0.083927	0.082044	0.085763	0.089084	0.08897	0.08767	0.088177	0.0402
Mod Rastrigin (24)	84.32059	84.6378	84.32059	84.32059	83.99599	83.72299	83.99599	83.99599	84.52851	87.92877	84.52851	84.52851	83.95172	87.25	83.95172	83.95172	58
Mineshaft 1 (25)	1.996568	1.837093	1.950505	1.837093	1.873964	1.745339	1.833244	1.745339	1.80949	1.690242	1.742145	1.690242	1.734971	1.777222	1.723452	1.777222	1.3805
Mineshaft 2 (26)	-1.38613	-1.40695	-1.41605	-1.40695	-1.41635	-1.4083	-1.41635	-1.4083	-1.41635	-1.41111	-1.41635	-1.41111	-1.41635	-1.40105	-1.41232	-1.40105	-1.4163535
Mineshaft 3 (27)	-6.73754	-6.83501	-6.73754	-6.73754	-6.94582	-6.97606	-6.94582	-6.94582	-6.99709	-6.99929	-6.99709	-6.99709	-6.99948	-6.99986	-6.99948	-6.99948	-7
Spherical Contours (28)	5.199985	5.293559	5.320987	5.320987	5.219591	5.221978	5.229533	5.229533	5.377304	5.377304	5.377304	5.377304	5.515747	5.515747	5.515747	5.515747	0
S1 (29)	7.29E-12	6.07E-11	9.87E-13	6.07E-11	9.59E-13	5.66E-15	1.54E-13	5.66E-15	7.40E-14	6.31E-07	2.43E-13	6.31E-07	3.31E-14	4.16E-06	4.56E-14	4.16E-06	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528878	0.528928	0.528878	0.528878	0.528898	0.528903	0.528898	0.528898	0.528904	0.528883	0.528904	0.528904	0.528885	0.528877	0.528885	0.528885	0.5289
Downhill Step (32)	9	9	9	9	9	9	9	9	9.012	9.016	9.012	9.012	9.005	9.017	9.005	9.005	9
Salomon (33)	0.049952	0.023286	0.049952	0.049952	0.049692	0.034927	0.049692	0.049692	0.05049	0.042868	0.05049	0.05049	0.055181	0.048646	0.055181	0.055181	0
Whitley (34)	0.142096	0.276579	0.142096	0.142096	0.173968	0.280997	0.173968	0.173968	0.231119	0.23023	0.231119	0.231119	0.159694	0.20907	0.159694	0.159694	0
Odd Square (35)	-1.0063	-1.00647	-1.0063	-1.0063	-1.00668	-1.00645	-1.00668	-1.00668	-1.00697	-1.0058	-1.00697	-1.00697	-1.00325	-0.88891	-1.00325	-1.00325	-1.14383
Storn Chebyshev (36)	1041.171	805.4443	1293.054	1041.118	899.2648	842.9661	745.1562	951.9698	1085.782	776.5357	655.7771	1341.333	1286.065	1377.325	1053.538	1181.463	0
Rana (37)	-1003.39	-1004.29	-1003.39	-1003.39	-1003.08	-1004.56	-1003.08	-1003.08	-1012.71	-1004.49	-1012.71	-1012.71	-1006.12	-1002.08	-1006.12	-1006.12	-1023.416
Rosenbrock 10D (38)	607.1979	577.2295	591.09	594.5801	560.8494	578.6269	573.2218	563.0043	552.2868	564.6332	579.8877	577.1875	579.0841	553.3457	561.9076	563.4683	0
Rosenbrock 30D (39)	15325.97	15020.88	15051.4	15051.4	15203.94	15432.48	15304.58	15304.58	15685.04	15685.04	15685.04	15685.04	16050.09	16050.09	16050.09	16050.09	0
Mod Rosenbrock 1 10D (40)	569.151	555.3366	566.7859	570.6406	551.4066	560.2537	558.135	584.1761	559.7055	550.1882	559.0018	571.4071	573.1957	582.5666	579.4625	590.7883	0
Mod Rosenbrock 1 30D (41)	5009.039	4911.643	4938.799	4938.799	5024.593	5034.948	5017.925	5017.925	5141.706	5141.706	5141.706	5141.706	5116.782	5116.782	5116.782	5116.782	0
Mod Rosenbrock 2 10D (42)	2.585672	2.504792	2.888373	2.81306	2.996251	2.442033	2.49073	3.063827	2.758367	2.441654	2.344067	3.060723	2.885828	2.646976	2.531671	3.151583	0
Mod Rosenbrock 2 30D (43)	5.095122	4.477052	5.223398	5.223398	5.132633	4.646637	5.697022	5.697022	7.125039	7.125039	7.125039	7.125039	7.756101	7.756101	7.756101	7.756101	0
Spherical Contours 10D (44)	0.499048	0.497702	0.486399	0.507183	0.497739	0.519598	0.521447	0.504833	0.504951	0.495589	0.503357	0.514162	0.48823	0.491712	0.495364	0.495546	0
Rastrigin 10D (45)	28.8054	28.3444	27.94229	28.12935	27.39644	27.73721	28.03062	27.81685	27.93084	27.57163	26.79416	28.15282	27.66014	26.93006	26.90906	27.01307	0
Rastrigin 30D (46)	180.5292	180.5723	179.8564	179.8564	179.7793	183.0733	181.7164	181.7164	183.0511	183.0511	183.0511	183.0511	183.1268	183.1268	183.1268	183.1268	0
Schwefel 10D (47)	-3787.76	-3832.12	-3852.57	-3825.87	-3787.87	-3822.55	-3823.47	-3785.46	-3763	-3768.61	-3770.83	-3729.15	-3649.64	-3637.71	-3647.09	-3649.42	-4189.829
Schwefel 30D (48)	-8313.56	-8310.49	-8418.95	-8418.95	-8093.94	-8072.29	-8100.27	-8100.27	-7664.28	-7666.47	-7660.83	-7663.49	-7449.68	-7449.68	-7449.68	-7449.68	-12569.487
Griewangk 10D (49)	1.449689	1.443719	1.439963	1.457848	1.443095	1.457595	1.460437	1.450498	1.446175	1.449354	1.439911	1.447229	1.446725	1.438715	1.446244	1.444397	0
Griewangk 30D (50)	5.314835	5.280795	5.332219	5.332219	5.264853	5.262369	5.22882	5.22882	5.34236	5.34236	5.34236	5.34236	5.340704	5.340704	5.340704	5.340704	0
Salomon 10D (51)	1.008712	0.99896	1.00996	1.004828	0.997877	1.01244	1.009367	1.006878	1.025635	1.043409	1.01605	1.008504	1.030789	1.01776	1.015784	1.016829	0
Salomon 30D (52)	4.459036	4.410435	4.372628	4.372628	5.295711	5.295711	5.295711	5.295711	7.645154	7.645154	7.645154	7.645154	10.82576	10.82576	10.82576	10.82576	0
Odd Square 10D (53)	-0.16396	-0.32526	-0.32641	-0.34333	-0.18736	-0.34177	-0.4249	-0.3548	-0.19872	-0.39865	-0.45469	-0.29752	-0.21677	-0.4102	-0.46662	-0.46731	-1.14383
Whitley 10D (54)	3517912	4191487	3993711	4014109	3219840	3977794	3838383	3649579	3648016	3606774	3694582	3732738	3335478	3568839	3430963	3365780	0
Whitley 30D (55)	4.8E+09	4.89E+09	4.8E+09	4.8E+09	4.94E+09	4.95E+09	4.9E+09	4.9E+09	5.28E+09	5.28E+09	5.28E+09	5.28E+09	5.92E+09	5.92E+09	5.92E+09	5.92E+09	0
Rana 10D (56)	-3518.22	-3551.63	-3641.59	-3639.63	-3533.45	-3546.34	-3567.44	-3600.9	-3534.69	-3531.74	-3526.45	-3556.78	-3476.22	-3508.6	-3471.52	-3511.4	-5117.08
Rana 30D (57)	-6969.57	-6952.08	-7228.72	-7228.72	-6999.32	-6927.89	-7248.8	-7248.8	-7082.76	-7007.4	-7114.43	-7305.68	-6980.08	-6980.08	-6980.08	-6980.08	-15351.24

Average Results (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.01462	0.020444	0.01462	0.01462	0.014362	0.022812	0.014362	0.014362	0.01957	0.01285	0.01957	0.01957	0.013987	0.004058	0.013987	0.013987	0
McCormic (2)	-1.91321	-1.91322	-1.91321	-1.91321	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91309	-1.91322	-1.91322	-1.9133
Box and Betts (3)	4.50E-08	2.60E-08	8.54E-08	1.24E-07	1.85E-08	1.09E-08	2.98E-08	6.30E-08	2.79E-07	1.38E-08	1.88E-08	2.82E-08	4.17E-08	1.34E-07	2.38E-07	3.04E-08	0
Goldstein (4)	3.001266	3.000277	3.001266	3.001266	3.000447	3.000081	3.000447	3.000447	3.000123	3.000032	3.000123	3.000123	3.028198	3.000018	3.028198	3.028198	3
Easom (5)	-0.9562	-0.92446	-0.9562	-0.9562	-0.94978	-0.93687	-0.94978	-0.94978	-0.94002	-0.93239	-0.94002	-0.94002	-0.92523	-0.91641	-0.92523	-0.92523	-1
Mod Rosenbrock 1 (6)	0.247643	0.360058	0.247643	0.247643	0.283724	0.403596	0.283724	0.283724	0.290704	0.215307	0.290704	0.290704	0.259658	0.109645	0.259658	0.259658	0
Mod Rosenbrock 2 (7)	2.941876	3.468682	2.941876	2.941876	2.977385	3.382206	2.977385	2.977385	3.164491	2.543169	3.164491	3.164491	2.928924	1.800809	2.928924	2.928924	0
Bohachevsky (8)	8.9185	10.13555	8.9185	8.9185	9.643802	11.94698	9.643802	9.643802	10.16052	8.982032	10.16052	10.16052	10.35025	12.18489	10.35025	10.35025	0
Powell (9)	1153435	1153435	936727.7	1011915	1004054	1004054	884816.4	850139.2	994495.3	994495.3	802007.3	710870	1160370	1160370	1151578	1160370	0
Wood (10)	423868.3	423868.3	417454.5	561735.7	406110.7	406110.7	421752.7	390540.4	365872.6	365872.6	404167.2	416261.5	378064.2	378064.2	378064.2	377237.6	0
Beale (11)	5.544812	12.59286	5.544812	5.544812	12.28071	17.06764	12.28071	12.28071	18.26692	43.79441	18.26692	18.26692	25.65386	18.26264	25.65386	25.65386	0
Engvall (12)	64.21189	119.9553	64.21189	64.21189	62.64135	91.25714	62.64135	62.64135	108.2406	101.635	108.2406	108.2406	68.35	73.43192	68.35	68.35	0
DeJong (13)	0.000101	0.000174	0.000101	0.000101	0.000119	4.54E-05	0.000119	0.000119	5.07E-05	7.07E-06	5.07E-05	5.07E-05	1.44E-05	2.09E-06	1.44E-05	1.44E-05	0
Rastrigin (14)	0.03106	0.041166	0.03106	0.03106	0.040565	0.01237	0.040565	0.040565	0.024234	0.682112	0.024234	0.024234	0.298589	0.504909	0.298589	0.298589	0
Schwefel (15)	-837.854	-837.808	-837.854	-837.854	-837.842	-837.777	-837.842	-837.842	-837.763	-837.807	-837.763	-837.763	-837.722	-837.695	-837.722	-837.722	-837.9658
Griewangk (16)	0.025417	0.020193	0.025417	0.025417	0.0261	0.024637	0.0261	0.0261	0.028015	0.024511	0.028015	0.028015	0.02306	0.024438	0.02306	0.02306	0
Ackley (17)	0.128163	0.193686	0.128163	0.128163	0.136413	0.191632	0.136413	0.136413	0.154629	0.107691	0.154629	0.154629	0.121667	0.056634	0.121667	0.121667	0
Langerman (18)	-1.40203	-1.40791	-1.40098	-1.38336	-1.37295	-1.37563	-1.38938	-1.36716	-1.32651	-1.33859	-1.35456	-1.37569	-1.30604	-1.30604	-1.30604	-1.30604	-1.5
Michaelewicz (19)	-7.16749	-7.33604	-7.28118	-7.24052	-7.13954	-7.27496	-7.3029	-7.22597	-7.05273	-7.05273	-7.05273	-7.05273	-7.14763	-7.14763	-7.14763	-7.14763	-9.66
Branin (20)	0.398011	0.398028	0.398011	0.398011	0.398047	0.397929	0.398047	0.398047	0.397921	0.397893	0.397921	0.397921	0.397896	0.397889	0.397896	0.397896	0.397887
Six Hump Camel (21)	-1.03161	-1.03162	-1.03161	-1.03161	-1.03162	-1.03163	-1.03162	-1.03162	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.03711	0.036824	0.036028	0.036948	0.038512	0.040086	0.038716	0.037928	0.044268	0.04454	0.041908	0.04409	0.057228	0.057228	0.057228	0.057228	5.46E-05
Osborne 2 (23)	0.105949	0.102362	0.104526	0.105617	0.110927	0.11091	0.11156	0.111358	0.115115	0.115115	0.115115	0.115115	0.125839	0.125839	0.125839	0.125839	0.0402
Mod Rastrigin (24)	86.56993	86.82459	86.56993	86.56993	86.33374	85.88622	86.33374	86.33374	86.89015	89.97245	86.89015	86.89015	88.04167	88.58708	88.04167	88.04167	58
Mineshaft 1 (25)	2.10866	1.935903	1.991993	1.935903	1.956148	1.8336	1.903217	1.8336	1.877641	1.89896	1.832186	1.89896	1.845641	2.108908	1.884736	2.108908	1.3805
Mineshaft 2 (26)	-1.38223	-1.39545	-1.41362	-1.39545	-1.41397	-1.39051	-1.41459	-1.39051	-1.41635	-1.32876	-1.41573	-1.32876	-1.40877	-1.31232	-1.37677	-1.31232	-1.4163535
Mineshaft 3 (27)	-6.5746	-6.82823	-6.5746	-6.5746	-6.91219	-6.97033	-6.91219	-6.91219	-6.9868	-6.99621	-6.9868	-6.9868	-6.99701	-6.9127	-6.99701	-6.99701	-7
Spherical Contours (28)	5.997541	5.997541	5.997541	5.997541	6.067851	6.067851	6.067851	6.067851	7.129421	7.129421	7.129421	7.129421	9.313409	9.313409	9.313409	9.313409	0
S1 (29)	3.85E-10	4.49E-07	2.25E-11	4.49E-07	3.08E-11	7.18E-05	9.31E-11	7.18E-05	2.72E-11	0.000173	2.84E-10	0.000173	6.64E-11	9.87E-05	3.85E-07	9.87E-05	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528936	0.529067	0.528936	0.528936	0.529009	0.528964	0.529009	0.529009	0.528964	0.528902	0.528964	0.528964	0.52891	0.528885	0.52891	0.52891	0.5289
Downhill Step (32)	9	9	9	9	9	9.006	9	9	9.012	9.034	9.012	9.012	9.013	9.052	9.013	9.013	9
Salomon (33)	0.086455	0.071211	0.086455	0.086455	0.085555	0.080302	0.085555	0.085555	0.085639	0.083487	0.085639	0.085639	0.088224	0.08349	0.088224	0.088224	0
Whitley (34)	0.752431	0.99938	0.752431	0.752431	0.70559	0.913536	0.70559	0.70559	0.809669	0.73492	0.809669	0.809669	0.651909	0.862144	0.651909	0.651909	0
Odd Square (35)	-1.00177	-1.00172	-1.00177	-1.00177	-1.00192	-1.00112	-1.00192	-1.00192	-0.99761	-0.97758	-0.99761	-0.99761	-0.9316	-0.85168	-0.9316	-0.9316	-1.14383
Storn Chebyshev (36)	4613.582	3806.592	4505.606	4697.438	4779.072	3810.964	3961.38	4573.167	6408.074	6408.074	6408.074	6408.074	6521.228	6521.228	6521.228	6521.228	0
Rana (37)	-998.587	-998.345	-998.587	-998.587	-998.546	-997.226	-998.546	-998.546	-997.169	-997.318	-997.169	-997.169	-997.391	-996.185	-997.391	-997.391	-1023.416
Rosenbrock 10D (38)	968.5334	927.9037	942.3922	901.7139	947.53	918.4831	937.3727	939.9579	931.0364	931.0364	931.0364	931.0364	868.0349	868.0349	868.0349	868.0349	0
Rosenbrock 30D (39)	19232.23	19232.23	19232.23	19232.23	19668.47	19668.47	19668.47	19668.47	25444.81	25444.81	25444.81	25444.81	34524.46	34524.46	34524.46	34524.46	0
Mod Rosenbrock 1 10D (40)	706.5452	697.5574	700.6939	713.6315	701.1692	698.8769	697.2306	697.494	711.8594	711.8594	711.8594	711.8594	710.7683	710.7683	710.7683	710.7683	0
Mod Rosenbrock 1 30D (41)	5666.674	5666.674	5666.674	5666.674	5704.082	5704.082	5704.082	5704.082	6564.919	6564.919	6564.919	6564.919	7509.809	7509.809	7509.809	7509.809	0
Mod Rosenbrock 2 10D (42)	5.293979	4.672274	5.111335	5.340235	5.442426	4.727618	5.279221	5.556913	6.137072	6.137072	6.137072	6.137072	6.016969	6.016969	6.016969	6.016969	0
Mod Rosenbrock 2 30D (43)	14.32416	13.9431	13.9431	13.9431	15.38689	15.38689	15.38689	15.38689	15.57241	15.57241	15.57241	15.57241	15.18482	15.18482	15.18482	15.18482	0
Spherical Contours 10D (44)	0.706316	0.669997	0.702795	0.739403	0.688502	0.70091	0.709555	0.692409	0.679581	0.679581	0.679581	0.679581	0.677224	0.677224	0.677224	0.677224	0
Rastrigin 10D (45)	36.13254	35.94384	36.27841	36.90472	34.05155	33.66966	34.02572	35.05909	34.73096	34.73096	34.73096	34.73096	33.86389	33.86389	33.86389	33.86389	0
Rastrigin 30D (46)	199.7876	199.7876	199.7876	199.7876	200.3187	200.3187	200.3187	200.3187	206.3459	206.3459	206.3459	206.3459	210.6346	210.6346	210.6346	210.6346	0
Schwefel 10D (47)	-3570.57	-3579.97	-3552.75	-3559.97	-3474.73	-3509.51	-3491.82	-3483.4	-3280.59	-3280.59	-3280.59	-3280.59	-3168.92	-3168.92	-3168.92	-3168.92	-4189.829
Schwefel 30D (48)	-7219.12	-7215.91	-7208.87	-7208.87	-7073.35	-7073.35	-7073.35	-7073.35	-7048.17	-7048.17	-7048.17	-7048.17	-7084.15	-7084.15	-7084.15	-7084.15	-12569.487
Griewangk 10D (49)	1.638343	1.609983	1.646276	1.613734	1.624969	1.62406	1.622146	1.640228	1.597706	1.597706	1.597706	1.597706	1.60176	1.60176	1.60176	1.60176	0
Griewangk 30D (50)	6.028609	6.028609	6.028609	6.028609	5.926295	5.926295	5.926295	5.926295	6.579206	6.579206	6.579206	6.579206	7.793015	7.793015	7.793015	7.793015	0
Salomon 10D (51)	1.199705	1.189348	1.185259	1.18092	1.182255	1.190449	1.198794	1.18948	1.242659	1.242659	1.242659	1.242659	1.255865	1.255865	1.255865	1.255865	0
Salomon 30D (52)	8.985719	8.985719	8.985719	8.985719	12.80663	12.80663	12.80663	12.80663	16.06182	16.06182	16.06182	16.06182	16.63137	16.63137	16.63137	16.63137	0
Odd Square 10D (53)	-0.10409	-0.22861	-0.29046	-0.30082	-0.11705	-0.23823	-0.3413	-0.32125	-0.05992	-0.05992	-0.05992	-0.05992	-0.06794	-0.06794	-0.06794	-0.06794	-1.14383
Whitley 10D (54)	10817462	13184926	14638339	14400193	11282747	11089122	11452647	12476458	11794321	11794321	11794321	11794321	10607619	10607619	10607619	10607619	0
Whitley 30D (55)	9.85E+09	9.85E+09	9.85E+09	9.85E+09	1.03E+10	1.03E+10	1.03E+10	1.03E+10	2.39E+10	2.39E+10	2.39E+10	2.39E+10	6.75E+10	6.75E+10	6.75E+10	6.75E+10	0
Rana 10D (56)	-3320.16	-3353.31	-3375.31	-3387.16	-3313.33	-3317.19	-3331.84	-3322.03	-3268.06	-3268.06	-3268.06	-3268.06	-3261.9	-3261.9	-3261.9	-3261.9	-5117.08
Rana 30D (57)	-6585.24	-6586.86	-6796.56	-6796.56	-6553.17	-6553.17	-6553.17	-6553.17	-6763.16	-6763.16	-6763.16	-6763.16	-6879.56	-6879.56	-6879.56	-6879.56	-15351.24

APPENDIX D2: ST. DEV. FOR SMOA WITH RAZOR VEG. STATE

Results St. Dev. (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.001533	0.00171	0.001533	0.001533	0.001775	0.002063	0.001775	0.001775	0.002421	0.001011	0.002421	0.002421	0.001036	0.000399	0.001036	0.001036
McCormic (2)	2.53E-06	4.92E-07	2.53E-06	2.53E-06	5.26E-07	8.35E-08	5.26E-07	5.26E-07	1.61E-07	1.19E-08	1.61E-07	1.61E-07	2.31E-08	4.66E-09	2.31E-08	2.31E-08
Box and Betts (3)	7.69E-09	3.27E-09	1.35E-08	1.78E-08	2.14E-09	1.20E-09	4.71E-09	9.32E-09	4.86E-10	3.09E-10	1.11E-09	2.36E-09	2.75E-10	1.92E-10	5.63E-10	7.84E-10
Goldstein (4)	0.00013	6.84E-05	0.00013	0.00013	6.67E-05	3.19E-05	6.67E-05	6.67E-05	9.14E-06	1.06E-06	9.14E-06	9.14E-06	2.07E-06	4.85E-07	2.07E-06	2.07E-06
Easom (5)	0.004825	0.008276	0.004825	0.004825	0.005628	0.006518	0.005628	0.005628	0.005631	0.006573	0.005631	0.005631	0.004406	0.005739	0.004406	0.004406
Mod Rosenbrock 1 (6)	0.039006	0.071514	0.039006	0.039006	0.047551	0.058118	0.047551	0.047551	0.045531	0.0365	0.045531	0.045531	0.031194	0.017311	0.031194	0.031194
Mod Rosenbrock 2 (7)	0.537612	0.579845	0.537612	0.537612	0.497417	0.675154	0.497417	0.497417	0.556916	0.456461	0.556916	0.556916	0.4806	0.337836	0.4806	0.4806
Bohachevsky (8)	0.778429	0.752753	0.778429	0.778429	0.860858	0.983304	0.860858	0.860858	1.092949	0.829654	1.092949	1.092949	0.944243	0.7014	0.944243	0.944243
Powell (9)	148342.9	148342.9	126238.4	249561.7	161199.4	161199.4	122070	114516.3	189793.5	189793.5	106024.7	97948.92	146111.2	146111.2	151586	118844.9
Wood (10)	67533.79	67533.79	59384.34	57792.25	65340.27	65340.27	74005.52	72498.47	56644.8	56644.8	63028.36	65681.34	71052.24	71052.24	68893.68	59775.02
Beale (11)	0.367139	0.506346	0.367139	0.367139	0.45837	0.446674	0.45837	0.45837	0.394286	0.356989	0.394286	0.394286	0.45652	0.580513	0.45652	0.45652
Engvall (12)	2.121297	1.300183	2.121297	2.121297	2.150967	1.440869	2.150967	2.150967	3.150705	1.348709	3.150705	3.150705	1.97306	1.218567	1.97306	1.97306
DeJong (13)	1.10E-05	2.70E-05	1.10E-05	1.10E-05	1.57E-05	5.28E-06	1.57E-05	1.57E-05	5.84E-06	9.80E-07	5.84E-06	5.84E-06	1.47E-06	2.79E-07	1.47E-06	1.47E-06
Rastrigin (14)	0.004263	0.006503	0.004263	0.004263	0.003997	0.001193	0.003997	0.003997	0.000902	0.422815	0.000902	0.000902	0.02357	0.416964	0.02357	0.02357
Schwefel (15)	0.011486	0.012775	0.011486	0.011486	0.011348	0.013545	0.011348	0.011348	0.014835	0.011441	0.014835	0.014835	0.009627	0.017706	0.009627	0.009627
Griewangk (16)	0.003739	0.003384	0.003739	0.003739	0.003951	0.00469	0.003951	0.003951	0.004619	0.0042	0.004619	0.004619	0.004453	0.003035	0.004453	0.004453
Ackley (17)	0.018494	0.026462	0.018494	0.018494	0.01858	0.022318	0.01858	0.01858	0.023053	0.014646	0.023053	0.023053	0.019188	0.008571	0.019188	0.019188
Langerman (18)	0.017963	0.013904	0.010092	0.018446	0.013986	0.015641	0.011174	0.01546	0.016661	0.016532	0.01276	0.008404	0.020672	0.020413	0.016673	0.007759
Michaelewicz (19)	0.292335	0.360713	0.341365	0.332513	0.332454	0.354508	0.353309	0.308495	0.266411	0.366805	0.39443	0.353743	0.262416	0.355189	0.35495	0.366502
Branin (20)	1.59E-05	1.12E-05	1.59E-05	1.59E-05	1.79E-05	4.55E-06	1.79E-05	1.79E-05	3.96E-06	7.09E-07	3.96E-06	3.96E-06	1.06E-06	1.51E-07	1.06E-06	1.06E-06
Six Hump Camel (21)	3.02E-06	2.68E-06	3.02E-06	3.02E-06	9.74E-07	2.65E-07	9.74E-07	9.74E-07	4.29E-07	2.06E-08	4.29E-07	4.29E-07	4.63E-08	7.65E-09	4.63E-08	4.63E-08
Osborne 1 (22)	0.006144	0.005198	0.005058	0.005195	0.005975	0.00649	0.005832	0.006238	0.005886	0.006429	0.005335	0.006605	0.006207	0.006289	0.006442	0.006076
Osborne 2 (23)	0.007849	0.008167	0.00975	0.010234	0.009375	0.008833	0.009877	0.009064	0.008655	0.009857	0.010147	0.010067	0.009345	0.008036	0.010559	0.010681
Mod Rastrigin (24)	1.710973	1.782449	1.710973	1.710973	1.976972	1.785739	1.976972	1.976972	1.93294	3.866131	1.93294	1.93294	2.204981	3.770517	2.204981	2.204981
Mineshaft 1 (25)	0.214464	0.189108	0.178925	0.189108	0.148859	0.10524	0.109061	0.10524	0.066205	0.037301	0.057742	0.037301	0.048189	0.080767	0.039877	0.080767
Mineshaft 2 (26)	0.09871	0.038468	0.001783	0.038468	5.63E-06	0.055585	2.27E-07	0.055585	2.66E-09	5.50E-12	3.01E-10	5.50E-12	2.98E-10	7.04E-09	7.40E-11	7.04E-09
Mineshaft 3 (27)	0.439964	0.383948	0.439964	0.439964	0.156484	0.089619	0.156484	0.156484	0.002448	0.001094	0.002448	0.002448	0.000474	0.00018	0.000474	0.000474
Spherical Contours (28)	0.480208	0.430964	0.439703	0.439703	0.447695	0.445138	0.465809	0.465809	0.357818	0.35882	0.358044	0.360123	0.404981	0.404981	0.404981	0.404981
S1 (29)	1.01E-11	1.13E-14	5.10E-13	1.13E-14	6.62E-13	5.50E-15	4.99E-14	5.50E-15	4.16E-14	4.04E-16	4.91E-15	4.04E-16	7.68E-15	2.89E-15	3.67E-15	2.89E-15
S2 (30)	2.03E-10	8.39E-10	2.03E-10	2.03E-10	3.37E-10	2.00E-10	3.37E-10	3.37E-10	1.50E-10	3.54E-11	1.50E-10	1.50E-10	3.90E-11	1.74E-11	3.90E-11	3.90E-11
S3 (31)	7.13E-06	3.19E-05	7.13E-06	7.13E-06	2.72E-05	1.58E-05	2.72E-05	2.72E-05	1.81E-05	4.91E-06	1.81E-05	1.81E-05	5.98E-06	2.02E-06	5.98E-06	5.98E-06
Downhill Step (32)	0	0	0	0	0	0	0	0	0.085182	0.099015	0.085182	0.085182	0.049749	0.102034	0.049749	0.049749
Salomon (33)	0.027978	0.015682	0.027978	0.027978	0.029113	0.022064	0.029113	0.029113	0.02694	0.027625	0.02694	0.02694	0.029995	0.031535	0.029995	0.029995
Whitley (34)	0.082166	0.148987	0.082166	0.082166	0.093499	0.153289	0.093499	0.093499	0.170368	0.156446	0.170368	0.170368	0.089608	0.193196	0.089608	0.089608
Odd Square (35)	0.000788	0.000781	0.000788	0.000788	0.000777	0.000873	0.000777	0.000777	0.000658	0.002945	0.000658	0.000658	0.002395	0.107832	0.002395	0.002395
Storn Chebyshev (36)	559.3645	423.7994	351.4214	385.5894	663.7113	369.9931	359.3044	409.2776	537.3978	336.1691	297.9012	513.8693	528.5746	521.7491	391.5115	632.4365
Rana (37)	10.92179	11.45291	10.92179	10.92179	11.30899	11.77784	11.30899	11.30899	8.503234	11.81372	8.503234	8.503234	12.30624	10.48614	12.30624	12.30624
Rosenbrock 10D (38)	155.1676	135.5434	147.5508	159.8412	153.9425	159.0482	146.2384	148.1223	133.0452	148.2492	158.053	148.8111	140.8449	143.633	132.919	139.819
Rosenbrock 30D (39)	1988.824	1867.39	2152.556	2152.556	2122.301	2033.272	2120.711	2120.711	2470.167	2580.777	2360.162	2405.429	2121.745	2121.745	2121.745	2121.745
Mod Rosenbrock 1 10D (40)	78.38568	94.32917	82.87979	70.42398	87.68717	85.44407	80.17623	74.99096	87.23694	93.69463	85.66351	87.56092	82.82693	81.72278	71.2062	72.50885
Mod Rosenbrock 1 30D (41)	347.6844	351.1598	335.7913	335.7913	367.4028	335.1538	326.9561	326.9561	348.2605	336.9184	345.6154	338.1215	353.5814	353.5814	353.5814	353.5814
Mod Rosenbrock 2 10D (42)	0.752968	0.732488	0.899367	1.131692	0.947127	0.770665	0.846996	1.366612	0.920896	0.89258	0.774725	0.946509	0.952186	0.83702	0.79374	1.054119
Mod Rosenbrock 2 30D (43)	1.564983	1.480102	1.743774	1.743774	1.616339	1.53214	1.469275	1.469275	1.904327	1.6941	1.560547	1.710757	2.565859	2.565859	2.549917	2.565859
Spherical Contours 10D (44)	0.115726	0.109105	0.110832	0.107663	0.112159	0.117796	0.105595	0.102102	0.098121	0.116221	0.092783	0.096338	0.104319	0.121881	0.11772	0.108028
Rastrigin 10D (45)	3.773964	4.205063	3.637787	3.992308	3.734364	3.546616	3.741231	4.099111	3.974465	3.353443	4.111302	5.010759	3.802418	3.97473	3.643057	3.839538
Rastrigin 30D (46)	9.003231	9.713451	10.88188	10.88188	9.027171	10.53551	12.8488	12.8488	13.58152	11.71329	12.44196	11.66518	8.968027	8.968027	8.968027	8.968027
Schwefel 10D (47)	66.03801	70.50295	61.35109	94.55275	65.78706	73.72782	57.211	60.02956	75.91161	70.3974	70.11273	101.694	90.74791	84.45049	71.47346	81.33298
Schwefel 30D (48)	329.9973	300.6373	404.1197	404.1197	344.7144	308.1704	352.1619	352.1619	321.8364	273.6032	344.552	341.3364	260.8888	260.9927	262.5896	258.3292
Griewangk 10D (49)	0.10525	0.095158	0.095442	0.091308	0.093705	0.084081	0.094858	0.093992	0.090409	0.098643	0.085771	0.08225	0.093354	0.094135	0.094002	0.092527
Griewangk 30D (50)	0.349506	0.366067	0.318358	0.318358	0.351553	0.3981	0.357523	0.357523	0.312625	0.31194	0.311694	0.311483	0.380928	0.380928	0.380928	0.380928
Salomon 10D (51)	0.120752	0.118654	0.098845	0.103058	0.122611	0.113073	0.100758	0.109448	0.106944	0.109456	0.106843	0.097861	0.096467	0.095987	0.09632	0.105184
Salomon 30D (52)	0.3834	0.330264	0.29886	0.29886	0.243568	0.324371	0.281647	0.281647	0.45302	0.45302	0.45302	0.45302	0.673355	0.673355	0.673355	0.673355
Odd Square 10D (53)	0.060175	0.057522	0.074226	0.085401	0.061681	0.06546	0.060882	0.118546	0.082398	0.061174	0.054744	0.135803	0.101126	0.062129	0.045995	0.104211
Whitley 10D (54)	1851388	1738694	2006825	1786516	1771394	1738480	1631017	2015432	1490261	1755616	1584331	1464308	1504837	1328986	1568828	2130755
Whitley 30D (55)	1.62E+09	1.32E+09	1.66E+09	1.66E+09	1.39E+09	1.38E+09	1.47E+09	1.47E+09	1.38E+09	1.39E+09	1.38E+09	1.38E+09	1.42E+09	1.42E+09	1.42E+09	1.42E+09
Rana 10D (56)	103.7626	100.7395	139.7557	102.3649	128.2083	99.82768	103.552	103.0047	117.9668	115.3123	113.2	139.7758	95.9865	119.8415	90.7317	122.024
Rana 30D (57)	307.3517	304.0927	293.476	293.476	298.1478	318.077	277.022	277.022	304.6747	293.0235	297.045	296.948	275.1459	314.4612	314.2847	315.9394

Results St. Dev. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.002824	0.004475	0.002824	0.002824	0.003762	0.003248	0.003762	0.003762	0.004779	0.001869	0.004779	0.004779	0.002419	0.000703	0.002419	0.002419
McCormic (2)	4.26E-06	1.66E-06	4.26E-06	4.26E-06	1.23E-06	1.92E-07	1.23E-06	1.23E-06	3.59E-07	2.50E-08	3.59E-07	3.59E-07	4.81E-08	1.12E-08	4.81E-08	4.81E-08
Box and Betts (3)	1.15E-08	5.92E-09	2.11E-08	3.14E-08	3.61E-09	1.92E-09	8.30E-09	1.54E-08	1.03E-09	5.46E-10	1.79E-09	3.57E-09	3.48E-09	1.08E-09	9.92E-10	1.61E-09
Goldstein (4)	0.000281	8.89E-05	0.000281	0.000281	9.01E-05	3.34E-05	9.01E-05	9.01E-05	1.96E-05	2.87E-06	1.96E-05	1.96E-05	4.67E-06	8.65E-07	4.67E-06	4.67E-06
Easom (5)	0.009459	0.01172	0.009459	0.009459	0.011922	0.016552	0.011922	0.011922	0.009857	0.01315	0.009857	0.009857	0.007926	0.009575	0.007926	0.007926
Mod Rosenbrock 1 (6)	0.061295	0.088746	0.061295	0.061295	0.073505	0.073473	0.073505	0.073505	0.078318	0.054803	0.078318	0.078318	0.057202	0.025128	0.057202	0.057202
Mod Rosenbrock 2 (7)	0.698797	0.751035	0.698797	0.698797	0.712867	0.838778	0.712867	0.712867	0.769207	0.603047	0.769207	0.769207	0.674866	0.449003	0.674866	0.674866
Bohachevsky (8)	1.397655	1.891485	1.397655	1.397655	1.665145	2.422375	1.665145	1.665145	2.450797	1.94365	2.450797	2.450797	1.642431	1.584747	1.642431	1.642431
Powell (9)	224061.8	224061.8	224759.6	301201.2	286730.6	286730.6	200480.2	213600.8	254272.9	254272.9	201632.9	150812.4	232737.5	232737.5	222879.5	200190.2
Wood (10)	112251.1	112251.1	115478.7	108326.2	95445.93	95445.93	101040.4	103872.7	97286.49	97286.49	106770.8	94397.71	108223.6	108223.6	91525.75	107575.9
Beale (11)	1.579879	1.28556	1.579879	1.579879	1.418333	1.299221	1.418333	1.418333	2.158516	1.663592	2.158516	2.158516	1.23685	1.344466	1.23685	1.23685
Engvall (12)	4.316578	4.996169	4.316578	4.316578	4.994454	5.021948	4.994454	4.994454	8.322091	5.809706	8.322091	8.322091	43.88927	5.967465	43.88927	43.88927
DeJong (13)	2.77E-05	4.05E-05	2.77E-05	2.77E-05	3.08E-05	1.48E-05	3.08E-05	3.08E-05	1.18E-05	1.84E-06	1.18E-05	1.18E-05	2.69E-06	5.23E-07	2.69E-06	2.69E-06
Rastrigin (14)	0.007936	0.010903	0.007936	0.007936	0.005905	0.00222	0.005905	0.005905	0.001767	0.425858	0.001767	0.001767	0.059076	0.415957	0.059076	0.059076
Schwefel (15)	0.022396	0.030602	0.022396	0.022396	0.01985	0.030905	0.01985	0.01985	0.025692	0.024208	0.025692	0.025692	0.028712	0.03224	0.028712	0.028712
Griewangk (16)	0.005366	0.00675	0.005366	0.005366	0.006346	0.008416	0.006346	0.006346	0.006746	0.007516	0.006746	0.006746	0.005933	0.006134	0.005933	0.005933
Ackley (17)	0.030575	0.042513	0.030575	0.030575	0.033494	0.044401	0.033494	0.033494	0.037022	0.028532	0.037022	0.037022	0.030532	0.011704	0.030532	0.030532
Langerman (18)	0.027207	0.023614	0.01688	0.032237	0.022204	0.020387	0.017463	0.022806	0.030979	0.030239	0.021598	0.014721	0.031643	0.030309	0.031956	0.018363
Michaelewicz (19)	0.294187	0.372413	0.348975	0.358272	0.341772	0.379382	0.346769	0.347967	0.284615	0.340717	0.413792	0.373633	0.270392	0.351647	0.368512	0.384218
Branin (20)	3.91E-05	3.00E-05	3.91E-05	3.91E-05	4.06E-05	8.09E-06	4.06E-05	4.06E-05	7.76E-06	1.21E-06	7.76E-06	7.76E-06	1.71E-06	3.19E-07	1.71E-06	1.71E-06
Six Hump Camel (21)	4.07E-06	2.81E-06	4.07E-06	4.07E-06	2.43E-06	4.07E-07	2.43E-06	2.43E-06	6.53E-07	7.86E-08	6.53E-07	6.53E-07	1.23E-07	1.78E-08	1.23E-07	1.23E-07
Osborne 1 (22)	0.006685	0.007288	0.006543	0.007629	0.007709	0.007176	0.007657	0.007309	0.007527	0.008169	0.00835	0.008449	0.008445	0.008613	0.008513	0.007892
Osborne 2 (23)	0.009657	0.009561	0.010896	0.01116	0.010341	0.009932	0.01186	0.01513	0.010068	0.011228	0.013871	0.011435	0.010068	0.009353	0.011354	0.011051
Mod Rastrigin (24)	1.900597	1.838657	1.900597	1.900597	2.055901	1.929489	2.055901	2.055901	2.21297	3.19652	2.21297	2.21297	2.503413	3.509133	2.503413	2.503413
Mineshaft 1 (25)	0.215646	0.194834	0.162761	0.194834	0.144537	0.103222	0.100186	0.103222	0.062886	0.090496	0.059629	0.090496	0.057515	0.183781	0.075761	0.183781
Mineshaft 2 (26)	0.104448	0.055056	0.001783	0.055056	5.63E-06	0.05558	2.28E-07	0.05558	9.73E-06	0.036801	1.80E-09	0.036801	9.57E-09	0.06085	0.040123	0.06085
Mineshaft 3 (27)	0.54771	0.383581	0.54771	0.54771	0.156058	0.08958	0.156058	0.156058	0.004664	0.0011	0.004664	0.004664	0.00064	0.000189	0.00064	0.00064
Spherical Contours (28)	0.52173	0.50853	0.467372	0.467372	0.482725	0.47047	0.4649	0.4649	0.416601	0.416601	0.416601	0.416601	0.475357	0.475357	0.475357	0.475357
S1 (29)	1.82E-11	6.03E-10	2.03E-12	6.03E-10	1.73E-12	1.45E-14	5.91E-13	1.45E-14	1.80E-13	6.28E-06	2.26E-12	6.28E-06	7.94E-14	2.91E-05	2.43E-13	2.91E-05
S2 (30)	1.15E-09	4.87E-09	1.15E-09	1.15E-09	4.60E-10	8.36E-10	4.60E-10	4.60E-10	7.35E-10	1.14E-10	7.35E-10	7.35E-10	2.46E-10	4.60E-11	2.46E-10	2.46E-10
S3 (31)	2.54E-05	5.86E-05	2.54E-05	2.54E-05	4.36E-05	3.13E-05	4.36E-05	4.36E-05	3.00E-05	8.06E-06	3.00E-05	3.00E-05	9.01E-06	3.51E-06	9.01E-06	9.01E-06
Downhill Step (32)	0	0	0	0	0	0	0	0	0.085182	0.100717	0.085182	0.085182	0.049749	0.102034	0.049749	0.049749
Salomon (33)	0.033579	0.035168	0.033579	0.033579	0.034006	0.037772	0.034006	0.034006	0.032993	0.039016	0.032993	0.032993	0.033428	0.03745	0.033428	0.033428
Whitley (34)	0.179573	0.288003	0.179573	0.179573	0.16506	0.266576	0.16506	0.16506	0.264873	0.226656	0.264873	0.264873	0.159278	0.229734	0.159278	0.159278
Odd Square (35)	0.001424	0.001358	0.001424	0.001424	0.001205	0.001231	0.001205	0.001205	0.000984	0.003784	0.000984	0.000984	0.007885	0.109452	0.007885	0.007885
Storn Chebyshev (36)	984.0927	626.8597	3845.648	2408.728	842.6227	886.7903	709.9932	828.9972	1091.053	666.3551	603.4901	1085.338	1134.305	1156.449	890.6488	847.1771
Rana (37)	9.686066	10.3821	9.686066	9.686066	10.02031	10.72244	10.02031	10.02031	10.5069	10.54791	10.5069	10.5069	11.5471	9.272778	11.5471	11.5471
Rosenbrock 10D (38)	195.3801	178.1814	176.8862	199.3749	179.7924	165.3119	187.1601	188.4466	180.2638	173.994	177.3843	182.9734	177.5078	169.0809	172.0599	168.6397
Rosenbrock 30D (39)	2365.103	2283.641	2332.724	2332.724	2589.639	2547.385	2376.019	2376.019	2637.014	2637.014	2637.014	2637.014	2585.243	2585.243	2585.243	2585.243
Mod Rosenbrock 1 10D (40)	94.33785	99.45118	88.58103	85.40848	89.36306	95.21339	85.67472	86.09784	97.54804	104.3832	103.6669	99.57409	89.28588	80.3428	82.02383	82.16312
Mod Rosenbrock 1 30D (41)	380.0179	395.0724	377.8164	377.8164	371.5823	344.374	365.9994	365.9994	366.1108	366.1108	366.1108	366.1108	373.7269	373.7269	373.7269	373.7269
Mod Rosenbrock 2 10D (42)	1.034391	0.996624	1.325026	1.260692	1.164667	1.041149	1.049857	1.569541	1.28966	1.049689	0.991557	1.316309	1.319117	1.070507	1.102653	1.288665
Mod Rosenbrock 2 30D (43)	2.495584	2.047435	2.48958	2.48958	2.034394	1.895374	2.176419	2.176419	3.250536	3.250536	3.250536	3.250536	3.561087	3.561087	3.561087	3.561087
Spherical Contours 10D (44)	0.124403	0.122435	0.130263	0.130357	0.129784	0.127955	0.109921	0.113236	0.127885	0.112538	0.101857	0.117299	0.120069	0.116225	0.118374	0.120645
Rastrigin 10D (45)	3.26703	4.271784	4.12891	4.080129	4.070739	4.200764	5.496458	4.154854	4.129071	3.991919	4.132832	4.892883	5.001572	4.570816	4.478223	4.937821
Rastrigin 30D (46)	11.0833	11.92732	12.92329	12.92329	9.262763	11.42969	12.27992	12.27992	12.49263	12.49263	12.49263	12.49263	9.390574	9.390574	9.390574	9.390574
Schwefel 10D (47)	75.32088	81.70536	77.18526	94.20317	70.04485	91.67375	85.11082	109.1433	98.84674	100.995	85.44801	115.9472	108.4164	109.1074	116.3915	114.3875
Schwefel 30D (48)	338.3628	347.2166	376.7478	376.7478	315.9185	333.7635	374.4775	374.4775	272.9183	264.4172	261.2398	258.0826	248.5979	248.5979	248.5979	248.5979
Griewangk 10D (49)	0.117067	0.117144	0.115056	0.109154	0.104829	0.107429	0.096824	0.110216	0.099059	0.110613	0.099205	0.09425	0.112866	0.103939	0.107556	0.106981
Griewangk 30D (50)	0.382352	0.408445	0.323823	0.323823	0.409656	0.403508	0.440054	0.440054	0.363393	0.363393	0.363393	0.363393	0.404966	0.404966	0.404966	0.404966
Salomon 10D (51)	0.125864	0.119478	0.108668	0.117745	0.126157	0.104067	0.116809	0.131535	0.10881	0.100924	0.108445	0.109486	0.115233	0.108264	0.112241	0.10733
Salomon 30D (52)	0.369951	0.416587	0.48411	0.48411	0.6816	0.6816	0.6816	0.6816	0.946258	0.946258	0.946258	0.946258	1.537085	1.537085	1.537085	1.537085
Odd Square 10D (53)	0.0583	0.063966	0.085106	0.103959	0.064079	0.065464	0.06078	0.123821	0.078214	0.062229	0.064788	0.149238	0.093638	0.068463	0.060008	0.107129
Whitley 10D (54)	2843025	3113771	2987288	3045868	2404838	3162530	2659399	2633605	2730086	2621021	2476355	3114375	2811015	3077874	2992036	2895490
Whitley 30D (55)	2.05E+09	1.89E+09	1.9E+09	1.9E+09	1.93E+09	1.86E+09	1.86E+09	1.86E+09	2.03E+09	2.03E+09	2.03E+09	2.03E+09	2.52E+09	2.52E+09	2.52E+09	2.52E+09
Rana 10D (56)	115.1852	117.2172	144.3313	112.4641	131.2215	109.8659	109.7588	98.68654	111.19	124.9053	120.7072	136.1741	109.5392	136.6149	108.4064	135.6229
Rana 30D (57)	289.7626	303.1311	301.3399	301.3399	364.1493	302.4577	325.1037	325.1037	348.2209	300.2164	331.5743	332.3019	292.7167	292.7167	292.7167	292.7167

Results St. Dev. (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.014486	0.019989	0.014486	0.014486	0.01474	0.025605	0.01474	0.01474	0.016987	0.017558	0.016987	0.016987	0.014505	0.005488	0.014505	0.014505
McCormic (2)	1.93E-05	3.59E-06	1.93E-05	1.93E-05	6.66E-06	8.85E-07	6.66E-06	6.66E-06	1.76E-06	4.05E-06	1.76E-06	1.76E-06	3.87E-07	0.00131	3.87E-07	3.87E-07
Box and Betts (3)	3.20E-08	1.89E-08	6.18E-08	9.28E-08	1.21E-08	1.36E-08	1.98E-08	5.01E-08	2.55E-06	3.28E-08	1.32E-08	2.39E-08	1.58E-07	4.20E-07	2.12E-06	5.12E-08
Goldstein (4)	0.001584	0.00033	0.001584	0.001584	0.000591	8.38E-05	0.000591	0.000591	0.000109	0.000126	0.000109	0.000109	0.280259	7.68E-05	0.280259	0.280259
Easom (5)	0.044553	0.074997	0.044553	0.044553	0.046992	0.062191	0.046992	0.046992	0.059246	0.080509	0.059246	0.059246	0.082531	0.09937	0.082531	0.082531
Mod Rosenbrock 1 (6)	0.165689	0.252028	0.165689	0.165689	0.203894	0.299372	0.203894	0.203894	0.21496	0.14472	0.21496	0.21496	0.172663	0.084258	0.172663	0.172663
Mod Rosenbrock 2 (7)	1.393438	1.54042	1.393438	1.393438	1.395947	1.513215	1.395947	1.395947	1.556748	1.154213	1.556748	1.556748	1.212383	0.804453	1.212383	1.212383
Bohachevsky (8)	7.919033	12.09344	7.919033	7.919033	9.476934	12.9501	9.476934	9.476934	8.373251	9.426922	8.373251	8.373251	9.618719	11.70148	9.618719	9.618719
Powell (9)	956993.2	956993.2	777219.5	726528.7	780771.7	780771.7	613419.9	644755	693365.5	693365.5	656386	471717.4	785596.1	785596.1	773200.3	785596.1
Wood (10)	267339.1	267339.1	273733.1	1191277	270627.9	270627.9	345772.1	268237.4	266921.3	266921.3	307199.1	289183.4	253432.5	253432.5	253432.5	251481.4
Beale (11)	5.302145	42.07541	5.302145	5.302145	26.49696	64.98932	26.49696	26.49696	68.31395	251.0043	68.31395	68.31395	69.54549	39.99002	69.54549	69.54549
Engvall (12)	152.2839	268.5179	152.2839	152.2839	90.5168	175.126	90.5168	90.5168	355.0663	204.8208	355.0663	355.0663	142.139	121.8372	142.139	142.139
DeJong (13)	0.000118	0.000171	0.000118	0.000118	0.000118	4.40E-05	0.000118	0.000118	4.71E-05	6.67E-06	4.71E-05	4.71E-05	1.60E-05	2.21E-06	1.60E-05	1.60E-05
Rastrigin (14)	0.027331	0.057772	0.027331	0.027331	0.039512	0.012432	0.039512	0.039512	0.139989	0.517197	0.139989	0.139989	0.311083	0.423536	0.311083	0.311083
Schwefel (15)	0.133205	0.154168	0.133205	0.133205	0.137412	0.205403	0.137412	0.137412	0.223773	0.149182	0.223773	0.223773	0.219081	0.249473	0.219081	0.219081
Griewangk (16)	0.013751	0.017028	0.013751	0.013751	0.014302	0.015835	0.014302	0.014302	0.013861	0.016128	0.013861	0.013861	0.013137	0.015722	0.013137	0.013137
Ackley (17)	0.080639	0.134928	0.080639	0.080639	0.100474	0.137836	0.100474	0.100474	0.142872	0.069297	0.142872	0.142872	0.108994	0.035386	0.108994	0.108994
Langerman (18)	0.065324	0.057785	0.07504	0.086515	0.101769	0.084912	0.086791	0.128344	0.085472	0.088149	0.081416	0.079156	0.124128	0.124128	0.124128	0.124128
Michaelewicz (19)	0.35715	0.424474	0.409319	0.415294	0.312005	0.393083	0.386162	0.425713	0.302737	0.302737	0.302737	0.302737	0.278512	0.278512	0.278512	0.278512
Branin (20)	0.000191	0.000135	0.000191	0.000191	0.000219	4.99E-05	0.000219	0.000219	3.39E-05	5.76E-06	3.39E-05	3.39E-05	8.93E-06	1.75E-06	8.93E-06	8.93E-06
Six Hump Camel (21)	2.51E-05	7.20E-06	2.51E-05	2.51E-05	1.07E-05	2.40E-06	1.07E-05	1.07E-05	2.99E-06	4.56E-07	2.99E-06	2.99E-06	4.90E-07	1.82E-07	4.90E-07	4.90E-07
Osborne 1 (22)	0.016117	0.015141	0.016615	0.015951	0.014789	0.018158	0.018525	0.017617	0.017876	0.018585	0.017359	0.017941	0.061544	0.061544	0.061544	0.061544
Osborne 2 (23)	0.017349	0.016323	0.018768	0.017619	0.021283	0.020583	0.020611	0.020462	0.018592	0.018592	0.018592	0.018592	0.021323	0.021323	0.021323	0.021323
Mod Rastrigin (24)	2.037004	1.981285	2.037004	2.037004	2.085457	2.075781	2.085457	2.085457	2.386478	3.061153	2.386478	2.386478	2.97422	2.955444	2.97422	2.97422
Mineshaft 1 (25)	0.190807	0.189307	0.134203	0.189307	0.136014	0.12306	0.093518	0.12306	0.065106	0.161471	0.098022	0.161471	0.080799	0.216105	0.131519	0.216105
Mineshaft 2 (26)	0.109585	0.076593	0.024119	0.076593	0.02345	0.085643	0.017274	0.085643	9.72E-06	0.142103	0.006119	0.142103	0.044691	0.143819	0.103563	0.143819
Mineshaft 3 (27)	0.683084	0.382246	0.683084	0.683084	0.164146	0.090564	0.164146	0.164146	0.016376	0.015595	0.016376	0.016376	0.003411	0.703798	0.003411	0.003411
Spherical Contours (28)	0.634097	0.634097	0.634097	0.634097	0.61913	0.61913	0.61913	0.61913	0.745879	0.745879	0.745879	0.745879	1.121056	1.121056	1.121056	1.121056
S1 (29)	9.50E-10	4.44E-06	3.85E-11	4.44E-06	6.81E-11	0.000555	8.62E-10	0.000555	2.21E-10	0.000833	2.79E-09	0.000833	5.92E-10	0.000275	3.26E-06	0.000275
S2 (30)	3.49E-08	1.10E-07	3.49E-08	3.49E-08	2.95E-08	5.57E-08	2.95E-08	2.95E-08	1.57E-08	4.70E-09	1.57E-08	1.57E-08	4.19E-09	1.61E-09	4.19E-09	4.19E-09
S3 (31)	0.000116	0.000168	0.000116	0.000116	0.000146	7.58E-05	0.000146	0.000146	7.07E-05	2.08E-05	7.07E-05	7.07E-05	2.53E-05	8.22E-06	2.53E-05	2.53E-05
Downhill Step (32)	0	0	0	0	0	0.059699	0	0	0.085182	0.149144	0.085182	0.085182	0.075703	0.136733	0.075703	0.075703
Salomon (33)	0.028911	0.043896	0.028911	0.028911	0.027451	0.035202	0.027451	0.027451	0.026225	0.03099	0.026225	0.026225	0.021679	0.032118	0.021679	0.021679
Whitley (34)	0.510634	0.532861	0.510634	0.510634	0.550136	0.656685	0.550136	0.550136	0.599382	0.569826	0.599382	0.599382	0.546888	0.616493	0.546888	0.546888
Odd Square (35)	0.00645	0.006005	0.00645	0.00645	0.005546	0.00741	0.005546	0.005546	0.019085	0.057968	0.019085	0.019085	0.080704	0.102141	0.080704	0.080704
Storn Chebyshev (36)	4471.468	4505.282	5168.583	6892.255	4210.209	3252.058	3375.456	4000.699	5040.131	5040.131	5040.131	5040.131	4355.599	4355.599	4355.599	4355.599
Rana (37)	6.729544	7.477388	6.729544	6.729544	7.061786	6.151085	7.061786	7.061786	7.048725	8.435076	7.048725	7.048725	8.015266	8.055899	8.015266	8.015266
Rosenbrock 10D (38)	323.8626	288.1792	289.3253	343.2493	321.1786	312.0014	293.5007	301.2077	278.5185	278.5185	278.5185	278.5185	258.8279	258.8279	258.8279	258.8279
Rosenbrock 30D (39)	3200.956	3200.956	3200.956	3200.956	3305.561	3305.561	3305.561	3305.561	3566.943	3566.943	3566.943	3566.943	6323.958	6323.958	6323.958	6323.958
Mod Rosenbrock 1 10D (40)	129.4234	130.5824	125.6696	127.9222	112.5625	114.655	117.8362	111.7582	104.6836	104.6836	104.6836	104.6836	114.3402	114.3402	114.3402	114.3402
Mod Rosenbrock 1 30D (41)	461.5575	461.5575	461.5575	461.5575	424.7642	424.7642	424.7642	424.7642	1684.201	1684.201	1684.201	1684.201	766.7308	766.7308	766.7308	766.7308
Mod Rosenbrock 2 10D (42)	1.972687	2.055406	2.476718	2.293483	2.040214	2.030827	2.373332	2.299486	2.280365	2.280365	2.280365	2.280365	2.819627	2.819627	2.819627	2.819627
Mod Rosenbrock 2 30D (43)	7.42338	6.780266	6.780266	6.780266	6.916187	6.916187	6.916187	6.916187	6.277924	6.277924	6.277924	6.277924	6.414046	6.414046	6.414046	6.414046
Spherical Contours 10D (44)	0.159159	0.170079	0.160241	0.163332	0.143338	0.151668	0.145348	0.145426	0.157022	0.157022	0.157022	0.157022	0.170749	0.170749	0.170749	0.170749
Rastrigin 10D (45)	4.971327	5.910123	5.954585	7.145157	5.16169	5.617637	6.555285	5.874272	6.135906	6.135906	6.135906	6.135906	5.327044	5.327044	5.327044	5.327044
Rastrigin 30D (46)	13.65801	13.65801	13.65801	13.65801	12.97823	12.97823	12.97823	12.97823	14.22287	14.22287	14.22287	14.22287	13.36935	13.36935	13.36935	13.36935
Schwefel 10D (47)	143.478	135.9474	148.4799	151.2986	155.556	146.9029	142.2121	159.254	124.7879	124.7879	124.7879	124.7879	130.9228	130.9228	130.9228	130.9228
Schwefel 30D (48)	373.0839	366.6318	363.7319	363.7319	329.0539	329.0539	329.0539	329.0539	241.0282	241.0282	241.0282	241.0282	246.4223	246.4223	246.4223	246.4223
Griewangk 10D (49)	0.141294	0.144597	0.156149	0.151423	0.139386	0.149906	0.137887	0.13706	0.139674	0.139674	0.139674	0.139674	0.13161	0.13161	0.13161	0.13161
Griewangk 30D (50)	0.433366	0.433366	0.433366	0.433366	0.494363	0.494363	0.494363	0.494363	0.550467	0.550467	0.550467	0.550467	0.762799	0.762799	0.762799	0.762799
Salomon 10D (51)	0.131473	0.133086	0.127279	0.136846	0.146873	0.143376	0.140863	0.14747	0.130508	0.130508	0.130508	0.130508	0.173484	0.173484	0.173484	0.173484
Salomon 30D (52)	1.538881	1.538881	1.538881	1.538881	2.032719	2.032719	2.032719	2.032719	1.820409	1.820409	1.820409	1.820409	1.532779	1.532779	1.532779	1.532779
Odd Square 10D (53)	0.04032	0.072513	0.098342	0.119639	0.0606	0.075005	0.073706	0.132268	0.032053	0.032053	0.032053	0.032053	0.040724	0.040724	0.040724	0.040724
Whitley 10D (54)	8596246	11164077	11245192	10895157	7840501	8321815	8746951	9146951	9650838	9650838	9650838	9650838	8064770	8064770	8064770	8064770
Whitley 30D (55)	3.67E+09	3.67E+09	3.67E+09	3.67E+09	4.24E+09	4.24E+09	4.24E+09	4.24E+09	1.11E+10	1.11E+10	1.11E+10	1.11E+10	5.97E+10	5.97E+10	5.97E+10	5.97E+10
Rana 10D (56)	130.1654	137.1138	161.1756	144.517	135.7136	140.8292	143.3617	126.404	149.2647	149.2647	149.2647	149.2647	120	120	120	120
Rana 30D (57)	362.6696	363.9328	316.4128	316.4128	339.6151	339.6151	339.6151	339.6151	357.0768	357.0768	357.0768	357.0768	319.5346	319.5346	319.5346	319.5346

APPENDIX D3: AVG. RUNTIMES FOR SMOA WITH RAZOR VEG. STATE

Average Times (s) for 1M	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	10.77946	8.450719	10.60431	10.93232	11.09417	8.817512	11.38025	10.23062	1.606468	2.024875	2.649695	3.831632	4.0228	4.559058	6.603406	6.973725
McCormic (2)	8.918537	7.302756	8.906493	8.964225	8.517874	7.58377	8.195411	9.108901	1.551619	1.923306	2.499839	3.485862	3.349443	4.275956	5.290552	5.708052
Box and Betts (3)	17.03582	17.39089	17.41159	16.90335	17.68142	17.76226	18.36019	19.55247	12.45909	15.04502	18.11232	20.01128	20.05539	20.43577	24.38254	27.66991
Goldstein (4)	10.47161	3.288581	10.21399	9.696346	9.229507	3.665022	9.883061	9.032949	1.504658	1.735867	3.405876	4.711244	4.157683	4.687793	5.324065	6.914967
Easom (5)	9.813093	7.776957	10.0117	10.46733	10.36726	8.139318	10.67908	10.15878	1.881369	2.792086	3.696589	4.960166	6.424395	6.386813	8.612373	10.89012
Mod Rosenbrock 1 (6)	10.86073	8.713259	11.41864	10.15712	10.76199	8.402314	10.50686	10.63904	1.871492	3.283156	3.795866	5.206766	5.853077	6.154013	7.983201	9.128733
Mod Rosenbrock 2 (7)	10.3156	8.467069	10.25841	10.85838	10.32877	8.580255	10.61253	10.88695	1.895667	3.890308	4.077014	5.315588	7.315535	6.346293	9.730487	8.411017
Bohachevsky (8)	10.25154	8.872054	10.25005	10.06684	9.67507	8.864778	9.718494	9.951374	1.96475	3.838892	5.532611	5.229186	7.203455	6.580559	9.571876	8.139348
Powell (9)	12.06628	13.64077	13.41807	16.87657	14.44349	16.02391	15.99104	20.09967	4.878748	8.999524	13.69733	17.85623	14.63456	14.74685	21.6831	22.57495
Wood (10)	14.86943	15.26074	17.00291	23.37243	18.27959	18.21369	19.49546	27.21259	6.650253	13.38433	18.05964	21.37821	16.47514	20.03787	25.33827	19.30799
Beale (11)	9.688461	7.662143	10.14421	9.4479	9.49462	7.354823	9.573004	9.600485	2.196442	4.974481	5.978987	6.370626	8.475551	9.005968	5.265916	5.145941
Engvall (12)	11.14562	8.68301	10.85674	10.86878	10.67891	8.823531	10.37635	11.28982	2.716109	5.870212	7.082821	7.60453	10.38944	8.116985	6.189353	5.871343
DeJong (13)	9.560341	7.601784	9.740397	10.34788	10.0052	6.927399	10.52501	9.832702	1.754686	4.244147	5.791598	6.860905	8.627559	5.368513	4.188035	4.135872
Rastrigin (14)	9.356323	7.966339	9.542421	9.655267	9.118591	9.057081	9.275326	8.523924	1.988132	4.613454	5.959653	8.797089	8.828994	6.719003	4.930718	5.192617
Schwefel (15)	9.06561	7.300054	8.933222	8.7161	8.86001	7.840816	8.943069	8.007519	1.994652	5.201223	5.936247	7.411368	8.367303	7.427885	4.882942	5.452372
Griewangk (16)	9.551897	7.89847	9.137642	8.12735	9.029735	7.677045	8.383502	7.812418	2.034126	6.31027	7.008533	6.522874	8.267833	7.28565	4.840041	5.450255
Ackley (17)	9.029215	8.47275	8.413741	7.67156	8.67756	7.882086	8.051132	7.807239	2.378063	5.97843	7.07695	7.329507	8.352606	6.835636	5.780277	5.133388
Langerman (18)	12.54517	15.30111	13.41383	13.81791	14.81222	18.16696	15.30098	16.17005	8.128466	17.37987	25.47766	27.37425	17.91416	15.66513	17.96906	19.69629
Michaelewicz (19)	16.86426	20.33671	17.36048	17.3529	18.42973	20.96458	20.04021	21.58263	20.08014	26.54796	26.85653	34.92923	30.89537	29.92879	24.78081	38.44734
Branin (20)	4.513097	5.441294	5.261856	5.569539	5.087214	4.076078	5.399109	3.26283	3.652585	6.92996	6.131824	4.060071	4.34304	3.970324	3.283822	2.885049
Six Hump Camel (21)	5.642379	5.34504	5.729611	4.778101	5.801482	3.752653	4.404764	3.446682	4.187998	6.708466	6.749001	4.544983	4.516103	4.308964	3.684881	3.141131
Osborne 1 (22)	23.05915	25.151	22.76	21.82618	22.14748	26.25083	22.55343	22.86175	24.88989	32.87489	29.41843	33.15333	26.53683	26.58401	26.05967	27.95468
Osborne 2 (23)	46.1673	47.69949	45.94676	46.45295	47.91705	47.47327	49.83635	52.04869	62.41712	57.6633	56.44631	58.43986	56.07641	55.50585	54.61373	60.8079
Mod Rastrigin (24)	4.868762	2.936444	6.206799	6.974931	6.724899	4.311149	7.004993	8.660699	9.526	5.304454	5.240953	5.337293	3.683489	4.468364	5.135148	2.87559
Mineshaft 1 (25)	5.541162	2.181649	4.988144	4.555074	5.935853	2.752594	5.885619	5.372623	6.946424	6.864192	4.210171	5.815568	4.644937	7.189223	5.525011	4.549306
Mineshaft 2 (26)	4.896349	1.105319	4.165393	3.279997	4.735005	1.722843	5.048325	3.627379	6.407572	3.728248	2.267651	3.645	3.411061	4.062467	1.801822	1.667037
Mineshaft 3 (27)	5.914898	1.649554	6.763562	7.678357	6.696417	2.740541	6.27573	6.170688	7.341815	3.020901	2.514554	3.325006	3.055686	2.805732	1.837081	1.706926
Spherical Contours (28)	3.68546	2.051887	4.461137	4.835853	4.974975	2.994866	5.491527	5.312239	4.604743	2.726163	2.478971	2.956287	1.966255	1.935156	1.369658	1.52249
S1 (29)	5.910644	1.366285	3.993775	2.980456	4.311129	2.908623	4.191694	4.256836	5.865957	3.193461	2.266875	3.38781	3.537406	3.438292	1.329412	1.253319
S2 (30)	6.821385	1.873999	5.962792	5.252782	5.387869	3.614762	6.081394	6.029438	6.21879	2.515958	2.278115	2.999927	3.171664	2.41352	1.515131	1.483388
S3 (31)	6.224507	1.896664	6.197812	6.658944	5.725811	3.874633	6.164661	5.834785	6.672084	2.807423	2.668225	3.330206	2.817483	2.853524	1.706069	1.639879
Downhill Step (32)	5.529876	2.524652	6.222541	6.185968	6.284354	4.512735	6.300858	4.941764	6.437947	2.886604	2.749674	3.457986	4.074209	3.113154	2.178416	2.009672
Salomon (33)	6.437428	3.15044	6.939296	6.563706	6.828098	5.36466	5.659893	3.147637	6.539161	2.974092	2.797117	3.56859	4.457022	3.837961	2.328019	2.135392
Whitley (34)	6.818409	3.74129	7.012133	6.633808	6.477768	5.887685	5.170823	2.634606	7.057162	3.518712	3.355489	3.700937	4.850878	4.220141	2.751201	2.55244
Odd Square (35)	7.85218	5.374016	6.857678	5.976116	5.933176	7.260852	3.194293	2.353591	7.509503	4.123959	3.562231	3.739518	5.732189	3.187085	3.043947	2.832733
Storn Chebyshev (36)	679.6839	685.3362	672.8791	674.0157	680.718	686.7031	680.5172	678.8483	702.6915	698.482	699.4671	694.7203	707.6681	708.3073	710.3917	716.7886
Rana (37)	4.93376	2.280724	3.558408	5.598258	5.836432	2.480102	7.126941	7.752385	2.515749	3.038199	4.000631	3.400546	5.284462	5.611928	6.917372	6.119298
Rosenbrock 10D (38)	4.55374	2.479655	5.43109	5.863366	9.567249	3.321457	10.96463	12.55562	7.217002	6.505726	7.116856	20.87015	19.9667	18.88598	14.81176	34.92937
Rosenbrock 30D (39)	3.156367	1.942398	3.723839	4.582138	4.678688	2.663112	5.455802	5.220908	2.26381	2.460858	2.85697	4.655466	2.664886	2.965918	2.459776	3.572769
Mod Rosenbrock 1 10D (40)	9.955319	5.182592	10.49786	11.66227	11.57721	7.090828	11.83029	12.6162	9.958417	8.910731	10.6439	26.67187	24.36372	22.18047	16.2787	39.38384
Mod Rosenbrock 1 30D (41)	11.73104	8.117118	12.52689	11.90027	11.093	8.999561	11.99562	12.41199	8.781185	9.557417	10.23683	11.90795	9.379973	9.531014	10.1744	10.6351
Mod Rosenbrock 2 10D (42)	8.247581	4.945192	9.364083	8.478947	9.406584	8.608701	11.60685	12.93177	9.217685	10.43234	9.529421	22.2297	20.27741	20.43319	17.00329	38.4813
Mod Rosenbrock 2 30D (43)	11.03644	9.525338	11.86844	12.12613	12.55625	12.76046	13.91719	14.1479	10.37678	11.03011	12.04208	15.50648	10.38124	10.39705	11.3139	10.99731
Spherical Contours 10D (44)	4.061357	3.045546	5.399289	5.818893	7.084294	8.178579	8.818824	10.64994	6.979181	6.805492	8.8949	25.26184	22.80339	21.74736	18.05314	37.71658
Rastrigin 10D (45)	5.936967	4.134555	7.449826	7.190895	8.378305	8.516746	10.52257	11.53864	7.831665	7.20449	12.31579	24.49879	22.06133	20.40839	15.18008	36.02133
Rastrigin 30D (46)	5.92084	4.176802	6.223531	6.521588	6.765283	6.329059	7.673681	7.773759	5.268304	5.594036	8.755415	9.8175	4.902495	4.915317	5.46286	4.432173
Schwefel 10D (47)	6.415689	3.861252	7.725874	8.055095	9.41408	7.470796	10.12621	10.05021	8.117461	8.740419	14.20106	24.37288	20.62023	22.18524	19.69973	24.41666
Schwefel 30D (48)	7.188806	6.347562	8.084352	7.950868	8.298056	7.521626	9.124591	9.045688	9.307496	7.091414	13.3475	19.07546	14.86057	13.32969	15.73962	21.14471
Griewangk 10D (49)	7.372515	7.160551	7.923517	8.467493	9.082581	8.745643	8.542697	9.134663	10.02639	9.913035	10.76102	24.85713	25.6192	24.2054	19.7823	20.3974
Griewangk 30D (50)	7.270662	7.853968	8.261889	7.711958	7.185639	7.730658	7.504136	7.234714	6.103052	7.780954	8.412515	9.648564	6.233144	6.301137	6.242882	5.096721
Salomon 10D (51)	5.197382	7.129506	5.748164	6.183118	5.090994	6.277816	5.345694	6.469873	6.884091	10.24935	10.00079	22.64756	17.22484	16.36105	13.46377	15.90382
Salomon 30D (52)	2.766167	3.452576	2.893847	2.874173	1.969773	2.517496	1.740785	1.654851	1.227491	1.986501	1.769364	2.500945	2.348618	2.361305	2.474466	1.871179
Odd Square 10D (53)	5.648292	7.491138	7.391337	5.938886	5.857178	8.155675	6.520003	6.653472	10.80597	12.20093	11.15117	25.68066	23.26198	22.44945	17.47627	19.35059
Whitley 10D (54)	24.86041	25.87247	24.5821	24.08718	23.81526	28.02613	23.01035	23.09251	28.38759	30.38907	33.86096	34.09767	39.61373	39.34559	37.36739	43.52014
Whitley 30D (55)	112.8598	120.8421	113.8764	113.7723	113.4739	114.377	116.5329	117.7233	120.7962	123.1897	123.4063	114.1344	118.3694	118.3869	118.8742	118.6346
Rana 10D (56)	8.1754	7.82356	9.116611	9.604658	12.37663	9.30941	14.67471	17.63148	22.51701	18.91579	20.42894	22.97081	19.1416	20.27166	17.30849	23.78745
Rana 30D (57)	13.91303	12.56978	15.1518	15.64124	16.61006	14.08125	19.79732	20.34972	23.30889	20.13625	21.18018	23.61033	23.46407	21.53352	23.95893	30.0823

Average Times (s) for 500k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	2.318462	2.069722	1.344815	1.448892	1.395936	1.272082	1.926113	0.880442	0.836144	0.694851	0.782712	0.785706	1.255438	1.040383	1.793421	1.212078
McCormic (2)	2.188909	1.676441	1.136158	1.34347	1.509065	0.991837	1.589865	0.790027	0.779224	0.594576	0.734868	0.733164	0.987229	0.901042	1.709336	0.927178
Box and Betts (3)	8.714883	9.021992	6.867074	7.096763	7.403534	7.307445	7.689334	6.202033	6.83109	6.153269	6.429246	7.074477	7.749777	7.961758	9.42526	7.509888
Goldstein (4)	2.041592	1.886464	1.170912	1.618887	1.2657	1.106825	1.288892	0.780699	0.801231	0.547649	0.699686	0.87296	1.006719	1.098849	1.422093	0.83079
Easom (5)	2.234154	2.065464	1.360878	1.549528	1.556956	1.533468	1.331647	0.980898	1.067177	0.920084	0.944073	1.16555	1.763433	1.941937	2.309581	1.457306
Mod Rosenbrock 1 (6)	2.432417	2.140853	1.48917	1.75399	1.935627	1.534644	1.34308	1.009561	1.14989	0.823535	0.922179	1.147519	1.514285	1.681903	1.937381	1.102829
Mod Rosenbrock 2 (7)	2.255585	2.330484	1.423348	1.4617	1.962292	1.535754	1.44313	1.01916	1.160773	0.83785	0.930412	1.031302	2.087258	1.609686	1.821113	1.043076
Bohachevsky (8)	2.31646	2.368718	1.436806	1.427316	1.971115	1.376331	1.718047	1.046386	1.101387	0.934312	0.968015	1.067148	2.188274	1.826334	1.856298	1.163707
Powell (9)	3.413506	3.797508	2.525418	3.202392	3.281323	3.114663	3.083377	2.677403	2.731344	2.377914	2.722727	3.849562	4.111993	3.885673	5.216201	4.305723
Wood (10)	3.838713	4.929479	2.79747	5.273117	3.887902	3.653899	2.976297	3.350222	3.447489	2.894874	3.205349	4.558108	4.324484	4.051347	6.000487	5.631656
Beale (11)	2.238233	2.480024	1.311824	1.857975	1.837865	1.41553	1.194973	1.412567	1.041026	0.926401	1.053815	1.141767	1.556316	2.086448	1.694208	1.330504
Engvall (12)	2.940613	2.728033	1.618783	2.086042	2.181387	1.779697	1.577178	1.770839	1.573911	1.273925	1.634399	1.524499	2.373563	2.562498	2.2176	1.668059
DeJong (13)	2.446671	2.245091	1.133065	1.620249	1.751382	1.213794	1.112769	1.028731	1.145202	0.733481	1.061832	1.293536	1.91384	1.419395	1.303073	1.086841
Rastrigin (14)	2.418835	2.404132	1.078019	1.572817	1.928447	1.742956	1.018136	0.950907	1.241864	1.126518	1.435619	1.492604	2.095456	1.745376	1.641083	1.392148
Schwefel (15)	2.373155	2.290817	1.195975	1.6007	1.786478	1.536655	1.047697	1.0596	1.112463	1.166921	1.289046	1.204598	2.207245	1.973602	1.727434	1.311853
Griewangk (16)	2.740516	2.261121	1.48942	1.785287	1.443723	1.294929	1.052534	1.07757	0.952774	1.141189	1.390114	1.759135	2.236824	2.04218	1.526279	1.19643
Ackley (17)	3.057084	2.367487	1.679639	1.871205	1.697471	1.337282	1.212979	1.204721	1.115567	1.386087	1.543662	2.118205	2.51303	2.059248	1.561593	1.335461
Langerman (18)	4.748033	4.261496	3.455676	4.47065	3.517544	3.635465	3.023554	4.056189	3.184987	4.082381	4.593719	7.498581	5.659027	5.815429	4.939752	5.534106
Michaelewicz (19)	7.762893	7.120194	6.53394	7.017376	7.09113	6.858859	6.404223	7.29387	7.74955	7.26611	7.676014	14.1503	10.91825	10.75331	8.861574	13.56149
Branin (20)	1.778119	1.247864	1.068323	1.37903	1.606158	0.990185	1.000197	1.167935	0.793291	0.669006	0.993413	1.846159	1.442464	1.303447	1.228429	1.180926
Six Hump Camel (21)	1.930171	1.224778	1.19426	1.614928	1.57686	1.257698	1.084599	1.143804	0.897655	0.781571	1.068814	1.947778	1.611626	1.442092	1.654521	1.279922
Osborne 1 (22)	12.00924	9.688417	9.101865	10.55174	9.654285	9.781841	10.27135	10.50069	8.943846	9.119887	10.87353	14.68468	11.42613	11.53857	12.62703	11.81808
Osborne 2 (23)	26.00048	23.28263	21.55291	21.47686	22.41563	22.27206	22.76653	21.7889	22.70902	22.35036	24.57552	27.08728	23.63733	23.97662	22.66171	23.68964
Mod Rastrigin (24)	3.471716	1.762183	1.546421	1.475777	2.229254	1.971332	1.292422	1.639145	2.090978	1.348195	2.693298	2.158381	2.382909	2.145785	1.389349	1.819174
Mineshaft 1 (25)	2.804026	1.340588	1.161258	1.049336	1.877036	1.69356	1.045053	1.366251	1.576425	2.696419	2.441711	2.811334	3.099382	3.621177	2.234949	2.627996
Mineshaft 2 (26)	2.237173	0.70984	0.635482	0.49729	1.347239	1.056488	0.536908	0.558362	0.936618	1.228969	1.203543	1.559845	1.715411	1.304815	0.809232	0.881327
Mineshaft 3 (27)	2.838201	0.943157	1.036843	1.021856	1.694947	1.16519	0.859985	0.919905	1.010295	0.998024	1.238822	1.154153	1.28243	1.190412	0.822236	0.889406
Spherical Contours (28)	1.547922	0.998268	0.93431	0.94193	1.021797	1.199019	0.972355	1.025758	0.683339	0.767881	0.858481	0.817816	1.143569	1.145847	0.849379	1.078933
S1 (29)	2.26015	0.64392	0.640599	0.503951	0.887886	1.223203	0.478651	0.579723	0.83015	0.980355	1.079795	0.94003	1.09516	1.059861	0.620818	0.646106
S2 (30)	2.521882	0.770869	1.075345	1.068233	1.182448	1.147302	0.80673	0.86374	0.865089	0.77392	1.191018	0.981422	0.986679	0.760461	0.641013	0.69335
S3 (31)	2.663443	0.803044	1.169837	1.24676	1.232358	0.866865	0.975316	0.920769	0.987916	0.904566	1.359224	1.135735	1.223837	1.066086	0.736389	0.817705
Downhill Step (32)	2.868074	0.872375	1.212249	1.501146	1.307704	0.956894	1.190947	1.019123	1.014914	0.95029	1.626816	1.572469	1.485464	1.190786	0.942259	1.042808
Salomon (33)	2.921571	0.916996	1.260991	1.761938	0.955315	1.065503	1.204528	1.119051	0.976319	1.063963	1.345976	1.543056	1.562132	1.306382	1.046285	1.120807
Whitley (34)	3.097677	1.181573	1.474066	1.904396	1.141514	1.283662	1.354288	1.332549	1.153814	1.307311	1.612733	1.854165	1.693019	1.55616	1.212774	1.317687
Odd Square (35)	3.161795	1.234762	1.552146	2.320352	1.197634	1.414883	1.346249	1.261621	1.203848	1.290115	1.931867	2.209777	2.013697	1.29002	1.350413	1.487738
Storn Chebyshev (36)	357.2908	353.4882	349.185	344.3797	349.4882	351.6837	350.3651	350.4585	361.5931	364.3811	363.4379	355.5168	363.4306	363.9399	365.3124	368.7989
Rana (37)	1.808314	1.175551	1.363691	1.550504	2.075551	1.513908	2.00129	2.771551	1.366147	1.855334	1.279022	1.253579	2.213814	2.174195	2.785526	2.314644
Rosenbrock 10D (38)	1.473188	1.269455	1.418124	1.717791	2.306615	2.278932	3.365278	4.436848	3.428931	3.712466	2.541781	6.310259	5.750992	5.28129	4.312509	11.34406
Rosenbrock 30D (39)	0.956496	1.164512	1.010708	1.151899	1.244139	1.317387	1.677406	1.853941	0.731304	0.990744	0.734209	0.915456	1.357539	1.345803	1.522833	1.68621
Mod Rosenbrock 1 10D (40)	2.783226	3.021302	3.066572	3.331273	3.809315	3.674024	5.078051	6.227012	5.483804	5.20299	4.003244	7.673882	6.741337	6.510845	7.780923	11.89452
Mod Rosenbrock 1 30D (41)	4.272643	4.41111	4.298363	4.373482	4.587712	4.511048	5.111205	5.246669	4.043734	4.139617	3.816069	4.004085	5.03642	5.106716	5.772825	5.334443
Mod Rosenbrock 2 10D (42)	2.684577	2.923696	2.759086	3.357883	3.367084	3.234008	4.706899	5.465731	5.20303	4.379701	3.750268	9.059028	7.293875	7.424784	6.919653	8.686012
Mod Rosenbrock 2 30D (43)	4.499796	4.410809	4.820449	5.376637	5.223827	4.948385	5.956628	6.13811	4.289316	4.215429	4.250675	4.618516	5.150565	5.181925	5.323592	4.640858
Spherical Contours 10D (44)	1.120776	1.120724	1.512245	1.934215	2.644088	1.914455	2.26793	3.690326	4.346637	2.484395	2.993093	6.764321	7.196854	6.65811	5.593641	7.0314
Rastrigin 10D (45)	1.812546	1.649311	2.112639	2.217509	3.273213	2.932985	2.629288	4.554973	4.675646	2.787948	3.155901	8.525602	7.043487	6.725431	6.477952	6.907829
Rastrigin 30D (46)	2.112636	1.942443	2.349767	2.244903	2.789332	2.662746	2.354506	2.718849	1.899535	1.719285	1.819366	2.129923	2.743208	2.737787	3.223654	2.352838
Schwefel 10D (47)	1.954201	1.852104	2.53883	2.571359	3.412187	3.598432	2.870305	3.981347	4.789946	3.52931	3.719739	9.977417	6.9957	7.477263	7.638688	7.662029
Schwefel 30D (48)	2.625809	2.4937	3.106594	3.035306	3.43822	3.314469	3.335233	3.676769	4.144142	3.358661	4.636902	7.102056	3.206505	3.161122	3.574986	2.752343
Griewangk 10D (49)	2.043326	1.935586	2.762889	2.644015	3.652695	3.309146	2.72672	4.193125	4.820441	3.359198	3.94916	10.00335	8.652962	8.010204	5.629424	6.992646
Griewangk 30D (50)	2.567384	2.504654	2.961449	3.371774	3.26773	3.259835	2.763479	3.266704	2.545639	2.346658	2.389917	2.903635	3.860076	3.842242	3.308654	3.04199
Salomon 10D (51)	1.080346	1.160832	1.860567	2.477231	2.377691	2.389666	1.84763	3.521325	3.678897	2.084788	2.196704	8.227964	5.936592	5.599703	3.18352	4.389692
Salomon 30D (52)	0.58615	0.584362	0.814582	0.970047	0.6576	0.694127	0.48197	0.682303	0.75549	0.616312	0.541022	0.96661	1.321653	1.487224	0.98492	0.979954
Odd Square 10D (53)	1.368247	1.51546	2.170869	3.040885	2.277375	2.711934	2.315557	4.361345	5.381517	3.2207	3.332115	10.50333	6.817758	6.428827	3.528657	6.365774
Whitley 10D (54)	9.841576	9.926318	10.60637	11.96811	11.09194	11.14473	10.59435	13.48129	12.99191	12.05738	11.2541	17.94215	15.14756	15.18254	12.83527	16.81506
Whitley 30D (55)	54.8014	55.65518	55.95515	55.52956	54.44481	54.48882	55.62222	54.93598	57.96724	58.13745	56.29957	56.69982	60.3125	60.24724	60.82619	60.79273
Rana 10D (56)	3.975478	3.948484	3.91087	3.754403	4.959305	4.475209	6.473636	4.847791	6.32943	5.420604	5.729779	8.720671	7.6501	7.981909	9.975116	8.719106
Rana 30D (57)	6.460637	6.402358	6.575539	6.506537	7.237782	6.972593	8.255584	7.764399	9.267764	7.701249	8.949082	11.75136	7.451786	7.403749	7.785124	6.934805

Average Times (s) for 100k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.201608	0.134104	0.17569	0.179267	0.200159	0.331587	0.483626	0.201755	0.182832	0.237112	0.34342	0.424543	0.30889	0.226526	0.190006	0.14043
McCormic (2)	0.189533	0.115024	0.164078	0.168127	0.179527	0.26718	0.391956	0.160993	0.129352	0.192249	0.229105	0.286353	0.198648	0.402998	0.146702	0.110688
Box and Betts (3)	1.31154	1.166398	1.193061	1.161606	1.423037	1.657083	1.834686	1.335626	1.501288	1.80404	1.812363	1.882421	2.037855	2.23041	1.785136	1.502487
Goldstein (4)	0.1935	0.109979	0.165447	0.167572	0.17822	0.221981	0.365524	0.158284	0.10681	0.246186	0.213379	0.30217	0.237884	0.524305	0.149276	0.109241
Easom (5)	0.212335	0.151924	0.186062	0.187367	0.243786	0.332335	0.457776	0.205084	0.215152	0.397427	0.3846	0.457834	0.397527	0.461836	0.26137	0.215133
Mod Rosenbrock 1 (6)	0.236836	0.159001	0.204762	0.20618	0.260829	0.343068	0.494464	0.227834	0.20532	0.328996	0.383114	0.433463	0.300082	0.333147	0.192214	0.172458
Mod Rosenbrock 2 (7)	0.235936	0.161844	0.20639	0.208542	0.262206	0.345137	0.489287	0.227646	0.206329	0.335278	0.385402	0.425281	0.301762	0.291467	0.230541	0.171137
Bohachevsky (8)	0.239235	0.165636	0.212643	0.214591	0.259171	0.340005	0.412911	0.223413	0.243555	0.405824	0.45015	0.446015	0.372489	0.373754	0.284128	0.213695
Powell (9)	0.38206	0.341647	0.376832	0.457819	0.462427	0.616121	0.726968	0.559225	0.547321	0.753167	0.939038	1.050605	0.32061	0.381318	0.314725	0.258332
Wood (10)	0.414198	0.374961	0.419563	0.550256	0.518005	0.589696	0.79926	0.646116	0.611549	0.916844	1.053579	1.169789	0.327676	0.523345	0.333669	0.396897
Beale (11)	0.229947	0.167914	0.201782	0.205487	0.246079	0.222832	0.433465	0.221262	0.350213	0.418026	0.43269	0.379392	0.234624	0.429029	0.219347	0.2837
Engvall (12)	0.311214	0.234233	0.270527	0.291489	0.335693	0.30722	0.515613	0.292566	0.37886	0.516683	0.518133	0.480608	0.333289	0.529014	0.316071	0.370685
DeJong (13)	0.238705	0.146973	0.186755	0.251324	0.237906	0.178067	0.407536	0.204036	0.258518	0.281222	0.315725	0.291878	0.1197	0.258304	0.110418	0.13133
Rastrigin (14)	0.238176	0.156106	0.179033	0.228875	0.223367	0.232977	0.370359	0.188462	0.345504	0.376545	0.351397	0.334905	0.19641	0.338323	0.18328	0.214146
Schwefel (15)	0.243944	0.151121	0.184087	0.245973	0.241316	0.213295	0.422625	0.207224	0.342447	0.407416	0.404831	0.390331	0.302615	0.345699	0.244949	0.284786
Griewangk (16)	0.25788	0.15405	0.193147	0.246549	0.244728	0.231722	0.44852	0.210236	0.311597	0.394638	0.371373	0.299217	0.422084	0.320735	0.259065	0.265921
Ackley (17)	0.295283	0.189425	0.223501	0.26993	0.289035	0.289769	0.51734	0.247035	0.443325	0.424195	0.430338	0.33725	0.515119	0.325956	0.303958	0.305758
Langerman (18)	0.531618	0.435292	0.485936	0.634589	0.586281	0.736615	1.115459	0.73074	0.859919	0.877305	0.948661	1.041498	0.557001	0.42402	0.444779	0.445521
Michaelewicz (19)	1.185835	1.077809	1.139432	1.171757	1.206999	1.573894	1.641289	1.308804	1.378037	1.351771	1.270306	1.271197	1.641353	1.418104	1.447922	1.505338
Branin (20)	0.234463	0.135406	0.183248	0.180444	0.218703	0.33076	0.441729	0.188746	0.342804	0.266586	0.246619	0.250823	0.327863	0.196073	0.141069	0.136155
Six Hump Camel (21)	0.26546	0.157075	0.207982	0.206542	0.234028	0.35695	0.456751	0.21023	0.37023	0.261884	0.295058	0.239578	0.374786	0.28821	0.187611	0.17333
Osborne 1 (22)	1.779537	1.68124	1.775358	1.760672	1.868226	2.479803	2.600172	2.009364	2.422995	2.185235	2.238975	2.461084	2.396309	2.01362	2.070289	2.046425
Osborne 2 (23)	4.325788	4.132202	4.322686	4.115657	4.163628	4.835918	4.831146	4.136446	5.178354	5.062572	5.11169	5.208885	5.836041	5.812094	5.690035	5.829117
Mod Rastrigin (24)	0.335239	0.240813	0.341032	0.255634	0.254504	0.544373	0.468962	0.255384	0.402807	0.457069	0.504767	0.617186	0.280182	0.317928	0.322359	0.271333
Mineshaft 1 (25)	0.310233	0.251092	0.270403	0.272886	0.230134	0.638962	0.406103	0.368505	0.415211	0.771731	0.68668	0.746897	0.520586	0.583335	0.596542	0.641655
Mineshaft 2 (26)	0.208292	0.107322	0.145852	0.155955	0.136122	0.345147	0.277613	0.139884	0.197158	0.301258	0.451416	0.353736	0.20045	0.215204	0.218831	0.223453
Mineshaft 3 (27)	0.211312	0.129154	0.241911	0.26155	0.179672	0.265242	0.356886	0.168319	0.271693	0.251998	0.4301	0.347221	0.228328	0.1949	0.215143	0.201239
Spherical Contours (28)	0.113218	0.096399	0.116162	0.139288	0.113416	0.207272	0.205159	0.111654	0.29097	0.332686	0.427738	0.418992	0.571305	0.565135	0.623459	0.771328
S1 (29)	0.152296	0.104366	0.110154	0.14245	0.122905	0.333433	0.272605	0.114482	0.214247	0.253829	0.381571	0.366956	0.170016	0.158168	0.164967	0.166896
S2 (30)	0.186703	0.119574	0.181174	0.199948	0.169431	0.253733	0.393754	0.155082	0.205447	0.112992	0.220616	0.212	0.097089	0.084449	0.093409	0.095966
S3 (31)	0.201244	0.130613	0.1872	0.210654	0.172961	0.269467	0.418553	0.15957	0.214991	0.181093	0.212005	0.231911	0.122787	0.148639	0.119216	0.119587
Downhill Step (32)	0.214839	0.144176	0.198873	0.22195	0.190543	0.357783	0.391066	0.176082	0.317901	0.27724	0.31576	0.319555	0.252267	0.202234	0.245395	0.235727
Salomon (33)	0.223754	0.146928	0.204444	0.20489	0.196443	0.412126	0.373675	0.181817	0.287053	0.450678	0.3497	0.305825	0.248871	0.18816	0.242051	0.216798
Whitley (34)	0.265589	0.188132	0.234836	0.241748	0.261338	0.445934	0.392327	0.21712	0.351423	0.512036	0.453053	0.344732	0.295363	0.231304	0.28719	0.262457
Odd Square (35)	0.274003	0.195161	0.244041	0.252835	0.326007	0.4598	0.4397	0.231646	0.38988	0.457403	0.549564	0.368215	0.283991	0.146095	0.274738	0.250639
Storn Chebyshev (36)	69.25513	69.90011	71.49144	71.80772	76.93047	73.1298	71.81779	72.23558	78.16902	78.11071	77.99287	78.15495	88.58651	88.78027	87.88348	86.15006
Rana (37)	0.312529	0.32103	0.52816	0.567364	0.611215	0.234051	0.331286	0.510483	0.280342	0.31123	0.305242	0.368516	0.400333	0.344396	0.29027	0.283324
Rosenbrock 10D (38)	0.231578	0.322438	0.510058	0.608148	0.554534	0.232954	0.413316	0.687436	0.142048	0.204111	0.166475	0.236619	0.279596	0.272907	0.243141	0.299433
Rosenbrock 30D (39)	0.147746	0.177093	0.21301	0.239358	0.287038	0.156895	0.221155	0.24257	0.249165	0.310949	0.291569	0.342442	0.657691	0.627737	0.626267	0.725087
Mod Rosenbrock 1 10D (40)	0.548157	0.639071	0.832643	0.950781	0.892119	0.521929	0.745128	0.986372	0.445547	0.561046	0.502721	0.567845	0.695519	0.692541	0.62266	0.656402
Mod Rosenbrock 1 30D (41)	0.79945	0.81715	0.917591	0.966271	1.098874	0.870062	0.99616	1.086861	0.997644	1.055666	1.086534	1.130662	1.681306	1.701737	1.628303	1.745275
Mod Rosenbrock 2 10D (42)	0.525008	0.489413	0.698247	0.890586	0.828202	0.511538	0.743778	1.116335	0.452082	0.51834	0.555456	0.570022	0.654512	0.668255	0.62784	0.658446
Mod Rosenbrock 2 30D (43)	0.839487	0.791557	0.904453	1.006084	1.053275	0.845018	0.954744	1.024563	1.069346	1.126732	1.161801	1.214695	1.720243	1.808947	1.674405	1.830389
Spherical Contours 10D (44)	0.221076	0.211635	0.401738	0.540106	0.462661	0.211962	0.412467	0.736489	0.106341	0.169054	0.150588	0.189007	0.190474	0.263173	0.216633	0.275808
Rastrigin 10D (45)	0.329765	0.303741	0.541319	0.628243	0.60535	0.329049	0.566554	0.80419	0.241467	0.325596	0.295989	0.325012	0.38003	0.463192	0.364267	0.422084
Rastrigin 30D (46)	0.354115	0.321383	0.415345	0.437879	0.501838	0.373523	0.470111	0.512543	0.514387	0.569686	0.574926	0.568646	1.033633	1.023238	0.905957	1.060032
Schwefel 10D (47)	0.377345	0.369123	0.613885	0.685514	0.653769	0.379636	0.625859	0.791131	0.322301	0.361076	0.366034	0.387005	0.459634	0.539845	0.460398	0.477323
Schwefel 30D (48)	0.52342	0.50001	0.659959	0.707704	0.630524	0.466369	0.569514	0.528138	0.68646	0.714012	0.733764	0.689383	1.138856	1.172505	1.142429	1.238563
Griewangk 10D (49)	0.382821	0.387054	0.61382	0.690476	0.707629	0.383796	0.625531	0.60809	0.320664	0.360884	0.367282	0.330686	0.424967	0.414328	0.454711	0.490786
Griewangk 30D (50)	0.470241	0.447513	0.598785	0.576774	0.706568	0.520206	0.633949	0.56901	0.69578	0.69282	0.693228	0.655461	1.139566	1.042955	1.121064	1.236617
Salomon 10D (51)	0.197001	0.199943	0.456339	0.439359	0.483782	0.194222	0.316813	0.336958	0.203922	0.179895	0.158731	0.168361	0.218489	0.227263	0.257864	0.303905
Salomon 30D (52)	0.098238	0.090571	0.173538	0.159979	0.214739	0.104863	0.154328	0.145378	0.297836	0.237348	0.241976	0.230108	0.492386	0.460292	0.502316	0.663924
Odd Square 10D (53)	0.278436	0.28374	0.655193	0.611354	0.579403	0.282472	0.483962	0.504023	0.211247	0.225254	0.220019	0.212625	0.265187	0.271704	0.287443	0.34655
Whitley 10D (54)	2.032149	1.958628	2.629833	2.403022	2.453558	2.148392	2.270924	2.321968	2.25838	2.242981	2.179742	2.125386	2.646725	2.480436	2.492948	2.541808
Whitley 30D (55)	11.34146	11.15095	12.27309	12.17896	12.63196	12.54271	12.91326	12.307	12.65582	12.4543	12.51118	12.61376	17.09561	17.10795	17.28822	17.07305
Rana 10D (56)	0.767754	0.882075	1.154518	1.251833	0.827608	0.98942	1.21578	0.983473	0.708941	0.845472	0.816468	0.837391	0.958293	0.987736	0.942865	0.965151
Rana 30D (57)	1.358369	1.451881	1.741572	1.827233	1.336055	1.377387	1.489428	1.393785	1.620923	1.72879	1.736382	1.804362	2.425568	2.491896	2.424927	2.55248

APPENDIX E1: AVG. RESULTS FOR SMOA WITH SIMPLEX VEG. STATE

Average Results (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	5.71925	6.430246	5.71925	5.71925	0.333629	0.506339	0.333629	0.333629	0.347691	0.126845	0.347691	0.347691	0.07173	0.325206	0.07173	0.07173	0
McCormic (2)	-1.91322	-1.90927	-1.91322	-1.91322	-1.91322	-1.91205	-1.91322	-1.91322	-1.91301	-1.90664	-1.91301	-1.91301	-1.91293	-1.90616	-1.91293	-1.91293	-1.9133
Box and Betts (3)	6.00E-05	8.22E-05	5.44E-05	3.12E-05	3.62E-05	5.93E-05	2.96E-05	2.51E-05	2.58E-05	2.42E-05	1.81E-05	8.35E-06	1.83E-05	2.88E-05	9.52E-06	7.01E-06	0
Goldstein (4)	3	4.979294	3	3	3.014856	3.546453	3.014856	3.014856	3.203862	3.842159	3.203862	3.203862	3.055906	4.243938	3.055906	3.055906	3
Easom (5)	-0.98532	-0.97542	-0.98532	-0.98532	-0.98867	-0.97931	-0.98867	-0.98867	-0.95015	-0.95841	-0.95015	-0.95015	-0.97933	-0.94372	-0.97933	-0.97933	-1
Mod Rosenbrock 1 (6)	0.004598	0.01134	0.004598	0.004598	0.008621	0.259123	0.008621	0.008621	0.026829	0.104769	0.026829	0.026829	0.100266	0.692315	0.100266	0.100266	0
Mod Rosenbrock 2 (7)	0.016098	0.061151	0.016098	0.016098	0.326659	0.650664	0.326659	0.326659	0.148164	0.265396	0.148164	0.148164	0.278731	0.998177	0.278731	0.278731	0
Bohachevsky (8)	0	9.53E-11	0	0	1.53E-11	3.25E-07	1.53E-11	1.53E-11	1.27E-05	0.144593	1.27E-05	1.27E-05	0.025032	0.025251	0.025032	0.025032	0
Powell (9)	7064622	7064622	7064622	6806486	2994029	2994029	2994029	2994029	596976.1	596976.1	587890.1	587890.1	415785.7	415785.7	415963.3	422187.7	0
Wood (10)	4.43E+08	4.43E+08	4.45E+08	4.44E+08	15655596	15655596	14236744	16028046	6921145	6921145	6916561	7048110	10724215	10724215	10719521	10689900	0
Beale (11)	941.9017	6708.482	941.9017	941.9017	649.7706	47826.74	649.7706	649.7706	2.585032	26.49351	2.585032	2.585032	8.61965	8.645682	8.61965	8.61965	0
Engvall (12)	0	1.33E-17	0	0	1.07E-07	9.12E-09	1.07E-07	1.07E-07	0.000217	1.97E-08	0.000217	0.000217	4.31E-08	4.30E-08	4.31E-08	4.31E-08	0
DeJong (13)	6.76E-18	8.63E-18	6.76E-18	6.76E-18	6.81E-18	1.21E-17	6.81E-18	6.81E-18	1.79E-09	2.87E-17	1.79E-09	1.79E-09	1.85E-17	1.96E-17	1.85E-17	1.85E-17	0
Rastrigin (14)	0.01316	0.104444	0.01316	0.01316	0.04303	0.467511	0.04303	0.04303	0.590448	1.163442	0.590448	0.590448	0.70897	0.754688	0.70897	0.70897	0
Schwefel (15)	-836.699	-831.076	-836.699	-836.699	-837.966	-837.919	-837.966	-837.966	-837.963	-837.963	-837.963	-837.963	-837.966	-837.966	-837.966	-837.966	-837.9658
Griewangk (16)	0.00187	0.001833	0.00187	0.00187	0.001489	0.002896	0.001489	0.001489	0.008024	0.008232	0.008024	0.008024	0.013279	0.012655	0.013279	0.013279	0
Ackley (17)	4.44E-16	4.44E-16	4.44E-16	4.44E-16	1.74E-12	4.28E-12	1.74E-12	1.74E-12	7.69E-07	0.003014	7.69E-07	7.69E-07	0.036614	0.019851	0.036614	0.036614	0
Langerman (18)	-0.48029	-0.57164	-0.63549	-0.60694	-0.48018	-0.54883	-0.7604	-0.67896	-0.57066	-0.60909	-0.75925	-0.95902	-0.60509	-0.63108	-0.69337	-0.86408	-1.5
Michaelewicz (19)	-5.25918	-5.67577	-5.87205	-5.79899	-5.81572	-6.0101	-6.129	-6.26959	-6.56437	-6.61821	-6.81172	-7.00934	-6.76172	-6.9009	-7.12226	-7.34841	-9.66
Branin (20)	0.397887	0.397956	0.397887	0.397887	0.402672	0.399437	0.402672	0.402672	0.39793	0.398066	0.39793	0.39793	0.3979	0.399363	0.3979	0.3979	0.397887
Six Hump Camel (21)	-1.03163	-1.02949	-1.03163	-1.03163	-1.03163	-1.03134	-1.03163	-1.03163	-1.03141	-1.0243	-1.03141	-1.03141	-1.03135	-1.02539	-1.03135	-1.03135	-1.0316
Osborne 1 (22)	1.065767	1.065302	1.068818	1.069663	1.008359	1.000402	0.997421	1.002155	0.889724	0.892939	0.888793	0.882962	0.795725	0.729511	0.758505	0.725393	5.46E-05
Osborne 2 (23)	2.27667	1.979744	1.900211	2.192205	1.324019	1.059813	1.053037	1.141829	0.495702	0.601992	0.441517	0.720832	0.402699	0.392765	0.347409	0.348536	0.0402
Mod Rastrigin (24)	60.82758	61.24061	60.82758	60.82758	60.81281	65.69764	60.81281	60.81281	61.39277	68.87264	61.39277	61.39277	64.53013	66.34871	64.53013	64.53013	58
Mineshaft 1 (25)	1.427722	2.008509	1.610372	2.008509	1.523942	2.208399	1.91734	2.208399	1.695217	2.262597	2.039713	2.262597	1.830054	2.239913	2.223343	2.239913	1.3805
Mineshaft 2 (26)	-1.39697	-1.25805	-1.38183	-1.25805	-1.39383	-1.16345	-1.2687	-1.16345	-1.35342	-1.27735	-1.21642	-1.27735	-1.34968	-1.35764	-1.28517	-1.35764	-1.4163535
Mineshaft 3 (27)	-6.17221	-4.07246	-6.17221	-6.17221	-5.88468	-3.9274	-5.88468	-5.88468	-4.61386	-4.43363	-4.61386	-4.61386	-5.23384	-4.4601	-5.23384	-5.23384	-7
Spherical Contours (28)	166.6615	153.1821	166.4667	166.4667	105.9369	72.7929	128.7658	128.7658	100.9274	22.87757	89.3173	86.10068	71.47292	16.29965	36.97578	66.22102	0
S1 (29)	0	5.90E-05	0.000524	5.90E-05	3.25E-06	0.000169	0.001005	0.000169	2.25E-05	7.94E-05	0.000245	7.94E-05	1.39E-05	9.22E-06	9.07E-05	9.22E-06	0
S2 (30)	2	2	2	2	2	2	2	2	2.000005	2.00001	2.000005	2.000005	2.000003	2	2.000003	2.000003	2
S3 (31)	0.543429	0.562731	0.543429	0.543429	0.538762	0.542729	0.538762	0.538762	0.53625	0.534637	0.53625	0.53625	0.531747	0.533813	0.531747	0.531747	0.5289
Downhill Step (32)	9	9.016	9	9	9	9.049	9	9	9.019	9.08	9.019	9.019	9	9.048	9	9	9
Salomon (33)	0.073428	0.07397	0.073428	0.073428	0.059847	0.061034	0.059847	0.059847	0.084881	0.080066	0.084881	0.084881	0.092818	0.090474	0.092818	0.092818	0
Whitley (34)	0.068414	0.128892	0.068414	0.068414	0.011623	0.021317	0.011623	0.011623	0.001405	0.001132	0.001405	0.001405	0.013682	0.002182	0.013682	0.013682	0
Odd Square (35)	-0.98099	-0.92423	-0.98099	-0.98099	-0.97118	-0.87139	-0.97118	-0.97118	-0.95523	-0.80389	-0.95523	-0.95523	-0.94724	-0.84285	-0.94724	-0.94724	-1.14383
Storn Chebyshev (36)	246685.1	236049.3	281329.5	237209	135897	136971.2	133724.9	126371.5	50693.71	52845.35	52237.92	49778.33	8852.954	16093.39	16533.31	10213.68	0
Rana (37)	-912.348	-890.488	-912.348	-912.348	-936.351	-920.18	-936.351	-936.351	-958.33	-950.223	-958.33	-958.33	-972.952	-966.183	-972.952	-972.952	-1023.416
Rosenbrock 10D (38)	999257.8	852779.1	698395.9	517122.5	55654.94	14783.68	25967.77	117584.7	123.8326	144.4054	748.4898	346.6201	63.38196	12.19135	4316.886	7130.904	0
Rosenbrock 30D (39)	17036226	15385246	13298451	13298451	8929816	3553343	8607557	8607557	3696814	414144.2	5072870	4583556	3198035	189435.8	371007.2	3087984	0
Mod Rosenbrock 1 10D (40)	5529.514	4332.924	2674.968	2949.714	1633.49	2524.594	1264.562	2336.666	462.5994	781.3919	586.2013	680.0253	317.4758	246.5524	384.3832	330.8152	0
Mod Rosenbrock 1 30D (41)	147583.5	146008.8	143909.5	143909.5	118534	84547.15	98968.76	98968.76	56357.01	25124.98	69114.76	64038.82	47570.83	24858.89	44787.35	55225.51	0
Mod Rosenbrock 2 10D (42)	7.437681	7.389795	6.534509	8.370551	2.391558	3.159784	2.544374	2.163157	2.776426	4.292219	1.606749	2.325334	0.721923	0.331351	0.494818	0.871287	0
Mod Rosenbrock 2 30D (43)	4.582718	3.611158	7.783732	7.783732	2.710691	2.386913	5.13334	5.13334	1.762726	1.345021	1.844195	2.671944	1.67811	1.499332	1.606879	2.585766	0
Spherical Contours 10D (44)	0.288197	1.248027	1.403077	1.142813	6.96E-08	1.13E-08	4.68E-05	8.24E-12	0.007667	8.32E-12	9.19E-16	0.619323	8.43E-16	8.41E-16	8.46E-16	8.71E-16	0
Rastrigin 10D (45)	100.8853	96.68617	96.36191	92.30648	87.8834	63.32863	79.68325	78.90729	72.94699	46.181	41.68278	53.83201	61.65795	37.0766	35.55448	40.07102	0
Rastrigin 30D (46)	428.8088	376.1982	400.926	400.926	395.505	334.528	379.4556	379.4556	391.288	294.4175	270.5268	349.8121	345.3397	260.8311	216.4292	318.2817	0
Schwefel 10D (47)	-2538.28	-2646.17	-2625.2	-2582.33	-2805.81	-2739.29	-2804.36	-2745.9	-2961.22	-2965.57	-2965.1	-2948.36	-3070.73	-3044.37	-3063.51	-3031.83	-4189.829
Schwefel 30D (48)	-5006.98	-4914.4	-4785.15	-4785.15	-5352.36	-5644.59	-5352.88	-5352.88	-6150.91	-6057.21	-6295.12	-5668.12	-6053.51	-6007.73	-6174.04	-6271.78	-12569.487
Griewangk 10D (49)	2.338405	0.780375	0.554305	0.819576	0.195024	0.106038	0.23341	1.481827	0.043042	0.330673	0.051591	0.05054	0.032082	0.053848	0.038509	0.019521	0
Griewangk 30D (50)	148.1552	146.3882	144.9383	144.9383	101.8887	55.76114	92.37471	92.37471	67.81963	16.0265	68.49633	66.50014	55.81955	10.10948	27.47415	52.18428	0
Salomon 10D (51)	2.777451	1.977969	2.306428	2.514784	2.928204	2.113018	2.098167	4.271618	2.445701	1.747252	1.611202	3.943255	1.885866	1.522506	1.431969	2.80092	0
Salomon 30D (52)	12.02822	8.854137	9.456537	9.456537	10.46848	7.648776	8.255926	8.255926	10.55434	6.351501	5.067376	8.964623	6.903407	5.266752	4.553302	9.195995	0
Odd Square 10D (53)	-0.06199	-0.11517	-0.0942	-0.0925	-0.0781	-0.17504	-0.24836	-0.12691	-0.09988	-0.25181	-0.36284	-0.18221	-0.12834	-0.34585	-0.42408	-0.29621	-1.14383
Whitley 10D (54)	2.74E+14	2.63E+14	2.65E+14	2.63E+14	1.91E+14	1.77E+14	3.9E+13	3.67E+13	1.16E+09	1.05E+12	1.81E+11	2.49E+11	6995216	561993.3	341118.4	17483027	0
Whitley 30D (55)	5.71E+15	1.72E+15	3.54E+15	3.54E+15	2.88E+15	4.6E+14	1.50E+15	1.50E+15	1.64E+15	4.82E+13	3.95E+14	5.23E+14	1.06E+15	2.73E+13	1.69E+12	4.08E+14	0
Rana 10D (56)	-2357.25	-2405.76	-2387.1	-2399.11	-2590.64	-2590.62	-2598.88	-2589.66	-2816.4	-2777.21	-2773.24	-2733.49	-2908.95	-2914.25	-2902.57	-2881.47	-5117.08
Rana 30D (57)	-4350.6	-4232.33	-4014.84	-4014.84	-4552.37	-4585.23	-4479.37	-4479.37	-4911.5	-4795.32	-4921.63	-4783.1	-4805.11	-4731.75	-4837.61	-5068.23	-15351.24

Average Results (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	8.693761	6.507592	8.693761	8.693761	0.34613	1.156063	0.34613	0.34613	0.364039	0.128728	0.364039	0.364039	0.077676	0.331594	0.077676	0.077676	0
McCormic (2)	-1.91322	-1.90927	-1.91322	-1.91322	-1.91322	-1.91205	-1.91322	-1.91322	-1.91301	-1.90664	-1.91301	-1.91301	-1.91293	-1.90616	-1.91293	-1.91293	-1.9133
Box and Betts (3)	6.00E-05	8.33E-05	5.44E-05	3.22E-05	3.62E-05	5.93E-05	2.96E-05	2.70E-05	2.58E-05	2.42E-05	1.83E-05	8.79E-06	1.85E-05	2.90E-05	9.55E-06	8.08E-06	0
Goldstein (4)	3	5.019214	3	3	3.014856	3.546453	3.014856	3.014856	3.203862	3.99175	3.203862	3.203862	3.055906	4.243938	3.055906	3.055906	3
Easom (5)	-0.96065	-0.935	-0.96065	-0.96065	-0.97076	-0.92858	-0.97076	-0.97076	-0.91312	-0.86726	-0.91312	-0.91312	-0.93207	-0.91037	-0.93207	-0.93207	-1
Mod Rosenbrock 1 (6)	0.015023	0.027853	0.015023	0.015023	0.228864	0.966437	0.228864	0.228864	0.78481	0.235994	0.78481	0.78481	0.138617	0.695192	0.138617	0.138617	0
Mod Rosenbrock 2 (7)	0.102851	0.15343	0.102851	0.102851	2.298143	1.228193	2.298143	2.298143	0.347038	0.735653	0.347038	0.347038	0.381745	1.001947	0.381745	0.381745	0
Bohachevsky (8)	3.33E-18	1.03E-09	3.33E-18	3.33E-18	4.41E-07	3.33E-07	4.41E-07	4.41E-07	1.27E-05	0.144596	1.27E-05	1.27E-05	0.025032	0.025251	0.025032	0.025032	0
Powell (9)	7064622	7064622	7064622	6806486	2994029	2994029	2994029	2994029	596976.1	596976.1	587890.1	587890.1	415785.7	415785.7	415963.3	422187.7	0
Wood (10)	4.43E+08	4.43E+08	4.45E+08	4.44E+08	15655596	15655596	14236744	16028046	6921145	6921145	6916561	7048110	10724215	10724215	10719521	10694623	0
Beale (11)	6622.922	6710.677	6622.922	6622.922	47828.34	47826.81	47828.34	47828.34	2.659997	27.7787	2.659997	2.659997	8.61965	8.645738	8.61965	8.61965	0
Engvall (12)	0	1.24E-16	0	0	1.18E-05	9.19E-09	1.18E-05	1.18E-05	0.000217	3.88E-06	0.000217	0.000217	4.31E-08	4.30E-08	4.31E-08	4.31E-08	0
DeJong (13)	9.52E-18	1.26E-17	9.52E-18	9.52E-18	7.88E-07	8.86E-17	7.88E-07	7.88E-07	1.79E-09	2.87E-17	1.79E-09	1.79E-09	1.86E-17	1.96E-17	1.86E-17	1.86E-17	0
Rastrigin (14)	0.027847	0.238064	0.027847	0.027847	0.28735	0.775381	0.28735	0.28735	0.758914	1.375346	0.758914	0.758914	0.754478	0.838617	0.754478	0.754478	0
Schwefel (15)	-833.588	-826.738	-833.588	-833.588	-836.018	-836.103	-836.018	-836.018	-837.912	-837.963	-837.912	-837.912	-837.966	-837.966	-837.966	-837.966	-837.9658
Griewangk (16)	0.003885	0.004351	0.003885	0.003885	0.010043	0.008342	0.010043	0.010043	0.018835	0.01557	0.018835	0.018835	0.013663	0.013024	0.013663	0.013663	0
Ackley (17)	3.47E-07	5.51E-16	3.47E-07	3.47E-07	7.75E-11	6.23E-08	7.75E-11	7.75E-11	7.69E-07	0.003014	7.69E-07	7.69E-07	0.036614	0.019851	0.036614	0.036614	0
Langerman (18)	-0.43056	-0.52908	-0.57662	-0.55613	-0.45764	-0.4995	-0.68939	-0.61797	-0.53145	-0.55095	-0.66583	-0.71164	-0.58532	-0.60492	-0.66752	-0.84073	-1.5
Michaelewicz (19)	-5.23109	-5.61928	-5.83049	-5.72357	-5.76326	-5.94671	-6.04806	-6.19231	-6.41087	-6.54511	-6.67265	-6.8415	-6.62867	-6.76435	-7.00593	-7.0582	-9.66
Branin (20)	0.397887	0.39899	0.397887	0.397887	0.403178	0.399437	0.403178	0.403178	0.39793	0.398066	0.39793	0.39793	0.3979	0.399363	0.3979	0.3979	0.397887
Six Hump Camel (21)	-1.03163	-1.02949	-1.03163	-1.03163	-1.03163	-1.03134	-1.03163	-1.03163	-1.03141	-1.0243	-1.03141	-1.03141	-1.03135	-1.02538	-1.03135	-1.03135	-1.0316
Osborne 1 (22)	1.066367	1.065302	1.068818	1.069663	1.008359	1.000402	0.997421	1.00396	0.889724	0.892939	0.888793	0.890718	0.795725	0.731618	0.764425	0.739566	5.46E-05
Osborne 2 (23)	2.27667	1.979744	1.900211	2.192205	1.368521	1.06772	1.055201	1.158441	0.510809	0.636088	0.443994	0.787399	0.432119	0.425723	0.392258	0.395281	0.0402
Mod Rastrigin (24)	60.8702	61.47083	60.8702	60.8702	61.40923	69.61056	61.40923	61.40923	64.81563	71.44996	64.81563	64.81563	64.84966	67.23444	64.84966	64.84966	58
Mineshaft 1 (25)	1.427722	2.24147	1.73892	2.24147	1.543395	2.212828	1.91734	2.212828	1.704275	2.263818	2.039889	2.263818	1.830054	2.241417	2.226224	2.241417	1.3805
Mineshaft 2 (26)	-1.39606	-1.10161	-1.33856	-1.10161	-1.37913	-1.14666	-1.26544	-1.14666	-1.35164	-1.27304	-1.21439	-1.27304	-1.34968	-1.3565	-1.2851	-1.3565	-1.4163535
Mineshaft 3 (27)	-6.09221	-4.05246	-6.09221	-6.09221	-5.77479	-3.77243	-5.77479	-5.77479	-4.29922	-3.56896	-4.29922	-4.29922	-5.0928	-4.18593	-5.0928	-5.0928	-7
Spherical Contours (28)	166.7803	154.7766	166.4691	166.4691	112.4073	76.46544	130.0627	130.0627	130.5098	29.54069	107.0929	105.4382	132.5818	33.51228	51.15185	97.52696	0
S1 (29)	3.56E-22	0.00186	0.007241	0.00186	3.25E-06	0.000959	0.001015	0.000959	2.25E-05	9.20E-05	0.000256	9.20E-05	1.39E-05	1.25E-05	9.15E-05	1.25E-05	0
S2 (30)	2	2	2	2	2	2.000032	2	2	2.000005	2.00001	2.000005	2.000005	2.000003	2	2.000003	2.000003	2
S3 (31)	0.547226	0.563554	0.547226	0.547226	0.539546	0.542818	0.539546	0.539546	0.536898	0.534693	0.536898	0.536898	0.531894	0.533824	0.531894	0.531894	0.5289
Downhill Step (32)	9	9.019	9	9	9	9.053	9	9	9.038	9.091	9.038	9.038	9.001	9.048	9.001	9.001	9
Salomon (33)	0.086657	0.097083	0.086657	0.086657	0.08873	0.105845	0.08873	0.08873	0.120564	0.122622	0.120564	0.120564	0.120822	0.130158	0.120822	0.120822	0
Whitley (34)	0.098883	0.148817	0.098883	0.098883	0.012023	0.055102	0.012023	0.012023	0.001406	0.005191	0.001406	0.001406	0.013682	0.002182	0.013682	0.013682	0
Odd Square (35)	-0.92459	-0.85218	-0.92459	-0.92459	-0.95714	-0.84842	-0.95714	-0.95714	-0.93848	-0.80081	-0.93848	-0.93848	-0.93589	-0.84285	-0.93589	-0.93589	-1.14383
Storn Chebyshev (36)	246685.1	236049.3	281329.5	238639.7	135897	136971.2	133724.9	126371.5	50735.33	52845.35	52237.92	49778.33	8931.745	16214.81	16701.82	10284.48	0
Rana (37)	-902.541	-882.511	-902.541	-902.541	-927.401	-912.245	-927.401	-927.401	-954.818	-947.422	-954.818	-954.818	-968.937	-964.111	-968.937	-968.937	-1023.416
Rosenbrock 10D (38)	999257.8	852779.1	698395.9	520177.4	55654.94	14783.68	25967.77	117584.7	123.8326	144.4566	748.4898	348.719	67.56159	12.55008	4316.976	7132.304	0
Rosenbrock 30D (39)	17044957	15418172	13369281	13369281	9762241	3728512	8876080	8876080	6599524	522405.1	6515983	5536971	8531430	563895	1251348	4870246	0
Mod Rosenbrock 1 10D (40)	5542.603	4332.924	2674.968	2949.714	1660.648	2524.594	1264.562	2336.666	462.5994	781.5445	586.2013	685.8687	322.7228	247.2759	385.7646	336.3267	0
Mod Rosenbrock 1 30D (41)	148936.6	148589.8	144035.3	144035.3	121260.6	85638.27	102341.4	102341.4	78769.74	30596.69	82381.59	78443.19	106435.1	42600.82	69371.35	80276.4	0
Mod Rosenbrock 2 10D (42)	8.732877	7.394498	6.57824	8.370551	2.436819	3.159784	2.544374	2.163157	2.801487	4.303665	1.609378	2.325362	0.729114	0.334406	0.495688	0.871372	0
Mod Rosenbrock 2 30D (43)	4.760328	3.75623	8.485173	8.485173	3.040714	2.597069	5.437896	5.437896	3.106426	2.443423	2.499182	2.826391	3.014361	2.485662	2.944943	3.882828	0
Spherical Contours 10D (44)	0.288197	1.248027	1.403077	1.142813	6.96E-08	1.13E-08	4.68E-05	8.24E-12	0.007667	8.32E-12	9.26E-16	0.619323	8.92E-16	8.81E-16	9.15E-16	2.67E-09	0
Rastrigin 10D (45)	101.6058	97.3615	97.12492	93.88646	88.38452	64.70054	82.0233	81.31309	73.79282	46.45614	42.10208	55.52596	61.82532	37.98271	36.22847	41.25168	0
Rastrigin 30D (46)	429.1251	377.1341	401.2693	401.2693	398.765	336.1478	381.3069	381.3069	399.2552	297.5594	273.1063	353.175	365.2617	288.5935	245.1957	331.3118	0
Schwefel 10D (47)	-2538.28	-2645.98	-2625.2	-2582.33	-2805.81	-2725.42	-2801.19	-2745.9	-2958.32	-2960.46	-2964.21	-2948.14	-3053.11	-3043.95	-3057.39	-3030.7	-4189.829
Schwefel 30D (48)	-5006.85	-4893.69	-4777.47	-4777.47	-5339.61	-5552.98	-5333.74	-5333.74	-5904.03	-5650.34	-6138.65	-5568.75	-5285.86	-5166.51	-5402.39	-5721.01	-12569.487
Griewangk 10D (49)	2.338405	0.780375	0.554305	0.819576	0.195024	0.106038	0.23341	1.481827	0.043042	0.330683	0.051591	0.05054	0.034945	0.057346	0.038959	0.021637	0
Griewangk 30D (50)	149.2662	146.6398	145.4176	145.4176	108.3968	60.17826	97.81472	97.81472	98.59677	21.08639	89.51036	82.62121	100.9833	25.66105	51.51071	74.18067	0
Salomon 10D (51)	3.969749	2.664481	4.59826	5.020375	2.928204	2.130393	2.104266	4.607477	2.504773	1.759511	1.612961	4.089266	1.949922	1.541391	1.442264	2.822195	0
Salomon 30D (52)	12.02822	8.854137	9.514885	9.514885	10.51124	7.656887	8.274674	8.274674	10.57303	6.353849	5.145742	8.976707	7.032698	5.302349	4.561777	9.277582	0
Odd Square 10D (53)	-0.0615	-0.11376	-0.09052	-0.0841	-0.07693	-0.17488	-0.24821	-0.11872	-0.09928	-0.25181	-0.36172	-0.17402	-0.12703	-0.34532	-0.42337	-0.28938	-1.14383
Whitley 10D (54)	2.74E+14	2.63E+14	2.65E+14	2.63E+14	1.91E+14	1.77E+14	3.9E+13	3.67E+13	1.16E+09	1.05E+12	1.81E+11	2.49E+11	6995241	561993.6	341119	17980198	0
Whitley 30D (55)	5.72E+15	1.80E+15	3.55E+15	3.55E+15	3.00E+15	4.62E+14	1.55E+15	1.55E+15	2.24E+15	5.66E+13	4.9E+14	6.98E+14	1.95E+15	3.39E+13	2.03E+12	4.95E+14	0
Rana 10D (56)	-2346.73	-2400.44	-2384.91	-2390.07	-2579.69	-2585.6	-2595.7	-2584.59	-2814.39	-2771.76	-2754.18	-2724.47	-2886.01	-2910.58	-2893.36	-2867.87	-5117.08
Rana 30D (57)	-4212.81	-4155.11	-3974.75	-3974.75	-4405.6	-4459.64	-4443.98	-4443.98	-4485.39	-4458.37	-4630.74	-4583.44	-4407.2	-4373.04	-4387.45	-4704.46	-15351.24

Average Results (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	8.733811	6.534812	8.733811	8.733811	0.458707	1.385009	0.458707	0.458707	0.587626	0.137834	0.587626	0.587626	0.097617	1.013599	0.097617	0.097617	0
McCormic (2)	-1.91322	-1.90335	-1.91322	-1.91322	-1.91322	-1.91205	-1.91322	-1.91322	-1.91301	-1.90629	-1.91301	-1.91301	-1.91288	-1.90451	-1.91288	-1.91288	-1.9133
Box and Betts (3)	6.22E-05	8.34E-05	5.48E-05	3.45E-05	3.75E-05	6.00E-05	3.24E-05	2.85E-05	3.16E-05	2.76E-05	2.19E-05	1.05E-05	2.50E-05	3.80E-05	1.63E-05	1.55E-05	0
Goldstein (4)	4.057764	6.046018	4.057764	4.057764	3.014856	4.437346	3.014856	3.014856	3.203862	4.065913	3.203862	3.203862	3.132947	4.615813	3.132947	3.132947	3
Easom (5)	-0.84938	-0.75361	-0.84938	-0.84938	-0.87342	-0.75045	-0.87342	-0.87342	-0.82475	-0.69532	-0.82475	-0.82475	-0.86895	-0.75042	-0.86895	-0.86895	-1
Mod Rosenbrock 1 (6)	5.043978	5.120911	5.043978	5.043978	1.726498	1.729629	1.726498	1.726498	0.785322	0.235997	0.785322	0.785322	0.186887	0.69572	0.186887	0.186887	0
Mod Rosenbrock 2 (7)	4.241897	4.159015	4.241897	4.241897	3.096882	3.35664	3.096882	3.096882	0.348872	0.735653	0.348872	0.348872	0.413099	1.066768	0.413099	0.413099	0
Bohachevsky (8)	0.013649	0.013649	0.013649	0.013649	0.005687	0.005687	0.005687	0.005687	1.27E-05	0.144596	1.27E-05	1.27E-05	0.025032	0.025251	0.025032	0.025032	0
Powell (9)	7064622	7064622	7064622	6806486	2994029	2994029	2994029	2994029	619403.2	619403.2	610317.3	610317.3	470465.4	470465.4	470424	467675.9	0
Wood (10)	4.43E+08	4.43E+08	4.45E+08	4.44E+08	15684317	15684317	14236744	16054854	6921145	6921145	6924068	7067973	10777603	10777603	10774919	10745013	0
Beale (11)	23116.49	8042.363	23116.49	23116.49	47828.92	47837.54	47828.92	47828.92	26.56865	27.7807	26.56865	26.56865	8.660151	8.665805	8.660151	8.660151	0
Engvall (12)	2.09E+08	2.09E+08	2.09E+08	2.09E+08	0.029512	1.18E-05	0.029512	0.029512	0.000217	3.88E-06	0.000217	0.000217	4.31E-08	4.30E-08	4.31E-08	4.31E-08	0
DeJong (13)	2.97E-09	9.05E-05	2.97E-09	2.97E-09	7.88E-07	9.24E-17	7.88E-07	7.88E-07	1.79E-09	2.89E-17	1.79E-09	1.79E-09	2.05E-17	0.000671	2.05E-17	2.05E-17	0
Rastrigin (14)	1.300161	1.891408	1.300161	1.300161	1.347032	2.006126	1.347032	1.347032	0.987612	1.470991	0.987612	0.987612	0.836547	0.845276	0.836547	0.836547	0
Schwefel (15)	-806.921	-795.207	-806.921	-806.921	-829.934	-827.941	-829.934	-829.934	-836.912	-837.819	-836.912	-836.912	-837.966	-836.774	-837.966	-837.966	-837.9658
Griewangk (16)	0.05233	0.046952	0.05233	0.05233	0.043173	0.036284	0.043173	0.043173	0.019861	0.016929	0.019861	0.019861	0.014453	0.014196	0.014453	0.014453	0
Ackley (17)	0.000151	0.000209	0.000151	0.000151	6.39E-08	6.25E-08	6.39E-08	6.39E-08	7.72E-07	0.003014	7.72E-07	7.72E-07	0.052912	0.07888	0.052912	0.052912	0
Langerman (18)	-0.31775	-0.37415	-0.40055	-0.44277	-0.40018	-0.41113	-0.52256	-0.52605	-0.49119	-0.50213	-0.57157	-0.65698	-0.5186	-0.54068	-0.57129	-0.70405	-1.5
Michaelewicz (19)	-5.14986	-5.39289	-5.57917	-5.42748	-5.53687	-5.68833	-5.69455	-5.77761	-5.74919	-6.1972	-6.21617	-6.00351	-5.52365	-5.97405	-6.40214	-5.75861	-9.66
Branin (20)	0.419308	0.412768	0.419308	0.419308	0.403178	0.399437	0.403178	0.403178	0.39793	0.398066	0.39793	0.39793	0.3979	0.399363	0.3979	0.3979	0.397887
Six Hump Camel (21)	-1.03163	-1.01439	-1.03163	-1.03163	-1.03163	-1.03134	-1.03163	-1.03163	-1.03141	-1.02409	-1.03141	-1.03141	-1.03135	-1.02474	-1.03135	-1.03135	-1.0316
Osborne 1 (22)	1.066367	1.065652	1.069167	1.069663	1.008359	1.003191	1.001338	1.00396	0.897829	0.910211	0.911686	0.913145	0.849159	0.834375	0.856338	0.828166	5.46E-05
Osborne 2 (23)	2.27667	2.022382	1.931263	2.309363	1.461861	1.274652	1.190519	1.260805	0.972166	1.324128	0.915116	1.261285	1.621948	1.687303	1.540294	1.562009	0.0402
Mod Rastrigin (24)	71.17316	75.82064	71.17316	71.17316	68.3314	77.75017	68.3314	68.3314	72.37996	75.0089	72.37996	72.37996	77.90728	77.3971	77.90728	77.90728	58
Mineshaft 1 (25)	1.550528	2.247644	1.912828	2.247644	1.690044	2.21369	1.920639	2.21369	1.720952	2.272917	2.058074	2.272917	1.8385	2.273999	2.226424	2.273999	1.3805
Mineshaft 2 (26)	-1.37547	-1.09189	-1.3125	-1.09189	-1.348	-1.13493	-1.26544	-1.13493	-1.34703	-1.24992	-1.2087	-1.24992	-1.34624	-1.34946	-1.28446	-1.34946	-1.4163535
Mineshaft 3 (27)	-4.78317	-2.98309	-4.78317	-4.78317	-4.37447	-2.44175	-4.37447	-4.37447	-4.15358	-3.36322	-4.15358	-4.15358	-4.487	-3.72016	-4.487	-4.487	-7
Spherical Contours (28)	183.7017	169.9385	174.288	174.288	177.8608	106.9693	147.2501	147.2501	194.4426	63.7373	137.7152	130.1522	174.3043	78.74274	94.75032	121.6056	0
S1 (29)	4.59E-06	0.014276	0.007241	0.014276	3.25E-06	0.00161	0.001015	0.00161	2.25E-05	0.000135	0.000258	0.000135	1.39E-05	1.73E-05	9.94E-05	1.73E-05	0
S2 (30)	2	2.000003	2	2	2.000014	2.000071	2.000014	2.000014	2.000005	2.00001	2.000005	2.000005	2.000003	2	2.000003	2.000003	2
S3 (31)	0.550319	0.567699	0.550319	0.550319	0.548788	0.543725	0.548788	0.548788	0.538362	0.534867	0.538362	0.538362	0.532325	0.534336	0.532325	0.532325	0.5289
Downhill Step (32)	9	9.029	9	9	9	9.078	9	9	9.116	9.152	9.116	9.116	9.069	9.087	9.069	9.069	9
Salomon (33)	0.175129	0.232743	0.175129	0.175129	0.208928	0.227425	0.208928	0.208928	0.176679	0.184526	0.176679	0.176679	0.143498	0.155107	0.143498	0.143498	0
Whitley (34)	0.317088	0.336746	0.317088	0.317088	0.06855	0.085489	0.06855	0.06855	0.002264	0.007236	0.002264	0.002264	0.058944	0.037876	0.058944	0.058944	0
Odd Square (35)	-0.85531	-0.78514	-0.85531	-0.85531	-0.88882	-0.80492	-0.88882	-0.88882	-0.87947	-0.78606	-0.87947	-0.87947	-0.88285	-0.83823	-0.88285	-0.88285	-1.14383
Storn Chebyshev (36)	246685.1	239039.2	281614.2	238883.9	135944.4	137066.7	134629.6	126371.5	86595.45	87071.63	105438.4	79791.99	75755.28	67704.75	67335.16	69050.74	0
Rana (37)	-883.582	-867.679	-883.582	-883.582	-904.877	-896.994	-904.877	-904.877	-944.716	-938.071	-944.716	-944.716	-961.42	-959.576	-961.42	-961.42	-1023.416
Rosenbrock 10D (38)	999257.8	852779.1	698395.9	520182.9	55667.84	14796.78	25970.22	117867.5	1525.152	385.7047	1321.716	1352.026	191781.4	33165.39	235043.6	60714.76	0
Rosenbrock 30D (39)	19678911	16464021	15327040	15327040	14931864	6191315	10774149	10774149	16638050	3007218	9491500	8438932	15758794	3609461	4249258	7153496	0
Mod Rosenbrock 1 10D (40)	5549.365	4529.728	2675.409	2951.771	1742.819	2532.502	1268.211	2369.432	903.8052	806.2559	661.1551	747.7678	3077.651	2019.825	2883.475	2410.562	0
Mod Rosenbrock 1 30D (41)	170367.1	164586.6	150259.7	150259.7	159192	118575.6	129043.3	129043.3	157340.1	66348.82	116669.5	109036.2	150434	90857.42	106576.6	99212.15	0
Mod Rosenbrock 2 10D (42)	8.780211	7.459895	6.619547	8.41058	2.442525	3.166994	2.546276	2.40343	4.924816	5.859072	3.063107	5.090162	9.960865	11.2935	8.84355	9.325355	0
Mod Rosenbrock 2 30D (43)	7.355164	5.730425	11.30162	11.30162	6.839081	5.946199	7.59988	7.59988	7.541485	5.14466	5.928589	7.131956	6.093098	4.394569	4.933047	8.431204	0
Spherical Contours 10D (44)	0.811456	1.248027	1.598791	1.272283	0.081451	1.13E-08	0.264334	1.037246	7.186816	3.882482	4.166703	4.283447	11.07061	7.560248	6.879366	8.413953	0
Rastrigin 10D (45)	104.4968	99.45972	100.9335	96.72043	89.71338	66.51844	83.13564	83.80125	79.72599	50.89642	48.57552	65.77263	81.19068	59.93619	52.81084	65.84696	0
Rastrigin 30D (46)	431.5188	383.6689	406.1136	406.1136	411.0765	351.9507	385.4728	385.4728	416.5546	335.4558	318.4199	359.9527	396.0528	330.133	291.2128	346.6424	0
Schwefel 10D (47)	-2534.01	-2626.16	-2604	-2578.11	-2783.24	-2724.02	-2794.24	-2732.94	-2876.62	-2915.3	-2911.86	-2908.94	-2990.2	-2938.51	-2953.47	-2931.24	-4189.829
Schwefel 30D (48)	-4550.74	-4648.29	-4683.86	-4683.86	-4532.64	-4590.24	-4737.56	-4737.56	-3809.15	-4070.64	-4187.66	-3925.04	-3752.29	-4039.16	-4148.3	-3495.06	-12569.487
Griewangk 10D (49)	2.348358	0.780957	0.55438	0.819858	0.208589	0.109971	0.236017	1.486531	0.711003	0.85273	1.552785	1.081064	5.13644	4.062326	4.916143	6.187114	0
Griewangk 30D (50)	169.8376	158.9551	152.8305	152.8305	157.0457	93.51826	124.1981	124.1981	162.2106	58.70239	118.8107	109.5668	148.0204	85.47694	90.03661	101.0417	0
Salomon 10D (51)	4.003966	2.863405	5.206218	5.577034	3.022477	2.147623	2.162615	4.83007	3.014822	1.784316	1.64996	4.291278	2.262354	1.624024	1.549122	3.020011	0
Salomon 30D (52)	12.11175	8.87527	9.646904	9.646904	10.61845	7.910659	8.423978	8.423978	11.61623	6.539072	5.290962	9.311105	8.972773	5.703356	4.882822	9.526014	0
Odd Square 10D (53)	-0.05951	-0.10939	-0.08465	-0.08113	-0.07607	-0.17341	-0.2453	-0.11005	-0.09541	-0.24232	-0.35262	-0.14574	-0.11337	-0.30731	-0.39106	-0.26078	-1.14383
Whitley 10D (54)	2.74E+14	2.63E+14	2.65E+14	2.63E+14	1.91E+14	1.77E+14	3.9E+13	3.67E+13	8.57E+12	3.82E+13	1.54E+13	1.01E+13	4.08E+13	3.09E+13	1.83E+13	1.09E+13	0
Whitley 30D (55)	6.34E+15	2.37E+15	4.10E+15	4.10E+15	4.78E+15	7.6E+14	1.83E+15	1.83E+15	4.63E+15	1.03E+14	9.7E+14	1.11E+15	3.02E+15	6.91E+13	4.11E+13	7.45E+14	0
Rana 10D (56)	-2317.89	-2389.22	-2365.22	-2366.13	-2558.26	-2542.68	-2549.58	-2548.85	-2733.28	-2693.81	-2713.15	-2687.24	-2705.18	-2711.82	-2713.79	-2708.4	-5117.08
Rana 30D (57)	-3845.36	-3649.87	-3836.71	-3836.71	-3771	-3809.97	-3921.32	-3921.32	-3776.19	-3938.39	-3904.8	-3688.13	-3847.97	-3931.5	-3893.85	-3621.35	-15351.24

APPENDIX E2: ST. DEV. FOR SMOA WITH SIMPLEX VEG. STATE

Results St. Dev. (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	52.00483	52.41072	52.00483	52.00483	1.003256	2.83936	1.003256	1.003256	2.037195	0.587065	2.037195	2.037195	0.42728	1.483653	0.42728	0.42728
McCormic (2)	4.00E-15	0.033728	4.00E-15	4.00E-15	5.07E-15	0.006967	5.07E-15	5.07E-15	0.001469	0.021969	0.001469	0.001469	0.002611	0.02188	0.002611	0.002611
Box and Betts (3)	9.99E-05	0.000153	8.06E-05	4.03E-05	5.69E-05	8.88E-05	5.74E-05	5.60E-05	4.25E-05	2.83E-05	3.64E-05	9.86E-06	2.66E-05	3.79E-05	2.10E-05	1.27E-05
Goldstein (4)	1.38E-14	10.92895	1.38E-14	1.38E-14	0.147815	2.544947	0.147815	0.147815	2.028398	2.781011	2.028398	2.028398	0.359114	2.914613	0.359114	0.359114
Easom (5)	0.023999	0.038935	0.023999	0.023999	0.020937	0.043461	0.020937	0.020937	0.152644	0.110031	0.152644	0.152644	0.066167	0.145254	0.066167	0.066167
Mod Rosenbrock 1 (6)	0.011674	0.030152	0.011674	0.011674	0.035356	2.145469	0.035356	0.035356	0.110314	0.721178	0.110314	0.110314	0.465467	3.738761	0.465467	0.465467
Mod Rosenbrock 2 (7)	0.020987	0.146855	0.020987	0.020987	2.111554	4.829287	2.111554	2.111554	0.675527	1.848336	0.675527	0.675527	1.559369	6.123253	1.559369	1.559369
Bohachevsky (8)	0	9.48E-10	0	0	1.52E-10	2.59E-06	1.52E-10	1.52E-10	7.03E-05	1.409328	7.03E-05	7.03E-05	0.246395	0.246385	0.246395	0.246395
Powell (9)	16712165	16712165	16712165	16702657	9303609	9303609	9303609	9303609	724604.2	724604.2	720769.9	720769.9	1159520	1159520	1159457	1159318
Wood (10)	3.12E+09	3.12E+09	3.12E+09	3.12E+09	50089931	50089931	47937479	50030709	27566991	27566991	27567234	27578867	81927989	81927989	81928518	81932012
Beale (11)	9371.108	55685.15	9371.108	9371.108	5100.809	469308.5	5100.809	5100.809	24.84502	238.859	24.84502	24.84502	84.91963	84.91744	84.91963	84.91963
Engvall (12)	0	9.84E-17	0	0	8.95E-07	9.06E-08	8.95E-07	8.95E-07	0.002154	1.57E-07	0.002154	0.002154	4.26E-07	4.26E-07	4.26E-07	4.26E-07
DeJong (13)	3.75E-18	4.89E-18	3.75E-18	3.75E-18	5.34E-18	1.44E-17	5.34E-18	5.34E-18	1.78E-08	8.20E-17	1.78E-08	1.78E-08	1.18E-16	2.44E-17	1.18E-16	1.18E-16
Rastrigin (14)	0.09231	0.536328	0.09231	0.09231	0.402899	0.681838	0.402899	0.402899	0.85018	1.09461	0.85018	0.85018	0.795183	0.937157	0.795183	0.795183
Schwefel (15)	11.80488	25.75743	11.80488	11.80488	2.12E-12	0.469516	2.12E-12	2.12E-12	0.026796	0.026796	0.026796	0.026796	1.15E-11	1.12E-07	1.15E-11	1.15E-11
Griewangk (16)	0.002409	0.0026	0.002409	0.002409	0.002515	0.007101	0.002515	0.002515	0.024922	0.024888	0.024922	0.024922	0.06783	0.06758	0.06783	0.06783
Ackley (17)	0	0	0	0	1.72E-11	4.25E-11	1.72E-11	1.72E-11	6.87E-06	0.029991	6.87E-06	6.87E-06	0.364296	0.197512	0.364296	0.364296
Langerman (18)	0.3684	0.31576	0.331046	0.296706	0.306544	0.335915	0.284451	0.316158	0.272065	0.326867	0.293768	0.331566	0.258116	0.254714	0.250367	0.290401
Michaelewicz (19)	0.974075	0.944819	0.959495	0.972543	0.979744	1.018522	0.982435	0.977534	0.847115	0.879157	0.762297	0.663001	0.735089	0.649131	0.694323	0.64472
Branin (20)	1.58E-07	0.000419	1.58E-07	1.58E-07	0.03615	0.011209	0.03615	0.03615	0.000279	0.001768	0.000279	0.000279	8.89E-05	0.00878	8.89E-05	8.89E-05
Six Hump Camel (21)	1.13E-15	0.021251	1.13E-15	1.13E-15	4.52E-07	0.002911	4.52E-07	4.52E-07	0.00189	0.033133	0.00189	0.00189	0.002732	0.022361	0.002732	0.002732
Osborne 1 (22)	0.109899	0.106858	0.108385	0.107988	0.119713	0.128415	0.139603	0.123817	0.202226	0.20559	0.195247	0.206288	0.204616	0.221823	0.22988	0.236392
Osborne 2 (23)	2.419825	2.15254	2.028638	2.399845	1.777457	1.40681	1.263436	1.486077	0.522847	0.75595	0.483943	1.280082	0.486078	0.577296	0.473697	0.456201
Mod Rastrigin (24)	0.120262	2.02908	0.120262	0.120262	0.057521	9.223247	0.057521	0.057521	2.21838	10.78018	2.21838	2.21838	7.374056	8.226155	7.374056	7.374056
Mineshaft 1 (25)	0.089326	0.432712	0.350706	0.432712	0.262489	0.273223	0.399193	0.273223	0.325727	0.218156	0.375778	0.218156	0.397406	0.239717	0.25157	0.239717
Mineshaft 2 (26)	0.06906	0.196254	0.093048	0.196254	0.074147	0.183191	0.147647	0.183191	0.113163	0.178619	0.171265	0.178619	0.120618	0.133554	0.149647	0.133554
Mineshaft 3 (27)	0.977575	2.55192	0.977575	0.977575	1.149003	2.647321	1.149003	1.149003	2.468996	2.457278	2.468996	2.468996	2.440265	2.614558	2.440265	2.440265
Spherical Contours (28)	65.02016	69.64798	54.17374	54.17374	78.19324	60.51323	52.75834	52.75834	79.82624	36.46187	60.15351	55.07823	61.90292	28.8196	49.87161	49.99494
S1 (29)	0	0.000554	0.003512	0.000554	2.75E-05	0.000639	0.00511	0.000639	0.000209	0.000228	0.000837	0.000228	8.03E-05	2.86E-05	0.0003	2.86E-05
S2 (30)	0	0	0	0	0	6.91E-11	0	0	3.37E-05	5.80E-05	3.37E-05	3.37E-05	2.73E-05	1.47E-06	2.73E-05	2.73E-05
S3 (31)	0.038314	0.073613	0.038314	0.038314	0.025164	0.027605	0.025164	0.025164	0.013443	0.009897	0.013443	0.013443	0.006474	0.012824	0.006474	0.006474
Downhill Step (32)	0	0.103653	0	0	0	0.171753	0	0	0.091318	0.200998	0.091318	0.091318	0	0.139628	0	0
Salomon (33)	0.03107	0.058413	0.03107	0.03107	0.041267	0.048637	0.041267	0.041267	0.074665	0.074222	0.074665	0.074665	0.058699	0.048623	0.058699	0.058699
Whitley (34)	0.274791	0.43042	0.274791	0.274791	0.070381	0.102547	0.070381	0.070381	0.008736	0.006885	0.008736	0.008736	0.123203	0.017524	0.123203	0.123203
Odd Square (35)	0.071586	0.122093	0.071586	0.071586	0.07993	0.13443	0.07993	0.07993	0.08639	0.110443	0.08639	0.08639	0.098595	0.109452	0.098595	0.098595
Storn Chebyshev (36)	688734.8	689234	790818.7	689203.8	218829.9	218901	220073.5	207233.1	162796.3	168158.7	162519.8	167597.8	22746	55099.43	55537.34	25712.72
Rana (37)	85.93455	87.64189	85.93455	85.93455	63.48419	62.30982	63.48419	63.48419	43.19985	43.11369	43.19985	43.19985	29.70976	31.49207	29.70976	29.70976
Rosenbrock 10D (38)	4416604	4173601	3733476	2406624	448972.1	111157.2	155652.1	785823.3	517.1386	594.2868	5526.989	2763.707	316.338	21.96759	36938.42	70717.33
Rosenbrock 30D (39)	11522122	9689144	9354389	9354389	8586414	4946778	5488584	5488584	5433504	620344.3	4706166	4025062	5356820	253597.5	1025948	2978036
Mod Rosenbrock 1 10D (40)	17096.38	13301.18	9292.47	9193.895	4970.715	7479.433	4811.406	9939.783	2034.736	3207.936	2068.637	2776.368	1357.042	879.9758	1603.05	1156.211
Mod Rosenbrock 1 30D (41)	66998.6	64142.47	51421.25	51421.25	64394.72	61598.76	50297.4	50297.4	56232.47	27172.39	49526.92	46076.08	46839.3	34382.59	42803.45	41511.04
Mod Rosenbrock 2 10D (42)	29.28304	22.02043	20.97114	29.30611	6.540177	9.325929	6.92875	6.378457	9.564477	13.46746	6.911066	7.955026	3.063494	0.824046	2.140643	3.876113
Mod Rosenbrock 2 30D (43)	5.226212	3.019221	8.169279	8.169279	2.453075	2.478066	3.86549	3.86549	1.756955	1.000754	1.765016	2.120279	1.107678	0.985426	1.157118	2.586816
Spherical Contours 10D (44)	2.824964	7.387408	6.693712	8.373493	6.93E-07	1.13E-07	0.000464	8.20E-11	0.076284	8.25E-11	2.47E-16	6.162189	7.82E-17	8.12E-17	8.13E-17	2.31E-16
Rastrigin 10D (45)	26.36328	27.86071	29.77532	29.2071	23.47262	21.70894	25.87246	28.07616	26.3244	17.91734	14.3076	22.43783	19.26601	15.65444	14.3912	19.78959
Rastrigin 30D (46)	38.28403	39.45197	41.39966	41.39966	44.2407	43.97854	38.29681	38.29681	51.98025	49.81702	63.84552	31.60284	54.94417	48.48243	44.97445	45.84754
Schwefel 10D (47)	512.7804	475.1249	456.0485	492.2645	382.8308	432.5328	377.3238	412.1621	367.6437	350.7267	364.1692	345.5145	276.1837	291.7847	277.6381	287.7345
Schwefel 30D (48)	1185.698	1259.816	1379.513	1379.513	1223.845	1161.682	1378.15	1378.15	1147.056	1172.544	935.3438	1403.212	1048.149	1062.443	1046.38	1247.133
Griewangk 10D (49)	8.486858	3.182822	2.778605	4.272705	0.992826	0.216192	1.002081	7.085836	0.206305	2.936784	0.12789	0.12724	0.143492	0.198962	0.1587	0.058289
Griewangk 30D (50)	64.34098	53.72633	44.0244	44.0244	69.7859	53.19937	51.23155	51.23155	66.39425	22.14239	50.40889	50.0969	58.431	15.44916	37.30076	41.49992
Salomon 10D (51)	0.541404	0.295686	0.8377	1.02555	0.887066	0.377485	0.624956	1.131228	1.026073	0.231371	0.235912	0.733885	0.467728	0.202911	0.173764	1.077296
Salomon 30D (52)	1.733092	1.232808	2.813159	2.813159	1.815768	0.838134	3.175537	3.175537	2.865244	0.566522	1.087954	2.929089	1.517565	0.442996	0.327941	2.443437
Odd Square 10D (53)	0.034649	0.06129	0.065856	0.062025	0.046838	0.088529	0.108315	0.070054	0.057126	0.084615	0.075884	0.058338	0.072039	0.088136	0.064028	0.13173
Whitley 10D (54)	2.58E+15	2.57E+15	2.57E+15	2.57E+15	1.59E+15	1.45E+15	3.35E+14	3.34E+14	6.53E+09	6.61E+12	1.38E+12	2.12E+12	69212906	3567364	3079613	1.73E+08
Whitley 30D (55)	4.85E+15	2.29E+15	4.19E+15	4.19E+15	3.40E+15	9.4E+14	1.24E+15	1.24E+15	2.50E+15	8.3E+13	6.43E+14	5.77E+14	1.39E+15	1.18E+14	1.37E+12	3.48E+14
Rana 10D (56)	439.1344	461.5441	435.1385	428.7479	358.4588	388.9336	359.6695	378.359	325.7933	345.7035	378.9593	336.0049	303.7987	291.5948	294.4397	296.3581
Rana 30D (57)	770.0309	831.5428	796.4837	796.4837	820.5404	686.6487	845.7508	845.7508	835.3325	690.1045	818.4915	822.1492	585.9762	599.253	561.7303	636.6735

Results St. Dev. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	59.27634	52.40193	59.27634	59.27634	1.003622	7.007598	1.003622	1.003622	2.040525	0.586847	2.040525	2.040525	0.427034	1.483173	0.427034	0.427034
McCormic (2)	4.00E-15	0.033728	4.00E-15	4.00E-15	1.66E-14	0.006967	1.66E-14	1.66E-14	0.001469	0.021969	0.001469	0.001469	0.002611	0.02188	0.002611	0.002611
Box and Betts (3)	9.99E-05	0.000153	8.06E-05	4.03E-05	5.69E-05	8.88E-05	5.74E-05	5.74E-05	4.25E-05	2.83E-05	3.64E-05	1.03E-05	2.65E-05	3.78E-05	2.10E-05	1.42E-05
Goldstein (4)	6.58E-09	10.92893	6.58E-09	6.58E-09	0.147815	2.544947	0.147815	0.147815	2.028398	2.984052	2.028398	2.028398	0.359114	2.914613	0.359114	0.359114
Easom (5)	0.10341	0.1017	0.10341	0.10341	0.050818	0.129055	0.050818	0.050818	0.186361	0.230149	0.186361	0.186361	0.17875	0.183536	0.17875	0.17875
Mod Rosenbrock 1 (6)	0.025095	0.093086	0.025095	0.025095	1.156744	5.749356	1.156744	1.156744	4.923935	0.845348	4.923935	4.923935	0.590301	3.738324	0.590301	0.590301
Mod Rosenbrock 2 (7)	0.541981	0.401064	0.541981	0.541981	10.2748	6.168989	10.2748	10.2748	1.02196	3.400559	1.02196	1.02196	1.850396	6.122714	1.850396	1.850396
Bohachevsky (8)	2.46E-17	9.31E-09	2.46E-17	2.46E-17	3.07E-06	2.59E-06	3.07E-06	3.07E-06	7.03E-05	1.409327	7.03E-05	7.03E-05	0.246395	0.246385	0.246395	0.246395
Powell (9)	16712165	16712165	16712165	16702657	9303609	9303609	9303609	9303609	724604.2	724604.2	720769.9	720769.9	1159520	1159520	1159457	1159318
Wood (10)	3.12E+09	3.12E+09	3.12E+09	3.12E+09	50089931	50089931	47937479	50030709	27566991	27566991	27567234	27578867	81927989	81927989	81928518	81931439
Beale (11)	55228.11	55684.89	55228.11	55228.11	469308.4	469308.5	469308.4	469308.4	24.83936	239.0269	24.83936	24.83936	84.91963	84.91743	84.91963	84.91963
Engvall (12)	0	1.11E-15	0	0	0.000117	9.06E-08	0.000117	0.000117	0.002154	3.73E-05	0.002154	0.002154	4.26E-07	4.26E-07	4.26E-07	4.26E-07
DeJong (13)	4.68E-18	8.03E-18	4.68E-18	4.68E-18	7.84E-06	6.98E-16	7.84E-06	7.84E-06	1.78E-08	8.20E-17	1.78E-08	1.78E-08	1.18E-16	2.44E-17	1.18E-16	1.18E-16
Rastrigin (14)	0.121903	0.691037	0.121903	0.121903	0.900959	1.028461	0.900959	0.900959	1.113087	1.449862	1.113087	1.113087	0.798734	0.963771	0.798734	0.798734
Schwefel (15)	21.38598	32.66231	21.38598	21.38598	13.49051	8.407019	13.49051	13.49051	0.511199	0.026796	0.511199	0.511199	3.56E-10	1.12E-07	3.56E-10	3.56E-10
Griewangk (16)	0.003239	0.006149	0.003239	0.003239	0.053538	0.018633	0.053538	0.053538	0.036111	0.03201	0.036111	0.036111	0.067871	0.067627	0.067871	0.067871
Ackley (17)	3.45E-06	1.06E-15	3.45E-06	3.45E-06	7.34E-10	6.18E-07	7.34E-10	7.34E-10	6.87E-06	0.029991	6.87E-06	6.87E-06	0.364296	0.197512	0.364296	0.364296
Langerman (18)	0.336405	0.319534	0.317881	0.271821	0.28223	0.303551	0.300539	0.286817	0.251181	0.257033	0.274565	0.298793	0.235327	0.239658	0.232557	0.302661
Michaelewicz (19)	0.975856	0.951609	0.929526	1.005639	0.968229	1.051738	0.933488	0.961635	0.764339	0.892304	0.841076	0.726171	0.771532	0.685201	0.675968	0.722701
Branin (20)	1.58E-07	0.009474	1.58E-07	1.58E-07	0.036337	0.011209	0.036337	0.036337	0.000279	0.001768	0.000279	0.000279	8.89E-05	0.00878	8.89E-05	8.89E-05
Six Hump Camel (21)	1.12E-15	0.021251	1.12E-15	1.12E-15	4.52E-07	0.002911	4.52E-07	4.52E-07	0.00189	0.033133	0.00189	0.00189	0.002732	0.022359	0.002732	0.002732
Osborne 1 (22)	0.109659	0.106858	0.108385	0.107988	0.119713	0.128415	0.139603	0.122879	0.202226	0.20559	0.195247	0.199195	0.204616	0.223162	0.228219	0.232636
Osborne 2 (23)	2.419825	2.15254	2.028638	2.399845	1.803554	1.40422	1.262053	1.485403	0.523273	0.772537	0.482872	1.361238	0.489269	0.578944	0.484511	0.458707
Mod Rastrigin (24)	0.197577	2.658405	0.197577	0.197577	3.645107	12.63107	3.645107	3.645107	8.403878	11.69017	8.403878	8.403878	7.565519	8.827149	7.565519	7.565519
Mineshaft 1 (25)	0.089326	0.251743	0.403646	0.251743	0.280813	0.274202	0.399193	0.274202	0.330469	0.21818	0.375909	0.21818	0.397406	0.239735	0.251698	0.239735
Mineshaft 2 (26)	0.07022	0.153034	0.126017	0.153034	0.090565	0.178641	0.147945	0.178641	0.11355	0.18007	0.170098	0.18007	0.120618	0.133203	0.149589	0.133203
Mineshaft 3 (27)	0.988335	2.53669	0.988335	0.988335	1.271642	2.65224	1.271642	1.271642	2.546315	2.819725	2.546315	2.546315	2.526536	2.699305	2.526536	2.526536
Spherical Contours (28)	64.96958	68.10939	54.17629	54.17629	79.31708	62.49464	51.58529	51.58529	69.13678	38.62635	48.92765	41.95435	60.61962	37.53915	51.76201	36.59321
S1 (29)	3.54E-21	0.005893	0.043758	0.005893	2.75E-05	0.002769	0.005109	0.002769	0.000209	0.000255	0.000836	0.000255	8.03E-05	3.83E-05	0.0003	3.83E-05
S2 (30)	0	0	0	0	6.07E-13	0.00027	6.07E-13	6.07E-13	3.37E-05	5.80E-05	3.37E-05	3.37E-05	2.73E-05	1.47E-06	2.73E-05	2.73E-05
S3 (31)	0.040779	0.073335	0.040779	0.040779	0.025065	0.027576	0.025065	0.025065	0.013661	0.009876	0.013661	0.013661	0.006447	0.01282	0.006447	0.006447
Downhill Step (32)	0	0.10742	0	0	0	0.181909	0	0	0.129445	0.212177	0.129445	0.129445	0.00995	0.139628	0.00995	0.00995
Salomon (33)	0.030904	0.054032	0.030904	0.030904	0.038463	0.099656	0.038463	0.038463	0.081911	0.08491	0.081911	0.081911	0.065554	0.075273	0.065554	0.065554
Whitley (34)	0.31303	0.434019	0.31303	0.31303	0.070424	0.259128	0.070424	0.070424	0.008736	0.039756	0.008736	0.008736	0.123203	0.017524	0.123203	0.123203
Odd Square (35)	0.111667	0.154165	0.111667	0.111667	0.086127	0.130468	0.086127	0.086127	0.094231	0.108399	0.094231	0.094231	0.106184	0.109442	0.106184	0.106184
Storn Chebyshev (36)	688734.8	689234	790818.7	688897.2	218829.9	218901	220073.5	207233.1	162784.8	168158.7	162519.8	167597.8	22724.95	55070.23	55518.36	25692.62
Rana (37)	87.52624	86.57225	87.52624	87.52624	62.44375	62.04037	62.44375	62.44375	43.1088	43.13328	43.1088	43.1088	29.66591	31.0826	29.66591	29.66591
Rosenbrock 10D (38)	4416604	4173601	3733476	2406160	448972.1	111157.2	155652.1	785823.3	517.1386	594.2749	5526.989	2763.529	318.181	21.9807	36938.41	70717.19
Rosenbrock 30D (39)	11520453	9648470	9281713	9281713	8896523	4965907	5268707	5268707	6533857	628455.4	4404888	3969451	7046951	1522468	2503388	2910906
Mod Rosenbrock 1 10D (40)	17092.91	13301.18	9292.47	9193.895	4970.726	7479.433	4811.406	9939.783	2034.736	3207.905	2068.637	2775.775	1356.484	879.8451	1602.769	1155.311
Mod Rosenbrock 1 30D (41)	66771.18	63013.95	51452.31	51452.31	63791.54	61966.21	47575.74	47575.74	57210.09	31584.97	44963.82	41169.58	47441.49	43306.56	42569.37	31378.97
Mod Rosenbrock 2 10D (42)	29.53857	22.01904	20.96252	29.30611	6.540383	9.325929	6.92875	6.378457	9.560457	13.46411	6.910521	7.955017	3.062316	0.823016	2.140482	3.876095
Mod Rosenbrock 2 30D (43)	5.33077	3.10368	9.005794	9.005794	2.798785	2.573364	3.839467	3.839467	2.1021	1.60717	1.848179	2.071415	1.553114	1.22954	1.188577	2.911069
Spherical Contours 10D (44)	2.824964	7.387408	6.693712	8.373493	6.93E-07	1.13E-07	0.000464	8.20E-11	0.076284	8.25E-11	2.45E-16	6.162189	1.56E-16	8.95E-17	3.49E-16	2.66E-08
Rastrigin 10D (45)	26.15326	27.5611	29.3728	28.47204	23.17649	22.28787	25.0006	25.41752	25.89949	17.70221	14.22957	22.2408	19.28666	15.94593	14.26095	19.3567
Rastrigin 30D (46)	38.23235	39.54321	41.65854	41.65854	41.23343	43.15257	36.89814	36.89814	43.98739	47.9337	63.49109	27.73476	47.6945	38.51896	36.60661	29.4159
Schwefel 10D (47)	512.7804	475.0627	456.0485	492.2645	382.8308	429.2847	376.8303	412.1621	365.4785	347.189	363.4676	345.4582	302.7453	291.5579	273.3194	286.704
Schwefel 30D (48)	1185.528	1234.117	1373.51	1373.51	1216.822	1113.844	1358.597	1358.597	1160.9	1134.16	910.2311	1375.742	1072.602	900.3664	859.9859	1273.543
Griewangk 10D (49)	8.486858	3.182822	2.778605	4.272705	0.992826	0.216192	1.002081	7.085836	0.206305	2.936782	0.12789	0.12724	0.144644	0.198543	0.158609	0.058309
Griewangk 30D (50)	64.27424	53.67365	44.17041	44.17041	69.97368	54.68506	46.10552	46.10552	63.41853	24.42812	41.47219	43.54584	53.36579	30.67825	44.14288	35.93997
Salomon 10D (51)	1.230386	0.836189	1.648476	1.521177	0.887066	0.383832	0.635169	0.950934	1.085425	0.233081	0.235956	0.719891	0.558028	0.214441	0.180016	1.090806
Salomon 30D (52)	1.733092	1.232808	2.815583	2.815583	1.796587	0.861697	3.196072	3.196072	2.880965	0.568283	1.280718	2.936411	1.634894	0.459373	0.332543	2.478779
Odd Square 10D (53)	0.034479	0.060639	0.063341	0.050615	0.045516	0.088588	0.108487	0.063875	0.057416	0.084615	0.076525	0.055745	0.072899	0.089158	0.063747	0.135596
Whitley 10D (54)	2.58E+15	2.57E+15	2.57E+15	2.57E+15	1.59E+15	1.45E+15	3.35E+14	3.34E+14	6.53E+09	6.61E+12	1.38E+12	2.12E+12	69212904	3567364	3079613	1.73E+08
Whitley 30D (55)	4.85E+15	2.39E+15	4.19E+15	4.19E+15	3.41E+15	9.39E+14	1.25E+15	1.25E+15	2.59E+15	8.44E+13	7.72E+14	6.48E+14	2.37E+15	1.19E+14	1.37E+12	3.36E+14
Rana 10D (56)	429.6898	455.7524	432.4356	424.5038	349.1688	383.4464	354.9538	371.1631	323.0723	337.2046	374.1821	340.8058	324.7314	288.9155	288.7347	290.0657
Rana 30D (57)	714.7147	800.1027	783.0118	783.0118	766.082	665.9741	837.4706	837.4706	712.4145	551.6794	716.277	779.2114	514.9886	481.0416	478.7543	580.8781

Results St. Dev. (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	59.27095	52.39883	59.27095	59.27095	1.018277	7.030665	1.018277	1.018277	2.858368	0.586034	2.858368	2.858368	0.463496	6.759767	0.463496	0.463496
McCormic (2)	5.07E-07	0.066932	5.07E-07	5.07E-07	6.25E-08	0.006967	6.25E-08	6.25E-08	0.001469	0.022048	0.001469	0.001469	0.002651	0.023413	0.002651	0.002651
Box and Betts (3)	0.000101	0.000153	8.07E-05	4.39E-05	5.68E-05	8.86E-05	6.06E-05	5.76E-05	5.23E-05	3.25E-05	3.69E-05	1.19E-05	3.02E-05	4.02E-05	2.66E-05	2.06E-05
Goldstein (4)	9.030577	11.96435	9.030577	9.030577	0.147815	5.364012	0.147815	0.147815	2.028398	2.993677	2.028398	2.028398	0.642265	2.982367	0.642265	0.642265
Easom (5)	0.182912	0.25184	0.182912	0.182912	0.153892	0.265752	0.153892	0.153892	0.241853	0.369058	0.241853	0.241853	0.219741	0.351168	0.219741	0.219741
Mod Rosenbrock 1 (6)	24.72516	24.71837	24.72516	24.72516	6.420331	6.424774	6.420331	6.420331	4.923856	0.845347	4.923856	4.923856	0.74352	3.73823	0.74352	0.74352
Mod Rosenbrock 2 (7)	19.12551	19.01729	19.12551	19.12551	10.79884	10.92156	10.79884	10.79884	1.02141	3.400559	1.02141	1.02141	1.861622	6.131241	1.861622	1.861622
Bohachevsky (8)	0.08271	0.08271	0.08271	0.08271	0.056577	0.056577	0.056577	0.056577	7.03E-05	1.409327	7.03E-05	7.03E-05	0.246395	0.246385	0.246395	0.246395
Powell (9)	16712165	16712165	16712165	16702657	9303609	9303609	9303609	9303609	740220.3	740220.3	736743.9	736743.9	1169268	1169268	1169284	1169937
Wood (10)	3.12E+09	3.12E+09	3.12E+09	3.12E+09	50083050	50083050	47937479	50022903	27566991	27566991	27565674	27574576	81921813	81921813	81922125	81925656
Beale (11)	158008.5	56410.54	158008.5	158008.5	469308.3	469307.4	469308.3	469308.3	238.8509	239.0267	238.8509	238.8509	84.91598	84.91542	84.91598	84.91598
Engvall (12)	2.07E+09	2.07E+09	2.07E+09	2.07E+09	0.293518	0.000117	0.293518	0.293518	0.002154	3.73E-05	0.002154	0.002154	4.26E-07	4.26E-07	4.26E-07	4.26E-07
DeJong (13)	2.95E-08	0.000901	2.95E-08	2.95E-08	7.84E-06	6.98E-16	7.84E-06	7.84E-06	1.78E-08	8.19E-17	1.78E-08	1.78E-08	1.18E-16	0.006676	1.18E-16	1.18E-16
Rastrigin (14)	1.657461	2.502172	1.657461	1.657461	1.913747	3.02277	1.913747	1.913747	1.142149	1.448794	1.142149	1.142149	0.80717	0.959938	0.80717	0.80717
Schwefel (15)	47.30855	58.70184	47.30855	47.30855	22.53447	25.25352	22.53447	22.53447	8.999175	1.047339	8.999175	8.999175	0.0006	9.194087	0.0006	0.0006
Griewangk (16)	0.088911	0.075718	0.088911	0.088911	0.086073	0.07766	0.086073	0.086073	0.036019	0.032285	0.036019	0.036019	0.067794	0.067555	0.067794	0.067794
Ackley (17)	0.00103	0.00208	0.00103	0.00103	6.18E-07	6.18E-07	6.18E-07	6.18E-07	6.87E-06	0.029991	6.87E-06	6.87E-06	0.397152	0.602568	0.397152	0.397152
Langerman (18)	0.24452	0.255711	0.268699	0.247623	0.260516	0.253035	0.250406	0.259459	0.232582	0.231784	0.214378	0.293231	0.198484	0.231998	0.226828	0.292252
Michaelewicz (19)	0.96838	0.952775	0.902519	0.956943	0.918528	1.01967	0.885902	0.920439	0.721327	0.973882	0.886472	0.694583	0.788715	0.872706	1.006448	0.663664
Branin (20)	0.158069	0.137304	0.158069	0.158069	0.036337	0.011209	0.036337	0.036337	0.000279	0.001768	0.000279	0.000279	8.89E-05	0.00878	8.89E-05	8.89E-05
Six Hump Camel (21)	1.74E-06	0.073888	1.74E-06	1.74E-06	4.89E-06	0.002911	4.89E-06	4.89E-06	0.00189	0.033151	0.00189	0.00189	0.002732	0.022529	0.002732	0.002732
Osborne 1 (22)	0.109659	0.106832	0.108349	0.107988	0.119713	0.12351	0.133438	0.122879	0.198059	0.187344	0.182776	0.180966	0.183846	0.19444	0.18474	0.198308
Osborne 2 (23)	2.419825	2.138368	2.013191	2.446478	1.794031	1.538531	1.284003	1.46636	0.831501	1.337377	0.940752	1.405899	1.155813	1.184313	1.146416	1.09779
Mod Rastrigin (24)	12.32998	13.50119	12.32998	12.32998	10.49961	13.84315	10.49961	10.49961	12.35913	12.37344	12.35913	12.35913	9.949863	9.318264	9.949863	9.949863
Mineshaft 1 (25)	0.303547	0.254241	0.401995	0.254241	0.35807	0.274613	0.401207	0.274613	0.338261	0.201041	0.369769	0.201041	0.398121	0.195556	0.251777	0.195556
Mineshaft 2 (26)	0.098149	0.145013	0.134911	0.145013	0.117626	0.174107	0.147945	0.174107	0.11558	0.181529	0.171334	0.181529	0.123413	0.136269	0.149187	0.136269
Mineshaft 3 (27)	2.092757	2.640927	2.092757	2.092757	2.283326	2.756211	2.283326	2.283326	2.535194	2.827825	2.535194	2.535194	2.743681	2.647484	2.743681	2.743681
Spherical Contours (28)	59.76445	62.63412	45.39598	45.39598	61.15368	63.15654	31.00409	31.00409	35.27718	36.44459	18.81228	17.82892	39.6223	58.7644	53.07333	14.29916
S1 (29)	4.00E-05	0.038228	0.043758	0.038228	2.75E-05	0.004066	0.005109	0.004066	0.000209	0.000315	0.000836	0.000315	8.03E-05	4.36E-05	0.000306	4.36E-05
S2 (30)	3.78E-08	2.38E-05	3.78E-08	3.78E-08	0.000108	0.000468	0.000108	0.000108	3.37E-05	5.80E-05	3.37E-05	3.37E-05	2.73E-05	1.47E-06	2.73E-05	2.73E-05
S3 (31)	0.042339	0.075004	0.042339	0.042339	0.045157	0.02743	0.045157	0.045157	0.013572	0.009858	0.013572	0.013572	0.006616	0.012984	0.006616	0.006616
Downhill Step (32)	0	0.121074	0	0	0	0.205709	0	0	0.202346	0.243097	0.202346	0.202346	0.124656	0.162268	0.124656	0.124656
Salomon (33)	0.109897	0.175094	0.109897	0.109897	0.135576	0.140722	0.135576	0.135576	0.090589	0.099185	0.090589	0.090589	0.068366	0.09281	0.068366	0.068366
Whitley (34)	0.610168	0.637242	0.610168	0.610168	0.261198	0.309692	0.261198	0.261198	0.010642	0.044423	0.010642	0.010642	0.340581	0.275339	0.340581	0.340581
Odd Square (35)	0.119704	0.14872	0.119704	0.119704	0.111049	0.123567	0.111049	0.111049	0.103878	0.097457	0.103878	0.103878	0.108857	0.107942	0.108857	0.108857
Storn Chebyshev (36)	688734.8	689125	790728.9	688824.6	218802.1	218847.1	219712.2	207233.1	175784.9	175448.8	320215	172648	112030.2	102655.6	102444.7	102796.7
Rana (37)	89.43531	82.29159	89.43531	89.43531	64.23487	64.31845	64.23487	64.23487	43.07384	43.38911	43.07384	43.07384	32.55501	32.03896	32.55501	32.55501
Rosenbrock 10D (38)	4416604	4173601	3733476	2406159	448970.5	111155.5	155651.7	785785.8	6198.941	821.6288	5843.435	6304.705	904351.9	124294.8	1441748	318241
Rosenbrock 30D (39)	10927813	8976479	8294852	8294852	8099681	5799140	4418125	4418125	6096131	3889440	2996740	2686714	5899388	5029117	4529596	1710449
Mod Rosenbrock 1 10D (40)	17090.9	13374.64	9292.348	9193.3	5007.008	7477.156	4810.741	9934.145	3291.702	3203.846	2083.931	2769.227	8891.935	6311.678	8790.052	7901.1
Mod Rosenbrock 1 30D (41)	53682.67	49718.94	46340.11	46340.11	42249	52448.22	24540.21	24540.21	29615.57	39083.65	20682.8	14433.88	25108.71	49466.91	22461.59	14645.29
Mod Rosenbrock 2 10D (42)	29.52872	22.00498	20.9552	29.2987	6.538474	9.323797	6.928201	6.706502	13.46383	14.93095	9.192796	13.21081	17.45693	18.27907	14.46034	15.56571
Mod Rosenbrock 2 30D (43)	5.088488	3.145115	11.27357	11.27357	3.071362	2.750431	4.735132	4.735132	4.091369	2.127741	2.950781	4.243645	3.937421	2.182741	2.770619	5.138408
Spherical Contours 10D (44)	5.897884	7.387408	6.931714	8.454523	0.771723	1.13E-07	2.512772	10.21315	19.04626	11.54173	11.49847	12.47691	20.92817	15.82978	15.8172	16.15917
Rastrigin 10D (45)	24.78969	26.97277	27.72006	26.92125	22.89241	22.34448	23.90515	23.39481	24.35707	17.31953	14.01285	20.09791	20.40949	15.21425	10.63142	15.32381
Rastrigin 30D (46)	37.53098	39.02749	39.59466	39.59466	39.03934	32.72869	34.57274	34.57274	34.27076	26.97668	43.47445	22.92578	40.0501	32.75891	25.12017	19.12068
Schwefel 10D (47)	511.9677	490.3252	443.3297	490.2567	370.2687	427.9457	372.4673	406.0582	390.1495	368.5063	359.917	348.3092	288.8803	317.8553	315.3722	313.5668
Schwefel 30D (48)	1038.671	1103.323	1323.324	1323.324	988.4461	861.9883	1157.688	1157.688	645.4501	597.9291	725.5653	812.9878	523.3694	511.5045	679.3954	411.5443
Griewangk 10D (49)	8.48474	3.182686	2.778591	4.272654	0.995932	0.215167	1.001593	7.084891	2.494059	3.269699	6.746275	4.471527	11.7124	8.860467	10.33943	13.62615
Griewangk 30D (50)	53.18046	45.76557	38.1457	38.1457	47.08511	53.23721	24.91989	24.91989	25.18751	35.29454	20.29983	19.23143	29.06306	52.55634	39.53126	11.32526
Salomon 10D (51)	1.232333	1.14415	1.545663	1.125362	0.929317	0.382985	0.743194	0.898092	1.57037	0.242341	0.255317	0.668745	0.881861	0.255662	0.197507	1.232246
Salomon 30D (52)	1.772073	1.25241	2.846607	2.846607	1.836028	0.86248	3.253188	3.253188	2.417476	0.712198	1.436959	2.866884	2.763044	0.684713	0.429829	2.408303
Odd Square 10D (53)	0.034441	0.061236	0.058015	0.046489	0.045674	0.089267	0.109853	0.060399	0.056477	0.087923	0.07586	0.048232	0.073362	0.110798	0.078786	0.149213
Whitley 10D (54)	2.58E+15	2.57E+15	2.57E+15	2.57E+15	1.59E+15	1.45E+15	3.35E+14	3.34E+14	7.65E+13	2.95E+14	1.39E+14	7.14E+13	1.87E+14	1.42E+14	9.11E+13	7.46E+13
Whitley 30D (55)	5.96E+15	2.88E+15	4.12E+15	4.12E+15	4.19E+15	1.25E+15	1.15E+15	1.15E+15	3.21E+15	1.35E+14	1.04E+15	6.8E+14	2.43E+15	1.72E+14	1.96E+14	3.44E+14
Rana 10D (56)	414.3807	444.337	409.8797	401.8145	340.5841	371.4396	354.1252	368.7164	319.3526	318.2178	366.16	338.368	290.2366	280.7408	278.8528	284.6714
Rana 30D (57)	611.184	624.4369	727.159	727.159	480.8802	568.6079	640.1597	640.1597	493.133	420.9921	552.3317	464.5583	384.7914	397.3463	451.2386	446.0645

APPENDIX E3: AVG. RUNTIMES FOR SMOA WITH SIMPLEX VEG. STATE

Average Times (s) for 1M	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	4.330361	4.090263	4.805068	4.852147	4.977554	4.545506	4.212037	4.299666	0.940452	0.918635	1.590551	1.689287	1.099941	1.329396	1.575029	1.669434
McCormic (2)	6.023972	6.115593	5.45981	5.929879	6.057946	4.898303	6.042562	6.010408	1.092007	1.109755	2.040441	1.782294	1.150562	1.366569	1.302047	1.781611
Box and Betts (3)	4.791811	4.702277	4.669238	4.837966	5.186427	5.011373	4.833412	4.811476	3.645842	3.868269	4.544742	4.490101	3.899249	4.315303	4.143543	4.549284
Goldstein (4)	5.65064	4.877296	5.215027	5.153542	5.141438	3.812917	5.810754	5.220573	1.143035	1.38501	1.50254	1.681825	1.108802	1.549175	1.779415	1.683836
Easom (5)	9.962231	9.393057	10.43474	10.93438	10.4173	8.642407	10.59457	10.90655	2.846933	3.307621	4.236096	4.616151	3.113678	3.450625	4.195694	4.272125
Mod Rosenbrock 1 (6)	5.375914	5.861131	5.970515	6.162471	5.844193	6.166225	6.510683	6.354357	1.600669	1.380616	2.113237	2.465153	1.026899	1.274621	1.383557	1.447456
Mod Rosenbrock 2 (7)	5.670904	5.626368	6.189136	5.81301	6.371299	6.251338	6.12341	6.294832	1.831883	1.401537	2.55369	2.424278	1.04517	1.450148	1.600728	1.142322
Bohachevsky (8)	6.046538	5.953731	6.040384	6.063902	6.417346	6.125501	6.409871	6.153719	2.195803	1.659116	2.984648	2.406862	1.336942	1.59153	1.682906	1.384197
Powell (9)	4.503196	4.491115	4.369966	4.447413	4.258804	4.645152	4.467541	4.460059	2.351167	2.329891	2.774604	2.54861	2.709837	2.997859	2.961465	2.763291
Wood (10)	4.247527	4.411971	4.38582	4.515672	4.92893	4.208646	4.859528	4.554188	2.156344	2.128659	2.265358	2.088692	2.494246	2.865893	2.598363	2.326383
Beale (11)	5.708019	5.969185	5.648818	5.571574	6.185656	5.385442	6.349347	6.204081	1.988141	1.774786	1.943306	1.905537	1.527282	1.60597	1.299149	1.139339
Engvall (12)	6.217571	6.32316	5.594748	6.081522	6.822549	6.493215	6.683858	6.35353	2.192123	2.107069	2.113651	2.175048	2.024006	1.674792	1.439735	1.392746
DeJong (13)	5.762154	5.669411	5.562343	5.884739	6.790865	6.043889	6.968324	6.350795	1.776171	1.557843	1.43481	1.621048	1.412749	1.790224	1.168301	1.253298
Rastrigin (14)	5.788498	5.959805	6.67686	6.502936	6.820697	6.158721	7.118764	7.029011	1.838831	1.601776	1.674729	1.729765	1.307187	1.585171	1.051588	1.272562
Schwefel (15)	5.43684	5.646802	5.541059	5.979493	6.531814	6.310275	6.05766	6.781614	1.824067	1.629564	1.617431	1.572342	1.33553	1.640965	1.070156	1.258428
Griewangk (16)	6.458696	5.893322	5.670955	5.892614	5.787753	5.973353	6.341996	6.359841	1.768094	1.506369	1.563507	1.433721	1.468696	1.451128	1.068148	1.091563
Ackley (17)	5.752643	5.95814	6.003438	5.610203	5.223004	6.241583	5.029601	5.393082	1.717444	1.54208	1.523063	1.377864	1.814967	1.896858	1.273083	1.347232
Langerman (18)	5.670885	5.626195	6.795997	6.837736	5.124835	6.999945	5.35697	7.038374	3.892088	4.40354	3.927682	4.763676	4.201839	4.640159	4.453071	4.924423
Michaelewicz (19)	7.507058	8.220854	9.019463	8.34273	9.850066	9.524984	11.83093	12.91863	19.9982	13.38705	13.03965	22.46667	22.89457	20.05561	17.45091	35.46038
Branin (20)	2.558702	2.642202	3.638244	3.300014	2.998451	3.260028	2.445285	2.416737	2.335701	2.138929	1.874282	1.224948	1.663756	1.331678	1.264002	1.46922
Six Hump Camel (21)	4.078094	3.82388	3.34973	3.211251	2.958146	3.315458	2.648335	2.028704	2.241778	2.432299	1.78024	1.333649	1.751012	1.421751	1.44076	1.700065
Osborne 1 (22)	7.717171	7.793738	7.053985	6.955451	6.38298	7.44758	5.981048	5.851239	7.055328	7.456469	6.777855	6.570286	7.498401	7.081091	7.102499	7.356901
Osborne 2 (23)	17.67168	17.65515	17.5639	17.71219	19.55482	18.841	19.97754	20.57049	22.52051	22.69317	22.72713	24.99592	24.17326	25.04388	24.68178	24.47987
Mod Rastrigin (24)	2.098146	2.015687	3.177994	3.643136	5.029808	3.777261	5.178644	5.224446	2.342231	1.72351	1.963335	2.316139	1.485913	1.921587	1.339494	1.127766
Mineshaft 1 (25)	2.689331	1.894358	3.489623	3.406119	4.395971	3.222439	3.445747	2.598313	2.175759	1.620654	1.582492	1.751185	1.515474	1.570138	1.102309	1.095907
Mineshaft 2 (26)	3.189867	2.491558	3.856569	3.346326	2.572852	3.070164	1.726409	1.593176	1.409794	1.299702	1.132137	1.257882	1.307011	0.899707	0.682927	0.662695
Mineshaft 3 (27)	4.92655	4.185019	4.408981	4.302045	2.980868	4.615801	2.966325	2.62971	2.355271	2.638391	3.01562	3.013074	2.610966	1.653924	1.477865	1.478226
Spherical Contours (28)	21.63244	22.75942	22.23332	22.15059	37.48939	38.17865	42.85124	42.82968	65.02518	55.07344	72.30645	76.2463	80.77272	73.04804	71.0691	105.1149
S1 (29)	1.577282	0.908154	1.983222	1.94429	0.974282	0.794922	1.030324	1.104831	1.218297	1.309399	1.077185	1.103493	0.834982	1.052437	0.641938	0.626574
S2 (30)	1.908367	1.646486	2.802461	2.827539	1.61441	1.257328	2.178518	2.105833	2.58293	2.072267	2.73146	3.077994	1.363398	1.574204	1.080559	1.097754
S3 (31)	1.289142	1.320585	1.901692	1.986105	1.123504	0.778635	1.193881	1.180636	1.406059	1.55298	1.191954	1.384963	1.199916	1.41433	0.954165	1.002057
Downhill Step (32)	5.356417	3.19424	4.852407	4.680206	3.650892	2.180049	3.514614	3.407711	3.568767	3.929239	3.141657	3.749283	3.545143	2.958862	2.790555	2.876899
Salomon (33)	3.108115	2.881632	2.060246	1.940915	2.389752	1.585183	1.486522	1.47944	2.161723	2.085714	2.110657	2.753385	2.008051	1.049147	1.242338	1.310437
Whitley (34)	2.194751	2.583637	1.499	1.436408	1.809634	1.511003	1.253393	1.319013	1.650188	1.854876	1.590538	1.860244	1.616426	1.142777	1.19091	1.260409
Odd Square (35)	2.001313	2.359989	1.319999	1.393357	1.646215	1.303631	1.12439	1.025371	1.591346	1.533299	1.858348	1.727844	1.456752	1.099404	1.062602	1.152543
Storn Chebyshev (36)	221.0833	221.6415	221.123	221.9867	220.936	221.3702	221.4741	222.3748	234.9835	235.8404	234.4009	234.2502	234.8299	233.702	239.024	244.2325
Rana (37)	1.121946	1.022141	1.189389	1.332639	1.448501	1.305009	1.628258	1.814916	1.373809	1.237453	1.43055	1.501011	1.795403	1.882126	2.186791	2.491187
Rosenbrock 10D (38)	2.072407	2.006632	2.468409	2.342406	3.240069	3.262707	3.822177	3.721468	5.152556	5.078426	5.332652	6.373021	7.069947	7.108289	7.984012	9.658216
Rosenbrock 30D (39)	17.14905	17.61569	18.3372	18.46158	32.66368	31.96144	37.84856	37.82844	52.53319	45.9774	61.31243	68.72168	81.60473	74.07928	88.23049	137.3651
Mod Rosenbrock 1 10D (40)	3.415924	3.361686	3.901095	3.86701	4.617879	4.475544	4.544466	4.685256	5.251031	5.156869	5.33526	6.906574	8.536942	8.156554	9.003443	10.4333
Mod Rosenbrock 1 30D (41)	21.26075	21.53855	21.78693	21.81032	35.47819	35.6577	38.07977	37.95701	52.2086	48.34226	62.03012	67.70073	78.3158	71.69744	87.75545	107.2582
Mod Rosenbrock 2 10D (42)	3.503676	3.510517	3.793278	3.780192	3.694746	3.703962	4.039045	4.209685	4.019067	4.090557	4.714317	5.392393	6.933762	7.117544	6.97458	7.773079
Mod Rosenbrock 2 30D (43)	13.10393	13.56129	20.17823	20.14806	17.6353	16.62955	33.86209	33.70484	39.29477	25.82163	58.33388	96.14154	57.87255	49.68566	87.74362	244.2028
Spherical Contours 10D (44)	2.612432	2.424887	2.344962	2.491559	3.073064	3.212667	3.289559	3.539429	4.033507	3.885442	4.422536	5.504332	7.082401	6.77313	7.008111	8.488589
Rastrigin 10D (45)	2.676102	3.163992	3.005587	2.964348	3.242801	3.305668	4.150771	4.733783	6.29871	4.440419	5.241758	9.54262	10.40753	9.95752	9.24531	16.69965
Rastrigin 30D (46)	19.3	20.36004	22.55402	22.60028	34.89295	33.63659	43.67454	43.54841	68.96616	53.60553	81.33025	102.4063	95.95564	88.5442	101.607	175.7167
Schwefel 10D (47)	2.85805	2.911906	2.939788	2.937957	3.510919	3.575499	3.084983	3.182092	4.638199	4.524507	5.184428	5.805588	7.71127	8.219166	9.061131	7.586006
Schwefel 30D (48)	19.50049	20.48711	22.43397	22.53313	29.46468	29.10074	40.30912	40.0978	53.33477	29.11814	70.04268	88.31249	52.38918	41.6152	70.52806	134.834
Griewangk 10D (49)	3.280394	3.332106	3.422473	3.748896	3.836086	3.947408	3.94893	4.173363	7.51814	7.307668	7.766448	8.403268	9.113264	10.13694	8.966846	10.46989
Griewangk 30D (50)	20.39223	21.07324	21.67494	21.59147	32.31691	31.82139	38.32408	38.57212	63.30068	54.51823	70.20452	72.8332	80.53997	71.52738	76.88658	103.2117
Salomon 10D (51)	2.73155	3.115213	5.197146	5.780661	2.706142	2.090837	4.166063	6.120767	6.731048	4.760473	5.901712	12.39126	10.93038	9.5763	7.221896	18.31026
Salomon 30D (52)	5.63297	6.130943	7.197978	7.132501	7.752395	7.180039	13.80479	14.03007	29.85049	20.97402	32.25618	41.69942	54.22867	55.87892	61.07335	113.8065
Odd Square 10D (53)	2.563351	2.73357	3.178951	3.151395	2.74723	3.009875	5.345745	6.037446	9.011939	6.30798	7.278814	16.44872	13.1226	14.18873	12.77568	36.18813
Whitley 10D (54)	9.377251	9.377855	9.096832	8.997926	9.806612	10.13836	10.59571	10.60015	13.0601	13.35263	12.72243	13.93639	13.53787	14.20209	14.11319	15.49797
Whitley 30D (55)	75.50065	76.50611	77.40133	77.53035	95.30069	93.75175	105.046	105.475	135.7947	118.9445	143.0263	153.5586	154.3725	144.8536	147.4595	232.5269
Rana 10D (56)	5.023495	5.147095	5.528174	5.818204	6.44827	7.095798	7.221709	7.611691	13.82001	14.18533	13.78224	20.41834	20.32183	20.42924	17.58757	34.70696
Rana 30D (57)	16.56318	17.84057	25.52289	25.75434	18.95134	18.31116	35.2499	35.70977	37.53216	25.55911	46.43875	76.98906	40.07814	36.32229	49.93861	182.7115

Average Times (s) for 500k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.728831	0.656722	0.477856	0.602343	0.718089	0.473997	0.604695	0.578145	0.496982	0.650789	0.572721	0.627839	0.845276	0.690155	0.923668	0.646753
McCormic (2)	1.070822	0.902049	0.707856	0.895778	1.007855	0.543462	0.742792	0.784873	0.528804	0.631737	0.621384	0.627363	0.799783	0.720784	0.922538	0.653563
Box and Betts (3)	2.090114	2.036203	1.837697	1.963009	2.064473	1.809328	1.91814	1.884801	1.869744	1.942792	1.962251	2.028744	2.254737	2.197846	2.247727	2.227804
Goldstein (4)	0.911752	0.784202	0.642169	0.729082	0.673268	0.50825	0.864116	0.543496	0.510911	0.64698	0.575679	0.615099	0.734396	0.705917	0.685475	0.70415
Easom (5)	1.9494	1.58666	1.455589	1.769623	1.714295	1.188234	2.094611	1.316777	1.261814	1.433401	1.45982	1.532386	2.035904	1.663259	1.837958	1.911168
Mod Rosenbrock 1 (6)	0.941672	0.904739	0.741277	0.882893	0.784557	0.609057	1.019624	0.619865	0.503413	0.569034	0.56068	0.581506	0.650005	0.626889	0.647593	0.631871
Mod Rosenbrock 2 (7)	0.98237	0.925865	0.781678	0.904547	0.894454	0.721722	1.073812	0.705635	0.558509	0.642004	0.535713	0.589521	0.662432	0.612779	0.653517	0.629735
Bohachevsky (8)	1.046944	0.989938	0.83419	0.986474	1.021213	0.878626	1.133739	0.822271	0.694286	0.667548	0.569734	0.638127	0.697168	0.64506	0.714255	0.672736
Powell (9)	1.075879	1.055374	0.903873	1.06561	1.107268	0.961482	1.1197	1.106418	1.218824	1.229515	1.217436	1.31193	1.339411	1.342529	1.435407	1.44919
Wood (10)	0.972534	0.988017	0.82782	1.033201	0.994288	1.037645	0.882984	0.983561	1.102047	1.143181	1.112528	1.167276	1.239377	1.298248	1.27363	1.362449
Beale (11)	1.022264	1.026291	0.859322	1.072629	0.909677	1.104232	0.819416	0.867754	0.657635	0.557866	0.533272	0.667837	0.628602	0.682087	0.672946	0.646549
Engvall (12)	1.143296	1.165652	1.008394	1.205727	1.099499	1.298627	0.941285	1.021806	0.787635	0.691118	0.663513	0.809272	0.771118	0.817857	0.838845	0.809379
DeJong (13)	0.948158	0.963238	0.793435	0.968284	0.853385	1.067594	0.674858	0.705142	0.614457	0.619519	0.488441	0.629279	0.611098	0.746282	0.746279	0.659916
Rastrigin (14)	1.007844	0.995085	0.84328	0.974314	0.928445	1.067945	0.736208	0.773253	0.63688	0.582879	0.587342	0.629483	0.581202	0.626202	0.698158	0.613001
Schwefel (15)	0.960331	0.95088	0.766733	0.884493	0.871626	1.004169	0.690324	0.720837	0.677462	0.599376	0.597121	0.709162	0.611683	0.714953	0.6967	0.622694
Griewangk (16)	1.032951	1.05341	0.777143	0.928596	0.873339	0.939685	0.674269	0.701165	0.599128	0.552046	0.546708	0.674241	0.60956	0.712373	0.77675	0.632066
Ackley (17)	1.106166	1.145678	0.81179	0.956812	0.827281	0.831149	0.726809	0.675676	0.614324	0.669599	0.66849	0.781233	0.697873	0.825221	0.866778	0.727814
Langerman (18)	1.572851	1.631317	1.53917	2.043451	1.595068	1.479471	1.629295	2.015357	1.55347	1.769111	1.754043	2.392075	1.906749	2.273468	2.428392	3.091166
Michaelewicz (19)	3.570605	3.896168	4.1102	3.97618	4.617899	4.416663	5.095564	5.694946	8.9375	6.05167	7.108562	11.80217	10.30637	11.93662	9.861499	20.8047
Branin (20)	0.893632	0.945477	0.664099	0.895537	0.885858	0.659902	0.580316	0.609647	0.580242	0.575899	0.570047	0.510162	0.637995	0.895641	0.667596	0.815888
Six Hump Camel (21)	1.055036	1.093024	0.792843	1.012359	1.077117	0.694901	0.776875	0.753463	0.625751	0.670251	0.629173	0.586	0.681562	1.057829	0.717919	0.830758
Osborne 1 (22)	3.268356	3.336097	3.039432	3.227853	3.447331	3.088393	3.082293	3.325178	3.458648	3.541051	3.4793	3.564462	3.566265	4.122079	3.69388	4.066149
Osborne 2 (23)	10.16626	10.29089	9.81396	9.91108	10.60196	10.38095	10.63488	10.59078	11.29285	11.41354	11.287	12.59407	12.46589	13.67249	13.12355	14.94156
Mod Rastrigin (24)	1.262041	1.188002	0.979699	1.231373	0.979394	0.939159	1.065428	1.058575	0.731778	0.748201	0.807147	0.838966	0.756338	0.906206	0.780942	0.925355
Mineshaft 1 (25)	1.268857	0.905822	0.8945	0.931897	0.976195	0.795805	0.825859	0.788334	0.757804	0.766456	0.756351	0.798487	0.843435	0.92502	0.846569	0.967268
Mineshaft 2 (26)	0.99845	0.651914	0.635963	0.569986	0.741535	0.455213	0.545941	0.502251	0.508957	0.511684	0.493662	0.527329	0.575889	0.689047	0.591002	0.714818
Mineshaft 3 (27)	1.217543	1.253363	0.920608	1.043303	0.975992	0.872966	1.000277	0.804706	0.99331	0.906077	1.058219	1.443765	1.072406	1.182562	1.169288	1.293425
Spherical Contours (28)	16.96002	17.95225	17.70391	18.23153	21.66653	21.63623	23.89497	22.82767	30.52657	26.50191	34.13778	37.7442	43.24829	37.46527	42.25589	64.4128
S1 (29)	0.738627	0.521955	0.704338	0.475225	0.632954	0.394393	0.383578	0.437742	0.601982	0.430639	0.498254	0.465602	0.746609	0.491554	0.526775	0.653694
S2 (30)	0.908809	1.131305	0.942345	0.825316	1.10823	0.76987	0.734962	0.915113	0.883986	0.789445	0.801672	0.766706	0.743943	0.596211	0.561179	0.699714
S3 (31)	0.644333	0.708846	0.643093	0.615124	0.814891	0.545869	0.494401	0.65201	0.766369	0.759623	0.726169	0.651977	0.861302	0.718161	0.738419	0.892862
Downhill Step (32)	1.953898	1.581903	1.906609	2.186772	2.519252	1.246927	1.459227	1.781807	1.895236	1.731143	1.736826	1.571711	2.385386	1.61309	1.968733	2.433791
Salomon (33)	1.027952	0.925118	0.947463	1.048507	1.318015	0.732957	0.903349	0.90387	0.997891	0.883042	0.993875	0.795679	0.882509	0.639039	0.706115	0.872717
Whitley (34)	0.907711	0.820766	0.844828	0.882589	1.025403	0.639327	0.816138	0.740627	0.831313	0.879799	0.797963	0.801356	1.076579	0.774193	0.814052	0.957377
Odd Square (35)	0.816568	0.72383	0.740457	0.761013	0.877535	0.564263	0.788177	0.708501	0.697259	0.779225	0.80819	0.78944	1.102101	0.714456	0.824037	1.002612
Storn Chebyshev (36)	123.0583	119.8547	120.3826	117.5898	117.9547	117.029	117.9712	117.6196	119.0975	119.1754	121.2466	122.8096	122.222	122.3207	123.7824	124.5584
Rana (37)	1.160974	0.987843	0.795579	0.675169	0.752205	0.906152	0.887507	0.82247	0.865466	0.765841	1.151886	0.92057	0.861169	1.051964	1.086031	1.050001
Rosenbrock 10D (38)	2.066427	2.042727	1.782706	1.640506	2.395103	2.593721	2.560699	2.644011	3.051876	3.06563	3.72075	3.786599	3.535242	4.167218	4.226145	5.127191
Rosenbrock 30D (39)	15.29751	15.69113	15.82039	15.39429	19.22932	19.44189	22.02956	22.58712	30.94114	26.60718	35.24923	36.98253	41.39135	39.33656	44.42922	65.67262
Mod Rosenbrock 1 10D (40)	2.373164	2.259176	2.640596	2.122512	2.517174	2.681635	2.527776	2.712552	3.469118	3.52778	3.405742	3.880402	4.83351	5.242631	5.609091	5.833163
Mod Rosenbrock 1 30D (41)	16.82653	17.15064	16.61153	15.93929	20.72007	21.15218	22.97449	22.45128	28.72087	26.33243	30.93334	32.7722	38.87753	36.86398	42.12727	51.41506
Mod Rosenbrock 2 10D (42)	1.858101	2.091953	1.795484	1.710657	2.060174	2.021673	1.885258	2.133934	2.546668	2.722915	2.490916	3.065938	4.067738	4.448308	4.137949	5.315082
Mod Rosenbrock 2 30D (43)	7.704062	8.620051	10.90295	10.60313	10.89467	10.87864	18.62794	18.61526	22.53682	15.37026	31.85505	56.08325	30.10256	25.26122	39.31472	126.1146
Spherical Contours 10D (44)	1.51894	1.8036	1.560505	1.451636	1.674416	1.670226	1.736295	1.765604	2.782726	2.571764	2.463071	3.500907	4.380837	4.35144	4.63774	6.227128
Rastrigin 10D (45)	1.469637	1.958086	1.724345	1.537067	1.818249	1.596031	2.229278	2.147288	4.864575	3.007533	3.283066	6.236074	7.10072	6.727367	6.82792	14.22038
Rastrigin 30D (46)	14.47491	15.89462	16.05511	15.35044	18.21684	18.43002	22.81294	22.9704	35.35534	27.84696	34.76828	48.64458	46.32801	41.1565	49.34597	82.66822
Schwefel 10D (47)	1.68094	1.767327	1.74557	1.630154	1.784468	1.893742	1.724917	1.983197	2.727772	3.327441	2.848393	3.844413	4.8412	5.594143	6.2449	5.445346
Schwefel 30D (48)	13.45491	15.09658	16.03586	16.15107	13.76428	13.18114	22.3929	23.10092	22.82101	14.84507	31.1486	42.75264	26.0453	21.4662	34.7507	63.19795
Griewangk 10D (49)	2.135132	2.304819	1.893963	2.185259	2.81529	2.832929	2.838211	3.0067	3.889947	3.964514	3.955194	4.620467	5.127121	5.037681	5.28674	5.101512
Griewangk 30D (50)	15.48353	16.6109	15.3102	16.06356	20.52302	19.6989	22.5689	21.66093	28.82903	25.61862	34.10988	36.66594	40.8007	36.71198	39.17242	44.31936
Salomon 10D (51)	1.010722	1.400299	1.429633	1.433706	1.2805	1.30759	1.963049	2.449951	3.406578	2.423789	3.30595	7.23265	6.459159	7.976711	5.59577	9.312963
Salomon 30D (52)	3.309176	3.661464	4.151434	4.025442	5.360947	5.308364	7.61018	8.406512	20.0867	14.38201	23.99467	29.73915	32.95845	33.73445	38.6352	54.69346
Odd Square 10D (53)	1.289374	1.428718	1.861007	1.741522	1.733085	1.740701	2.138492	3.660734	4.959849	3.353064	4.857892	11.38005	10.77939	9.375422	9.712543	15.45715
Whitley 10D (54)	5.117966	4.961219	4.985457	4.862061	5.653363	5.613147	5.595166	6.0934	6.079827	6.271126	6.804472	7.349239	7.170328	6.853528	6.776456	6.354055
Whitley 30D (55)	44.57112	44.82011	44.18638	45.29733	48.90534	48.41444	55.2672	55.58625	64.48431	55.80287	71.10823	79.12709	79.27695	74.81074	78.59494	94.62222
Rana 10D (56)	3.097478	2.91314	3.039372	3.011675	3.928376	4.085385	4.75281	5.511372	7.834997	6.602399	7.761528	10.14594	11.47307	12.31521	13.30938	12.07481
Rana 30D (57)	8.846703	8.868373	12.61953	12.87131	10.25068	9.722483	19.63166	21.31896	18.96179	12.58896	24.64333	46.04868	25.69714	19.5138	30.28479	67.85086

Average Times (s) for 100k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.13248	0.148453	0.156879	0.145585	0.155672	0.154417	0.124271	0.163702	0.168409	0.145806	0.212691	0.122631	0.139695	0.17425	0.22487	0.213801
McCormic (2)	0.122805	0.143673	0.152323	0.131725	0.13076	0.145795	0.102976	0.137905	0.162502	0.152483	0.203661	0.116554	0.145577	0.180579	0.220697	0.219738
Box and Betts (3)	0.415418	0.43918	0.441495	0.427008	0.458539	0.46454	0.422168	0.467429	0.488087	0.458042	0.517144	0.427588	0.441334	0.503586	0.551009	0.56962
Goldstein (4)	0.134911	0.150341	0.147645	0.14127	0.144677	0.155134	0.113796	0.14443	0.175706	0.154924	0.169259	0.120717	0.143769	0.190222	0.191111	0.241647
Easom (5)	0.340247	0.312084	0.345848	0.350747	0.378352	0.323886	0.311886	0.386024	0.447258	0.347022	0.433749	0.300663	0.329364	0.395327	0.408919	0.502936
Mod Rosenbrock 1 (6)	0.156471	0.143227	0.135792	0.134653	0.147095	0.141064	0.116613	0.141645	0.174066	0.144923	0.174316	0.119739	0.149884	0.186223	0.204728	0.204123
Mod Rosenbrock 2 (7)	0.156047	0.147861	0.141139	0.138456	0.150045	0.143104	0.118212	0.141615	0.17245	0.143198	0.176366	0.121775	0.153307	0.1768	0.205386	0.205206
Bohachevsky (8)	0.16527	0.156486	0.152624	0.150342	0.15792	0.152583	0.12625	0.148672	0.181472	0.149153	0.185656	0.129172	0.163624	0.177927	0.220095	0.216908
Powell (9)	0.298717	0.302151	0.288384	0.293724	0.298555	0.29839	0.262242	0.306157	0.310449	0.28663	0.32075	0.266434	0.275717	0.2969	0.35301	0.377804
Wood (10)	0.276087	0.277489	0.263015	0.279925	0.278749	0.279232	0.246376	0.291355	0.295996	0.273253	0.30141	0.256551	0.261151	0.277855	0.335766	0.333649
Beale (11)	0.15653	0.154622	0.141275	0.15066	0.149219	0.146887	0.118051	0.16048	0.180889	0.152082	0.163881	0.125816	0.154995	0.175599	0.210992	0.185254
Engvall (12)	0.185133	0.184079	0.174286	0.213529	0.196343	0.177354	0.163896	0.208082	0.207187	0.184433	0.184795	0.151598	0.24408	0.214538	0.248458	0.222839
DeJong (13)	0.148929	0.141498	0.131777	0.171861	0.137276	0.140935	0.108729	0.149126	0.166853	0.153339	0.14419	0.113733	0.184089	0.181137	0.207233	0.185956
Rastrigin (14)	0.172666	0.159599	0.153878	0.194822	0.154032	0.181271	0.124241	0.165163	0.186363	0.138771	0.164024	0.128879	0.192096	0.164238	0.206764	0.180638
Schwefel (15)	0.168071	0.149183	0.147309	0.186446	0.14143	0.182116	0.116291	0.152801	0.169815	0.170367	0.150923	0.123592	0.198471	0.176812	0.210719	0.181683
Griewangk (16)	0.166097	0.1476	0.136858	0.170835	0.142766	0.181166	0.117643	0.153029	0.17852	0.176169	0.156437	0.125189	0.189792	0.192662	0.216772	0.187307
Ackley (17)	0.187039	0.169449	0.160498	0.19542	0.159601	0.187835	0.14609	0.176285	0.195671	0.195079	0.180629	0.141827	0.193084	0.24349	0.243094	0.216991
Langerman (18)	0.338493	0.318919	0.342876	0.42532	0.357971	0.423779	0.362144	0.498104	0.494723	0.511003	0.53148	0.584506	0.482078	0.617577	0.750816	0.902415
Michaelewicz (19)	1.053823	1.133099	1.254932	1.203944	1.180148	1.202607	1.339457	1.663143	2.256607	1.570476	1.852298	2.594087	2.617499	2.803253	3.158757	4.775906
Branin (20)	0.169168	0.155009	0.151284	0.146306	0.146386	0.149974	0.125699	0.150227	0.165303	0.164428	0.147047	0.149327	0.170514	0.180739	0.207953	0.190103
Six Hump Camel (21)	0.148788	0.164559	0.158724	0.151525	0.146063	0.154837	0.124144	0.153602	0.164525	0.170436	0.162661	0.152575	0.177963	0.185731	0.215335	0.200717
Osborne 1 (22)	0.737944	0.767123	0.761099	0.776258	0.762227	0.766837	0.734535	0.802517	0.769263	0.762376	0.766412	0.778702	0.761489	0.794178	0.854134	0.882866
Osborne 2 (23)	2.293178	2.348428	2.319923	2.330048	2.377021	2.346818	2.280509	2.451727	2.526411	2.589026	2.372096	2.684858	2.796497	2.934971	3.172012	3.374806
Mod Rastrigin (24)	0.216395	0.185082	0.200664	0.194419	0.195812	0.173982	0.161586	0.2117	0.234613	0.213306	0.156626	0.23278	0.193466	0.195901	0.242458	0.214725
Mineshaft 1 (25)	0.243439	0.186357	0.204523	0.175382	0.206322	0.184416	0.159558	0.201645	0.212027	0.214368	0.152059	0.201453	0.207297	0.203357	0.23432	0.207767
Mineshaft 2 (26)	0.208182	0.134023	0.167349	0.117562	0.157667	0.130754	0.115266	0.154018	0.160097	0.167932	0.100604	0.15096	0.1624	0.146201	0.184031	0.14384
Mineshaft 3 (27)	0.257453	0.218325	0.213483	0.202072	0.250307	0.211308	0.201754	0.277112	0.34344	0.320209	0.233577	0.347205	0.379781	0.303425	0.439995	0.356917
Spherical Contours (28)	4.086583	4.184212	4.266652	4.184635	4.640539	4.615367	4.878924	5.325874	6.523545	5.909882	6.460086	7.35853	8.160491	8.198665	9.050957	11.91508
S1 (29)	0.151766	0.111636	0.159192	0.111309	0.178157	0.122902	0.152166	0.146395	0.157698	0.13737	0.103363	0.116119	0.141932	0.1625	0.148381	0.12727
S2 (30)	0.163741	0.147435	0.204658	0.149732	0.162311	0.12305	0.122043	0.145696	0.156234	0.143748	0.105703	0.128885	0.151627	0.183752	0.158701	0.148198
S3 (31)	0.164224	0.150131	0.19191	0.151343	0.213246	0.163525	0.16495	0.199744	0.194222	0.17712	0.139785	0.176169	0.185769	0.207817	0.202693	0.182024
Downhill Step (32)	0.409168	0.319117	0.489751	0.391134	0.494577	0.327767	0.415968	0.49287	0.474612	0.37652	0.342642	0.431008	0.389138	0.432862	0.446402	0.376557
Salomon (33)	0.194239	0.164393	0.217077	0.180098	0.185805	0.162046	0.159904	0.195552	0.250273	0.182583	0.16273	0.16997	0.216059	0.224068	0.242534	0.208859
Whitley (34)	0.188583	0.18019	0.202376	0.178044	0.189873	0.186887	0.179567	0.206942	0.230578	0.191485	0.166273	0.17486	0.203268	0.210918	0.223494	0.206517
Odd Square (35)	0.187826	0.174397	0.198617	0.178833	0.208176	0.196111	0.200647	0.231455	0.237967	0.19274	0.177496	0.203507	0.228795	0.213072	0.236563	0.222618
Storn Chebyshev (36)	24.65519	24.39005	24.45415	24.49509	24.39611	24.13952	24.30513	24.60174	24.25361	24.20361	24.50665	24.79156	24.7424	25.44686	25.09519	24.83609
Rana (37)	0.232861	0.211893	0.20442	0.203596	0.206216	0.222971	0.190302	0.178737	0.200271	0.232751	0.20433	0.209095	0.30851	0.235929	0.2062	0.221331
Rosenbrock 10D (38)	0.63473	0.670591	0.641904	0.656169	0.627324	0.695435	0.662718	0.665109	0.723564	0.819701	0.774666	0.965674	1.101225	1.158813	0.997923	1.303353
Rosenbrock 30D (39)	3.675905	3.856754	3.887675	3.947144	3.961392	4.075233	4.814653	4.519337	6.07748	5.482796	6.985293	7.67568	8.32372	8.023187	7.940688	11.59163
Mod Rosenbrock 1 10D (40)	0.671014	0.697639	0.699057	0.708193	0.729715	0.771929	0.830992	0.814358	0.978253	0.918512	0.996726	1.332063	1.370083	1.463982	1.359056	1.844193
Mod Rosenbrock 1 30D (41)	4.075023	4.170483	4.143655	4.248934	4.319542	4.389251	4.795813	4.469008	5.78858	5.444667	6.064898	6.832044	7.692473	6.92781	7.531461	8.862857
Mod Rosenbrock 2 10D (42)	0.491149	0.507761	0.477318	0.512677	0.583437	0.588359	0.67726	0.621211	0.844515	0.830922	0.776681	1.025785	1.185234	1.105067	1.245049	1.287106
Mod Rosenbrock 2 30D (43)	2.190584	2.396896	3.56859	3.639578	2.696462	2.363416	5.341041	4.955836	5.436946	4.047093	6.080739	12.14352	9.119311	6.507336	8.723366	23.58106
Spherical Contours 10D (44)	0.493704	0.496147	0.499594	0.520016	0.590821	0.612849	0.650561	0.671908	0.84693	0.920287	0.896569	1.33031	1.460091	1.239393	1.235111	1.595946
Rastrigin 10D (45)	0.493691	0.541325	0.576105	0.620811	0.721607	0.690454	1.005776	1.011252	1.548094	1.085499	1.370399	2.518697	2.399007	1.829696	1.753313	2.954324
Rastrigin 30D (46)	3.150074	3.464591	3.633381	3.803131	3.550927	3.705702	5.215394	4.883405	6.264271	4.755128	7.198799	8.894504	7.383834	6.255013	6.897212	10.33779
Schwefel 10D (47)	0.493891	0.50809	0.52301	0.582796	0.630901	0.698514	0.800618	0.717243	0.919818	0.950601	1.271102	1.407682	1.683095	1.528068	1.442439	1.747555
Schwefel 30D (48)	2.574721	3.095293	3.924364	4.016599	2.719354	2.631065	4.975791	4.744996	4.724909	3.443274	6.176471	8.352632	6.37652	4.907803	6.444512	12.68915
Griewangk 10D (49)	0.734086	0.729848	0.748203	0.787612	0.711344	0.733136	0.83777	0.793445	0.87339	0.882065	1.006482	1.308187	1.371621	1.53044	1.255495	1.464853
Griewangk 30D (50)	3.906707	4.006163	4.164917	4.063653	4.234101	4.141669	4.732514	4.725268	5.744681	5.269041	6.805257	7.247745	7.533066	7.272442	7.250706	8.482589
Salomon 10D (51)	0.361504	0.368809	0.526535	0.458219	0.516265	0.52875	0.699437	0.964792	1.644713	1.267961	1.518977	2.718094	2.004231	1.803265	1.677799	2.671385
Salomon 30D (52)	1.655145	1.776021	2.165404	1.957627	2.351606	2.502732	3.797521	3.57551	5.262741	4.010671	6.443072	6.976876	6.3832	5.907951	6.895105	11.6356
Odd Square 10D (53)	0.554162	0.605965	0.841669	0.750166	0.825714	0.837602	1.115976	1.441723	1.782909	1.337139	1.730909	2.598806	1.608271	1.690381	1.484643	2.390969
Whitley 10D (54)	1.326664	1.30903	1.370109	1.315869	1.281357	1.329527	1.352716	1.324687	1.410955	1.444487	1.534358	1.472023	1.482751	1.455233	1.41515	1.521014
Whitley 30D (55)	9.805971	9.822636	10.10102	10.12008	10.32369	10.4322	10.93753	10.85635	13.36015	11.90065	14.30103	14.27977	15.22939	13.76898	14.02648	18.54774
Rana 10D (56)	0.8871	0.953197	0.963377	0.991549	1.083821	1.074008	1.126133	1.297346	2.019927	1.768631	1.941101	2.388616	2.523044	2.310269	2.031892	2.962918
Rana 30D (57)	1.991628	2.103593	3.3675	3.452234	2.590956	2.485693	4.298442	4.818874	5.852716	4.206393	5.999894	9.25382	7.4768	5.941373	6.708568	11.18691

APPENDIX F1: AVG. RESULTS FOR SMOA-HTDE

Average Results (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.000269	0.000311	0.000269	0.000269	0.000311	0.000279	0.000311	0.000311	0.000315	0.000105	0.000315	0.000315	0.000176	3.63E-05	0.000176	0.000176	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.9131	-1.91322	-1.91322	-1.9133
Box and Betts (3)	1.36E-08	4.56E-09	2.19E-08	1.00E-08	4.06E-09	3.55E-08	9.01E-09	9.84E-09	4.67E-08	5.93E-07	5.76E-08	5.65E-08	1.35E-06	1.56E-06	4.01E-08	1.01E-06	0
Goldstein (4)	3.000011	3.000003	3.000011	3.000011	3.000004	3.000001	3.000004	3.000004	3.000001	3	3.000001	3.000001	3	3.102064	3	3	3
Easom (5)	-0.99967	-0.99949	-0.99967	-0.99967	-0.99969	-0.99982	-0.99969	-0.99969	-0.99985	-0.99997	-0.99985	-0.99985	-0.99999	-0.99996	-0.99999	-0.99999	-1
Mod Rosenbrock 1 (6)	0.019978	0.020616	0.019978	0.019978	0.0207	0.023873	0.0207	0.0207	0.025401	0.012797	0.025401	0.025401	0.016735	0.006921	0.016735	0.016735	0
Mod Rosenbrock 2 (7)	0.275902	0.671278	0.275902	0.275902	0.575594	0.653915	0.575594	0.575594	0.793915	0.524657	0.793915	0.793915	0.562281	0.38277	0.562281	0.562281	0
Bohachevsky (8)	0.514056	0.629368	0.514056	0.514056	0.64583	0.599156	0.64583	0.64583	0.629402	0.275008	0.629402	0.629402	0.272148	0.0632	0.272148	0.272148	0
Powell (9)	56398.37	56398.37	18914.59	19174.34	51229.64	51229.64	19566.97	1430.952	38383.09	38383.09	38839.57	2475.968	48823.55	48823.55	42950.67	1533.436	0
Wood (10)	197625.2	197625.2	49515.07	29695.9	156468.1	156468.1	43657.95	3347.775	76994.92	76994.92	86716.73	2448.561	128065.5	128065.5	111382.7	1522.882	0
Beale (11)	0.189098	0.271313	0.189098	0.189098	0.259553	0.218115	0.259553	0.259553	0.253807	0.080518	0.253807	0.253807	0.076142	0.02621	0.076142	0.076142	0
Engvall (12)	0.300446	0.378395	0.300446	0.300446	0.374452	0.294442	0.374452	0.374452	0.377142	0.152988	0.377142	0.377142	0.17686	0.056549	0.17686	0.17686	0
DeJong (13)	2.22E-06	1.67E-06	2.22E-06	2.22E-06	3.19E-06	5.98E-07	3.19E-06	3.19E-06	5.35E-07	7.61E-08	5.35E-07	5.35E-07	1.49E-07	3.43E-08	1.49E-07	1.49E-07	0
Rastrigin (14)	0.00066	0.000569	0.00066	0.00066	0.000646	0.000168	0.000646	0.000646	0.00022	0.049103	0.00022	0.00022	0.00187	0.014875	0.00187	0.00187	0
Schwefel (15)	-837.963	-837.963	-837.963	-837.963	-837.963	-837.963	-837.963	-837.963	-837.963	-837.964	-837.963	-837.963	-837.963	-837.964	-837.963	-837.963	-837.9658
Griewangk (16)	0.003682	0.003063	0.003682	0.003682	0.002529	0.003681	0.002529	0.002529	0.003066	0.002752	0.003066	0.003066	0.003339	0.003264	0.003339	0.003339	0
Ackley (17)	0.01118	0.015521	0.01118	0.01118	0.01585	0.014823	0.01585	0.01585	0.017034	0.003649	0.017034	0.017034	0.003997	0.002067	0.003997	0.003997	0
Langerman (18)	-1.49588	-1.496	-1.49693	-1.49603	-1.49594	-1.496	-1.49659	-1.49641	-1.49605	-1.49558	-1.49624	-1.4964	-1.49498	-1.49532	-1.49563	-1.4958	-1.5
Michaelewicz (19)	-6.92434	-8.44565	-7.66706	-7.61219	-6.95624	-8.48957	-7.87361	-7.53081	-7.8046	-8.27612	-8.20293	-7.43828	-7.87556	-8.04511	-8.17134	-7.35735	-9.66
Branin (20)	0.39789	0.397889	0.39789	0.39789	0.39789	0.397888	0.39789	0.39789	0.397888	0.397887	0.397888	0.397888	0.397887	0.398608	0.397887	0.397887	0.397887
Six Hump Camel (21)	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.031977	0.030685	0.024594	0.023497	0.028913	0.028577	0.026173	0.024182	0.027659	0.02938	0.0299	0.026011	0.031089	0.034423	0.032421	0.028386	5.46E-05
Osborne 2 (23)	0.10747	0.093998	0.10514	0.101946	0.110183	0.099577	0.09799	0.110008	0.112549	0.106855	0.091027	0.110644	0.117289	0.118561	0.103653	0.117139	0.0402
Mod Rastrigin (24)	76.9887	80.10652	76.9887	76.9887	80.05989	80.80951	80.05989	80.05989	82.09669	81.44839	82.09669	82.09669	81.03605	80.11173	81.03605	81.03605	58
Mineshaft 1 (25)	1.709188	1.772636	1.75863	1.772636	1.704245	1.712695	1.705785	1.712695	1.711343	1.79028	1.68264	1.79028	1.686994	2.116836	1.744139	2.116836	1.3805
Mineshaft 2 (26)	-1.41635	-1.36019	-1.41398	-1.36019	-1.41635	-1.38629	-1.41635	-1.38629	-1.41635	-1.3471	-1.41264	-1.3471	-1.41635	-1.29427	-1.38626	-1.29427	-1.4163535
Mineshaft 3 (27)	-6.99351	-6.99896	-6.99351	-6.99351	-6.99911	-6.99976	-6.99911	-6.99911	-6.99989	-6.99999	-6.99989	-6.99989	-6.99997	-6.99999	-6.99997	-6.99997	-7
Spherical Contours (28)	21.50328	22.70766	18.04152	18.04152	20.66898	23.67109	19.3075	19.3075	21.92403	23.3881	21.58469	21.60891	25.37086	25.01945	25.35192	25.59165	0
S1 (29)	2.10E-14	0.001602	5.64E-15	0.001602	9.93E-15	1.10E-06	5.61E-16	1.10E-06	1.32E-15	3.04E-05	1.83E-05	3.04E-05	1.71E-13	0.000146	9.04E-15	0.000146	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.5289
Downhill Step (32)	9	9	9	9	9	9	9	9	9.016	9	9.016	9.016	9.002	9	9.002	9.002	9
Salomon (33)	0.00813	0.008267	0.00813	0.00813	0.007657	0.00671	0.007657	0.007657	0.006839	0.007533	0.006839	0.006839	0.008028	0.007138	0.008028	0.008028	0
Whitley (34)	0.004072	0.005938	0.004072	0.004072	0.005906	0.006254	0.005906	0.005906	0.010245	0.003937	0.010245	0.010245	0.005538	0.002944	0.005538	0.005538	0
Odd Square (35)	-1.00804	-1.00811	-1.00804	-1.00804	-1.00811	-1.0082	-1.00811	-1.00811	-1.00824	-1.00549	-1.00824	-1.00824	-1.00827	-0.99713	-1.00827	-1.00827	-1.14383
Storn Chebyshev (36)	15.83456	1.103854	7.039413	8.416679	16.17716	0.327972	2.042266	9.329044	10.94183	6.857183	0.443502	15.41171	12.5027	13.79919	0.311535	39.71224	0
Rana (37)	-1023.42	-1023.42	-1023.42	-1023.42	-1022.19	-1019.41	-1022.19	-1022.19	-1011.72	-1022.69	-1011.72	-1011.72	-1020.17	-1023.42	-1020.17	-1020.17	-1023.416
Rosenbrock 10D (38)	685.1713	674.2301	557.0372	571.6668	708.5905	718.9922	518.202	589.4049	701.3926	766.7694	498.7314	656.252	776.6214	747.5192	580.8104	693.385	0
Rosenbrock 30D (39)	173990.9	194223.1	114669.9	114669.9	153428.9	213534.9	126923.8	126923.8	167545.8	198456.8	170903.1	165303.7	233798.8	235082.8	233074.3	228123.7	0
Mod Rosenbrock 1 10D (40)	687.5387	646.5326	612.3014	626.1859	701.4589	692.4675	535.3595	641.4432	687.3176	705.8213	430.9395	662.6864	722.7814	729.2902	476.293	692.2283	0
Mod Rosenbrock 1 30D (41)	17513.23	17786.15	14535.56	14535.56	16709.26	18738.85	15645.45	15645.45	17261.19	18767.13	17145.27	17332.74	19674.93	19650.04	19640.76	19619.82	0
Mod Rosenbrock 2 10D (42)	0.426065	0.238835	0.625911	0.66925	0.629533	0.200176	0.59979	0.676141	0.75519	0.316811	0.442934	0.728143	0.69364	0.550433	0.473894	0.739144	0
Mod Rosenbrock 2 30D (43)	0.407622	0.218371	0.676769	0.676769	0.643947	0.18024	0.650518	0.650518	0.670101	0.38125	0.682301	0.698655	0.618455	0.577783	0.63623	0.720381	0
Spherical Contours 10D (44)	0.536376	0.526485	0.458394	0.479921	0.530055	0.540576	0.402392	0.495782	0.531971	0.535777	0.29954	0.483604	0.538309	0.541192	0.370428	0.503542	0
Rastrigin 10D (45)	30.51774	26.81987	26.41403	26.64542	29.98201	26.64045	27.67391	27.15417	29.89838	28.75387	29.957	28.91264	30.55744	30.27201	31.25793	29.57287	0
Rastrigin 30D (46)	242.9803	229.0556	215.9107	215.9107	236.2617	235.2734	218.7911	218.7911	234.9	241.9168	227.8884	226.3756	248.8469	251.6524	245.7803	234.2653	0
Schwefel 10D (47)	-3551.11	-3452.93	-3117.29	-3110.84	-3604.37	-3543.45	-3342.09	-3105.13	-3454.48	-3599.81	-3546.93	-3128.21	-3589.88	-3620.05	-3567.62	-3151.79	-4189.829
Schwefel 30D (48)	-7048.89	-6881.75	-6116.2	-6116.2	-7126.05	-7063.62	-6111.78	-6111.78	-7144.49	-7104.42	-6258.57	-5955.6	-7148.76	-7169.28	-6309.24	-5967.51	-12569.487
Griewangk 10D (49)	1.502594	1.472277	1.41048	1.440909	1.495451	1.484158	1.335717	1.434951	1.466017	1.486922	1.23426	1.45331	1.502154	1.500626	1.315331	1.466892	0
Griewangk 30D (50)	17.67501	18.35447	14.56075	14.56075	17.08889	19.12936	15.45869	15.45869	17.74841	19.16396	17.34197	17.56989	20.08632	19.80481	20.02857	20.05287	0
Salomon 10D (51)	1.019386	0.999775	0.909738	0.915929	0.996145	0.990489	0.959913	0.940597	0.992331	1.00871	0.989336	0.936994	1.025508	1.01316	0.982666	0.97927	0
Salomon 30D (52)	4.682388	4.798983	4.184036	4.184036	4.591431	4.946201	4.331289	4.331289	4.715398	4.936579	4.653916	4.646175	5.035475	5.065308	5.071825	5.034442	0
Odd Square 10D (53)	-0.54902	-0.56444	-0.666	-0.64464	-0.55198	-0.54785	-0.59272	-0.63205	-0.56788	-0.54685	-0.54509	-0.60644	-0.54245	-0.54803	-0.54407	-0.55976	-1.14383
Whitley 10D (54)	2823283	3000963	10340955	1.22E+08	2669047	3359073	2371461	2651062	3343009	3398100	3412717	3041430	3836463	3495565	3161328	2878738	0
Whitley 30D (55)	5.25E+11	6.52E+11	2.3E+11	2.3E+11	4.26E+11	8.1E+11	2.96E+11	2.96E+11	4.95E+11	7.43E+11	4.95E+11	5.05E+11	9.26E+11	8.5E+11	8.25E+11	8E+11	0
Rana 10D (56)	-4771.68	-4299.5	-3747.84	-3646.85	-4823.79	-4526.55	-4045.96	-3555.6	-4461.66	-4885.73	-4538.61	-3515.3	-4754.65	-4944.62	-4750.33	-3528.48	-5117.08
Rana 30D (57)	-8649.93	-8540.35	-6528.12	-6528.12	-9112.14	-8905.85	-6370.65	-6370.65	-9188.51	-9286.89	-6816.95	-6167.14	-9735.79	-9956.95	-7717.1	-6069.54	-15351.24

Average Results (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.000776	0.000672	0.000776	0.000776	0.000628	0.000581	0.000628	0.000628	0.000652	0.000227	0.000652	0.000652	0.000498	9.31E-05	0.000498	0.000498	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.9131	-1.91322	-1.91322	-1.9133
Box and Betts (3)	2.47E-08	1.08E-08	3.57E-08	1.90E-08	1.70E-06	1.61E-07	3.21E-08	2.03E-08	1.67E-07	1.00E-06	7.30E-08	7.41E-08	1.71E-06	2.89E-06	1.46E-07	1.06E-06	0
Goldstein (4)	3.000023	3.000005	3.000023	3.000023	3.000009	3.000002	3.000009	3.000009	3.000002	3.000001	3.000002	3.000002	3.000002	3.102066	3.000002	3.000002	3
Easom (5)	-0.99908	-0.99885	-0.99908	-0.99908	-0.99909	-0.99962	-0.99909	-0.99909	-0.99961	-0.99992	-0.99961	-0.99961	-0.99996	-0.99983	-0.99996	-0.99996	-1
Mod Rosenbrock 1 (6)	0.030646	0.036214	0.030646	0.030646	0.037106	0.03883	0.037106	0.037106	0.044336	0.021656	0.044336	0.044336	0.026172	0.012358	0.026172	0.026172	0
Mod Rosenbrock 2 (7)	0.516174	0.95198	0.516174	0.516174	0.827988	0.937101	0.827988	0.827988	0.999856	0.696766	0.999856	0.999856	0.787008	0.552511	0.787008	0.787008	0
Bohachevsky (8)	0.77917	0.840687	0.77917	0.77917	0.906311	0.832202	0.906311	0.906311	0.861947	0.507588	0.861947	0.861947	0.614423	0.185144	0.614423	0.614423	0
Powell (9)	105611.3	105611.3	41427.51	41237.94	89647.89	89647.89	50944.19	5160.11	78045.36	78045.36	88547.97	7956.454	103797	103797	110509.4	33969.73	0
Wood (10)	319599.1	319599.1	93080.76	61302.2	271461.7	271461.7	101112.1	5020.948	183769	183769	192618.4	8122.754	299246.8	299246.8	286273.3	27752.1	0
Beale (11)	0.290398	0.38502	0.290398	0.290398	0.343688	0.341604	0.343688	0.343688	0.440445	0.178923	0.440445	0.440445	0.246238	0.089629	0.246238	0.246238	0
Engvall (12)	0.797297	0.745037	0.797297	0.797297	0.763627	0.647485	0.763627	0.763627	0.775825	0.39817	0.775825	0.775825	0.555205	0.180623	0.555205	0.555205	0
DeJong (13)	5.82E-06	3.14E-06	5.82E-06	5.82E-06	5.48E-06	1.00E-06	5.48E-06	5.48E-06	1.21E-06	1.79E-07	1.21E-06	1.21E-06	3.48E-07	8.56E-08	3.48E-07	3.48E-07	0
Rastrigin (14)	0.001411	0.001283	0.001411	0.001411	0.001436	0.000472	0.001436	0.001436	0.000468	0.137636	0.000468	0.000468	0.020398	0.059439	0.020398	0.020398	0
Schwefel (15)	-837.959	-837.961	-837.959	-837.959	-837.96	-837.96	-837.96	-837.96	-837.957	-837.959	-837.957	-837.957	-837.956	-837.962	-837.956	-837.956	-837.9658
Griewangk (16)	0.005601	0.004895	0.005601	0.005601	0.004998	0.005655	0.004998	0.004998	0.005141	0.004307	0.005141	0.005141	0.00482	0.005194	0.00482	0.00482	0
Ackley (17)	0.018733	0.024858	0.018733	0.018733	0.022607	0.022423	0.022607	0.022607	0.02504	0.009278	0.02504	0.02504	0.012924	0.004805	0.012924	0.012924	0
Langerman (18)	-1.49436	-1.49455	-1.49545	-1.49344	-1.49445	-1.49442	-1.49515	-1.49498	-1.49331	-1.4932	-1.49357	-1.49399	-1.49214	-1.493	-1.49303	-1.49223	-1.5
Michaelewicz (19)	-6.77248	-8.25935	-7.52904	-7.47129	-6.77395	-8.35816	-7.72282	-7.31138	-7.50726	-8.12503	-7.99851	-7.20926	-7.48962	-7.79696	-7.93894	-7.11748	-9.66
Branin (20)	0.397892	0.397891	0.397892	0.397892	0.397892	0.397888	0.397892	0.397892	0.397889	0.397888	0.397889	0.397889	0.397888	0.398608	0.397888	0.397888	0.397887
Six Hump Camel (21)	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03125	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.037205	0.035101	0.030354	0.028176	0.034368	0.034758	0.032475	0.031539	0.039506	0.040398	0.03843	0.034308	0.054878	0.057136	0.048085	0.054425	5.46E-05
Osborne 2 (23)	0.118435	0.1051	0.119724	0.119073	0.123495	0.112132	0.126659	0.122491	0.133092	0.123111	0.119592	0.130879	0.14129	0.140948	0.141679	0.142024	0.0402
Mod Rastrigin (24)	79.13218	81.64867	79.13218	79.13218	81.96909	81.95149	81.96909	81.96909	83.14685	82.83151	83.14685	83.14685	82.88808	81.43853	82.88808	82.88808	58
Mineshaft 1 (25)	1.754727	1.83898	1.807361	1.83898	1.76767	1.787393	1.753839	1.787393	1.747039	1.992637	1.74273	1.992637	1.734469	2.260179	1.992109	2.260179	1.3805
Mineshaft 2 (26)	-1.41635	-1.33576	-1.41032	-1.33576	-1.41635	-1.34233	-1.41432	-1.34233	-1.41635	-1.28446	-1.39934	-1.28446	-1.4056	-1.26007	-1.34665	-1.26007	-1.4163535
Mineshaft 3 (27)	-6.98871	-6.99299	-6.98871	-6.98871	-6.99817	-6.99922	-6.99817	-6.99817	-6.9998	-6.99219	-6.9998	-6.9998	-6.99995	-6.99998	-6.99995	-6.99995	-7
Spherical Contours (28)	23.34782	24.19461	20.63753	20.63753	23.40344	25.30614	21.91096	21.91096	26.33852	26.44991	26.3677	26.36351	32.91937	32.91937	32.91937	32.91937	0
S1 (29)	1.19E-13	0.001762	1.56E-14	0.001762	3.35E-14	8.33E-05	8.17E-15	8.33E-05	3.39E-14	0.000228	1.84E-05	0.000228	1.88E-05	0.00019	6.28E-05	0.00019	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.5289
Downhill Step (32)	9	9	9	9	9	9	9	9	9.016	9	9.016	9.016	9.007	9.014	9.007	9.007	9
Salomon (33)	0.014037	0.017516	0.014037	0.014037	0.013903	0.015004	0.013903	0.013903	0.013664	0.01541	0.013664	0.013664	0.015619	0.012491	0.015619	0.015619	0
Whitley (34)	0.021271	0.022541	0.021271	0.021271	0.014088	0.017201	0.014088	0.014088	0.022981	0.0167	0.022981	0.022981	0.017191	0.01097	0.017191	0.017191	0
Odd Square (35)	-1.00777	-1.00788	-1.00777	-1.00777	-1.00786	-1.00803	-1.00786	-1.00786	-1.0081	-1.00414	-1.0081	-1.0081	-1.00797	-0.97918	-1.00797	-1.00797	-1.14383
Storn Chebyshev (36)	40.80173	10.57006	43.94857	48.67533	48.12192	5.931929	5.859969	31.52742	38.77751	29.02368	2.597565	43.86236	69.04352	82.40736	26.2826	74.62423	0
Rana (37)	-1023.42	-1023.42	-1023.42	-1023.42	-1019.1	-1011.09	-1019.1	-1019.1	-1011.72	-1018.16	-1011.72	-1011.72	-1019.38	-1023.42	-1019.38	-1019.38	-1023.416
Rosenbrock 10D (38)	854.1811	830.0601	690.5763	714.301	857.3875	911.3072	735.7911	789.2425	908.9694	977.3341	736.6232	869.8465	971.0684	968.885	967.7971	971.0683	0
Rosenbrock 30D (39)	201403.5	221437.9	150026.8	150026.8	198327.2	242992.1	175779.4	175779.4	255904.1	258737.9	259865	256160.8	507104.4	507104.4	507104.4	507104.4	0
Mod Rosenbrock 1 10D (40)	788.5139	738.4796	682.6546	697.0191	774.3249	786.1146	622.9925	744.2402	789.9867	790.7422	569.8011	784.6431	821.682	821.682	817.1932	821.3425	0
Mod Rosenbrock 1 30D (41)	18378.38	19034.94	16223.9	16223.9	18968.35	20255.16	18022.99	18022.99	20523.16	20477.26	20368.01	20537.48	25223.52	25223.52	25223.52	25223.52	0
Mod Rosenbrock 2 10D (42)	0.639236	0.383844	0.956291	0.880631	0.919516	0.319287	0.710177	0.975512	0.975123	0.489599	0.639314	0.940223	0.946027	0.846291	0.736089	0.985171	0
Mod Rosenbrock 2 30D (43)	0.587038	0.359928	0.890388	0.890388	0.979112	0.281179	0.889658	0.889658	0.914371	0.594617	0.969994	0.916821	0.891053	0.845625	0.86672	0.993714	0
Spherical Contours 10D (44)	0.626531	0.612232	0.54511	0.546163	0.622656	0.625063	0.492055	0.568389	0.643401	0.65672	0.458637	0.58383	0.643433	0.643433	0.642711	0.643443	0
Rastrigin 10D (45)	33.33578	29.87455	29.88049	29.56119	33.10619	29.24666	30.2831	30.45571	33.27157	32.41291	33.14987	32.21292	34.19422	33.84409	34.33475	34.65795	0
Rastrigin 30D (46)	250.7899	238.6941	225.8756	225.8756	245.344	245.3154	229.7949	229.7949	253.5349	257.551	249.4078	246.1011	281.5002	287.04	279.2583	279.3113	0
Schwefel 10D (47)	-3490.19	-3386.49	-3044.51	-3046.67	-3535.65	-3459.67	-3275.82	-3046.42	-3300.78	-3506.51	-3418.05	-3062.53	-3440.24	-3448.22	-3423.81	-3070.62	-4189.829
Schwefel 30D (48)	-6899.56	-6663.61	-5951.64	-5951.64	-6961.69	-6888.31	-5946.88	-5946.88	-6918.59	-6895.06	-5984.95	-5758.31	-6832.05	-6852.66	-6068.58	-5727.07	-12569.487
Griewangk 10D (49)	1.581811	1.551686	1.489028	1.519399	1.570948	1.562544	1.437001	1.524427	1.562598	1.584749	1.40029	1.563082	1.630711	1.630711	1.630711	1.630711	0
Griewangk 30D (50)	19.05578	19.56282	16.54641	16.54641	18.88788	20.3806	17.80893	17.80893	21.18915	21.21915	21.21139	21.16616	25.84642	25.84642	25.84642	25.84642	0
Salomon 10D (51)	1.091542	1.077758	0.979608	1.002171	1.075972	1.058209	1.032943	1.020515	1.101185	1.108821	1.069816	1.087883	1.114335	1.101174	1.111909	1.10421	0
Salomon 30D (52)	4.906982	5.009541	4.51926	4.51926	4.895194	5.149522	4.706435	4.706435	5.179124	5.199422	5.160728	5.155453	5.994579	5.99001	5.993119	5.992761	0
Odd Square 10D (53)	-0.5386	-0.5423	-0.59199	-0.59475	-0.53883	-0.54236	-0.55534	-0.57757	-0.54371	-0.53871	-0.5383	-0.5605	-0.53387	-0.53678	-0.53576	-0.53403	-1.14383
Whitley 10D (54)	5422338	5406995	1.23E+08	1.25E+08	5086759	5980773	4414587	5504989	6703457	7041453	5561806	5323664	6990138	7028678	7286276	7028364	0
Whitley 30D (55)	7.67E+11	8.4E+11	3.58E+11	3.58E+11	6.59E+11	1.14E+12	4.84E+11	4.84E+11	1.16E+12	1.12E+12	1.13E+12	1.38E+12	3.53E+12	3.53E+12	3.6E+12	3.38E+12	0
Rana 10D (56)	-4619.73	-4153.49	-3606.07	-3502.81	-4682.65	-4350.91	-3908.13	-3440.99	-4276.87	-4741.89	-4323.22	-3357.96	-4527.21	-4759.14	-4511.07	-3418.97	-5117.08
Rana 30D (57)	-8367.47	-8082.77	-6342.65	-6342.65	-8644.48	-8359.08	-6126.76	-6126.76	-8783.18	-8932.38	-6616.29	-5969.7	-9313.7	-9481.17	-7388.76	-5853.07	-15351.24

Average Results (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.003719	0.003539	0.003719	0.003719	0.003786	0.003579	0.003786	0.003786	0.0057	0.002071	0.0057	0.0057	0.004057	0.003091	0.004057	0.004057	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91293	-1.91322	-1.91322	-1.91322	-1.90166	-1.91322	-1.91322	-1.9133
Box and Betts (3)	2.14E-06	8.25E-07	4.83E-07	1.68E-07	1.99E-06	1.33E-06	6.76E-07	1.32E-06	1.89E-06	6.28E-06	2.11E-06	4.39E-07	1.92E-05	2.37E-05	1.01E-05	4.74E-06	0
Goldstein (4)	3.000167	3.000049	3.000167	3.000167	3.000116	3.504947	3.000116	3.000116	3.000174	3.490538	3.000174	3.000174	3.224086	5.156892	3.224086	3.224086	3
Easom (5)	-0.99331	-0.9928	-0.99331	-0.99331	-0.99213	-0.99599	-0.99213	-0.99213	-0.99407	-0.99687	-0.99407	-0.99407	-0.97311	-0.97512	-0.97311	-0.97311	-1
Mod Rosenbrock 1 (6)	0.111261	0.118302	0.111261	0.111261	0.120548	0.113057	0.120548	0.120548	0.115392	0.084471	0.115392	0.115392	0.117339	0.133214	0.117339	0.117339	0
Mod Rosenbrock 2 (7)	1.509149	1.822585	1.509149	1.509149	1.782731	1.82293	1.782731	1.782731	2.056043	1.536045	2.056043	2.056043	2.02553	2.101303	2.02553	2.02553	0
Bohachevsky (8)	2.269499	2.164355	2.269499	2.269499	2.014049	2.183515	2.014049	2.014049	2.309156	2.309156	2.309156	2.309156	2.78908	2.78908	2.78908	2.78908	0
Powell (9)	326514.2	326514.2	199511.5	300113.5	385731.3	385731.3	282161	260006.1	491923.7	491923.7	495841.6	488825.5	648778.6	648778.6	648778.6	648778.6	0
Wood (10)	1134891	1134891	576138.3	490899.4	1157531	1157531	794788.9	458407.5	1724791	1724791	1715651	1735243	1963031	1963031	1963031	1963031	0
Beale (11)	1.237617	2.659759	1.237617	1.237617	2.402608	2.415451	2.402608	2.402608	4.826361	4.570888	4.826361	4.826361	10.25196	10.25196	10.25196	10.25196	0
Engvall (12)	5.002165	3.962557	5.002165	5.002165	3.253983	3.406642	3.253983	3.253983	4.159679	4.117014	4.159679	4.159679	3.522215	3.522215	3.522215	3.522215	0
DeJong (13)	2.86E-05	1.83E-05	2.86E-05	2.86E-05	2.81E-05	5.63E-06	2.81E-05	2.81E-05	7.29E-06	1.88E-06	7.29E-06	7.29E-06	9.73E-06	0.000475	9.73E-06	9.73E-06	0
Rastrigin (14)	0.00861	0.007315	0.00861	0.00861	0.007543	0.005916	0.007543	0.007543	0.031931	0.608148	0.031931	0.031931	0.499535	0.580432	0.499535	0.499535	0
Schwefel (15)	-837.908	-837.911	-837.908	-837.908	-837.908	-837.824	-837.908	-837.908	-837.842	-837.357	-837.842	-837.842	-837.742	-837.742	-837.742	-837.742	-837.9658
Griewangk (16)	0.011015	0.011622	0.011015	0.011015	0.011168	0.011088	0.011168	0.011168	0.011276	0.011181	0.011276	0.011276	0.012465	0.012465	0.012465	0.012465	0
Ackley (17)	0.057493	0.069097	0.057493	0.057493	0.061296	0.059243	0.061296	0.061296	0.06257	0.084254	0.06257	0.06257	0.062469	0.057242	0.062469	0.062469	0
Langerman (18)	-1.48383	-1.48443	-1.48602	-1.47661	-1.46772	-1.46682	-1.47474	-1.46819	-1.45955	-1.45955	-1.45955	-1.45991	-1.424	-1.424	-1.424	-1.424	-1.5
Michaelewicz (19)	-6.30718	-7.76073	-7.13502	-6.912	-6.25667	-7.94698	-7.2661	-6.73415	-6.5581	-7.37832	-7.19338	-6.34976	-5.8426	-5.8426	-5.8426	-5.8426	-9.66
Branin (20)	0.397925	0.397906	0.397925	0.397925	0.397914	0.397892	0.397914	0.397914	0.397895	0.39789	0.397895	0.397895	0.397896	0.39869	0.397896	0.397896	0.397887
Six Hump Camel (21)	-1.03162	-1.03163	-1.03162	-1.03162	-1.03162	-1.03163	-1.03162	-1.03162	-1.03163	-1.03076	-1.03163	-1.03163	-1.03035	-1.02	-1.03035	-1.03035	-1.0316
Osborne 1 (22)	0.078983	0.06742	0.072231	0.07688	0.092688	0.102949	0.098343	0.089154	0.112339	0.112277	0.112348	0.111861	0.171489	0.171489	0.171489	0.171489	5.46E-05
Osborne 2 (23)	0.167625	0.16624	0.171616	0.170281	0.190585	0.190816	0.196367	0.192707	0.258226	0.258226	0.258226	0.258226	0.414724	0.414724	0.414724	0.414724	0.0402
Mod Rastrigin (24)	83.73278	85.31511	83.73278	83.73278	85.45783	85.37017	85.45783	85.45783	86.40093	87.32495	86.40093	86.40093	88.75725	87.56937	88.75725	88.75725	58
Mineshaft 1 (25)	1.937338	2.02507	1.927696	2.02507	1.888167	2.063715	1.862662	2.063715	1.892411	2.29222	2.025927	2.29222	2.080758	2.323916	2.280202	2.323916	1.3805
Mineshaft 2 (26)	-1.41608	-1.22494	-1.40341	-1.22494	-1.41628	-1.15741	-1.38021	-1.15741	-1.38067	-1.15695	-1.24531	-1.15695	-1.32732	-1.22442	-1.2417	-1.22442	-1.4163535
Mineshaft 3 (27)	-6.97031	-6.96008	-6.97031	-6.97031	-6.99263	-6.92964	-6.99263	-6.99263	-6.92837	-6.90797	-6.92837	-6.92837	-6.73943	-5.09109	-6.73943	-6.73943	-7
Spherical Contours (28)	30.87021	30.95735	30.83219	30.83219	37.52425	37.52425	37.52425	37.52425	62.52586	62.52586	62.52586	62.52586	121.1291	121.1291	121.1291	121.1291	0
S1 (29)	4.73E-12	0.009982	1.27E-12	0.009982	4.00E-12	0.002725	3.96E-05	0.002725	9.23E-07	0.000587	0.000236	0.000587	8.72E-05	0.000211	0.00019	0.000211	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.529575	0.528872	0.528872	0.528923	0.529906	0.528923	0.528923	0.5289
Downhill Step (32)	9	9	9	9	9	9.016	9	9	9.047	9.106	9.047	9.047	9.084	9.126	9.084	9.084	9
Salomon (33)	0.057458	0.0571	0.057458	0.057458	0.049184	0.046294	0.049184	0.049184	0.050563	0.051105	0.050563	0.050563	0.062391	0.059772	0.062391	0.062391	0
Whitley (34)	0.161554	0.177354	0.161554	0.161554	0.138244	0.130518	0.138244	0.138244	0.166083	0.166362	0.166083	0.166083	0.179894	0.192315	0.179894	0.179894	0
Odd Square (35)	-1.0067	-1.00677	-1.0067	-1.0067	-1.00684	-1.0073	-1.00684	-1.00684	-1.00665	-0.93191	-1.00665	-1.00665	-0.98783	-0.87124	-0.98783	-0.98783	-1.14383
Storn Chebyshev (36)	281.9294	183.2996	278.0215	264.5542	313.1659	242.6493	301.2619	292.7093	815.3117	815.3117	811.822	810.3418	1225.455	1225.455	1225.455	1225.455	0
Rana (37)	-1019.25	-1006.37	-1019.25	-1019.25	-992.871	-987.051	-992.871	-992.871	-1011.72	-1011.72	-1011.72	-1011.72	-1019.38	-1019.38	-1019.38	-1019.38	-1023.416
Rosenbrock 10D (38)	1493.422	1423.228	1475.732	42546.15	1591.557	1591.557	1574.751	1591.557	2768.679	2768.679	2768.679	2768.679	4656.455	4656.455	4656.455	4656.455	0
Rosenbrock 30D (39)	557572.3	554770.7	564532.2	564532.2	794939	797247.2	797247.2	797247.2	4542416	4542416	4542416	4542416	16226260	16226260	16226260	16226260	0
Mod Rosenbrock 1 10D (40)	1022.596	1012.23	978.6697	980.6449	1084.177	1084.329	1084.329	1081.197	1325.06	1325.06	1325.06	1325.06	1877.504	1877.504	1877.504	1877.504	0
Mod Rosenbrock 1 30D (41)	24251.35	24146.44	24243.25	24243.25	29083.57	29083.57	29083.57	29083.57	47748.25	47748.25	47748.25	47748.25	85427.94	85427.94	85427.94	85427.94	0
Mod Rosenbrock 2 10D (42)	1.608352	1.032925	1.921275	1.943575	1.961517	1.049906	1.775495	1.88269	2.006445	1.950481	1.929912	2.05832	2.169398	2.169398	2.169398	2.169398	0
Mod Rosenbrock 2 30D (43)	1.743707	1.059208	1.961374	1.961374	2.056881	1.354624	1.933383	1.933383	1.941167	1.87322	1.937336	1.954814	2.298725	2.298725	2.298725	2.298725	0
Spherical Contours 10D (44)	0.878944	0.874175	0.814164	0.853665	0.92424	0.92424	0.92424	0.922643	1.257534	1.257534	1.257534	1.257534	2.155032	2.155032	2.155032	2.155032	0
Rastrigin 10D (45)	40.8003	38.07945	39.24959	38.06889	40.98482	39.46908	40.79169	41.01127	48.1604	48.1604	48.1604	48.1604	58.15936	58.15936	58.15936	58.15936	0
Rastrigin 30D (46)	280.9433	269.0272	265.1899	265.1899	312.7547	312.4636	308.7531	308.7531	365.0024	365.4306	361.1488	361.4041	435.7895	435.7895	435.7895	435.7895	0
Schwefel 10D (47)	-3279.22	-3140.92	-2851.26	-2867.4	-3269.38	-3142.56	-3030.24	-2878.72	-2874.59	-2955.42	-2978.58	-2894.55	-2820.52	-2820.52	-2820.52	-2820.52	-4189.829
Schwefel 30D (48)	-6324.37	-6099.08	-5522.37	-5522.37	-6400.52	-6198.06	-5370.04	-5370.04	-5520.8	-5648.94	-5388.49	-5262.6	-5204.84	-5204.84	-5204.84	-5204.84	-12569.487
Griewangk 10D (49)	1.817236	1.797318	1.795732	1.818037	1.8804	1.8804	1.884204	1.8804	2.277633	2.277633	2.277633	2.277633	3.032524	3.032524	3.032524	3.032524	0
Griewangk 30D (50)	24.22298	24.22766	24.30302	24.30302	30.21411	30.21411	30.21411	30.21411	48.74501	48.74501	48.74501	48.74501	94.43771	94.43771	94.43771	94.43771	0
Salomon 10D (51)	1.300709	1.263993	1.240492	1.26436	1.303586	1.296951	1.300562	1.299224	1.560916	1.560916	1.560916	1.560916	2.099224	2.099224	2.099224	2.099224	0
Salomon 30D (52)	5.668977	5.67497	5.671804	5.671804	6.475221	6.475221	6.475221	6.475221	8.928658	8.928658	8.928658	8.928658	12.48599	12.48599	12.48599	12.48599	0
Odd Square 10D (53)	-0.4945	-0.50885	-0.52745	-0.52569	-0.47	-0.45618	-0.47895	-0.46649	-0.31258	-0.32705	-0.31582	-0.3179	-0.1926	-0.1926	-0.1926	-0.1926	-1.14383
Whitley 10D (54)	25885561	1.64E+08	1.66E+08	1.68E+08	22977523	22977523	22977523	22977523	54611508	54611508	54611508	54611508	3.21E+08	3.21E+08	3.21E+08	3.21E+08	0
Whitley 30D (55)	5.1E+13	5.04E+13	5.05E+13	5.05E+13	9.46E+12	9.21E+12	9.16E+12	9.16E+12	1.11E+15	1.11E+15	1.11E+15	1.11E+15	6.77E+15	6.77E+15	6.77E+15	6.77E+15	0
Rana 10D (56)	-4130.75	-3760.29	-3302.49	-3217.56	-4224.04	-3802.19	-3562.78	-3108.83	-3420.95	-4102.89	-3644.04	-3076.73	-3018.69	-3018.69	-3018.69	-3018.69	-5117.08
Rana 30D (57)	-7527.56	-7107.45	-5956.59	-5956.59	-7832.11	-7219.44	-5662.15	-5662.15	-7446.85	-7554.26	-5998.18	-5442.03	-5261.62	-5261.62	-5261.62	-5261.62	-15351.24

APPENDIX F2: ST. DEV. FOR SMOA-HTDE

Results St. Dev. (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.000307	0.000318	0.000307	0.000307	0.000322	0.00027	0.000322	0.000322	0.000288	0.00012	0.000288	0.000288	0.000202	4.06E-05	0.000202	0.000202
McCormic (2)	2.03E-07	4.99E-08	2.03E-07	2.03E-07	6.85E-08	9.78E-09	6.85E-08	6.85E-08	1.29E-08	2.46E-09	1.29E-08	1.29E-08	5.74E-09	0.001188	5.74E-09	5.74E-09
Box and Betts (3)	1.79E-08	4.28E-09	2.37E-08	2.52E-08	5.31E-09	3.28E-07	6.43E-09	2.14E-08	1.76E-07	3.87E-06	3.23E-07	4.16E-07	8.04E-06	1.32E-05	2.43E-07	8.76E-06
Goldstein (4)	1.10E-05	3.99E-06	1.10E-05	1.10E-05	5.60E-06	2.00E-06	5.60E-06	5.60E-06	8.65E-07	3.12E-07	8.65E-07	8.65E-07	3.73E-07	0.994924	3.73E-07	3.73E-07
Easom (5)	0.000513	0.000805	0.000513	0.000513	0.000424	0.000423	0.000424	0.000424	0.000238	0.000142	0.000238	0.000238	2.07E-05	0.000158	2.07E-05	2.07E-05
Mod Rosenbrock 1 (6)	0.018743	0.014496	0.018743	0.018743	0.015153	0.015576	0.015153	0.015153	0.019373	0.008332	0.019373	0.019373	0.011041	0.004439	0.011041	0.011041
Mod Rosenbrock 2 (7)	0.311908	0.388641	0.311908	0.311908	0.387711	0.325946	0.387711	0.387711	0.295953	0.244136	0.295953	0.295953	0.233663	0.157551	0.233663	0.233663
Bohachevsky (8)	0.334739	0.302846	0.334739	0.334739	0.317213	0.324563	0.317213	0.317213	0.314274	0.318612	0.314274	0.314274	0.313999	0.149238	0.313999	0.313999
Powell (9)	41414.71	41414.71	26023.37	17084.22	36323.65	36323.65	27203.12	3190.364	44027.26	44027.26	35495.16	10170.65	42171.56	42171.56	34970.16	5015.052
Wood (10)	135577.7	135577.7	68716.17	23761.3	117298.4	117298.4	54506.76	20628.78	62040.44	62040.44	85439.11	11600.52	114536.6	114536.6	96803.05	4238.57
Beale (11)	0.162886	0.178854	0.162886	0.162886	0.146246	0.168331	0.146246	0.146246	0.170978	0.119608	0.170978	0.170978	0.114653	0.060065	0.114653	0.114653
Engvall (12)	0.294959	0.317852	0.294959	0.294959	0.404015	0.259221	0.404015	0.404015	0.302075	0.268171	0.302075	0.302075	0.338264	0.166298	0.338264	0.338264
DeJong (13)	2.20E-06	1.78E-06	2.20E-06	2.20E-06	3.28E-06	5.71E-07	3.28E-06	3.28E-06	5.85E-07	7.67E-08	5.85E-07	5.85E-07	1.21E-07	3.54E-08	1.21E-07	1.21E-07
Rastrigin (14)	0.000795	0.000618	0.000795	0.000795	0.000678	0.000175	0.000678	0.000678	0.000218	0.160799	0.000218	0.000218	0.005858	0.068046	0.005858	0.005858
Schwefel (15)	0.004407	0.00292	0.004407	0.004407	0.004381	0.004	0.004381	0.004381	0.00286	0.004551	0.00286	0.00286	0.004449	0.003057	0.004449	0.004449
Griewangk (16)	0.002641	0.002586	0.002641	0.002641	0.002366	0.002817	0.002366	0.002366	0.002404	0.002369	0.002404	0.002404	0.002715	0.002666	0.002715	0.002715
Ackley (17)	0.00925	0.009655	0.00925	0.00925	0.009026	0.010323	0.009026	0.009026	0.009451	0.005171	0.009451	0.009451	0.006386	0.002795	0.006386	0.006386
Langerman (18)	0.002034	0.001774	0.001586	0.002775	0.002013	0.002149	0.001903	0.0023	0.002034	0.001991	0.002097	0.001703	0.004255	0.004256	0.002374	0.002241
Michaelewicz (19)	0.316243	0.327444	0.406829	0.353477	0.325599	0.329538	0.428782	0.277529	0.457978	0.357182	0.343863	0.293192	0.478476	0.354434	0.33356	0.287252
Branin (20)	3.09E-06	2.07E-06	3.09E-06	3.09E-06	2.86E-06	3.82E-07	2.86E-06	2.86E-06	2.40E-06	8.92E-08	2.40E-06	2.40E-06	1.39E-07	0.00717	1.39E-07	1.39E-07
Six Hump Camel (21)	6.02E-07	7.70E-08	6.02E-07	6.02E-07	1.24E-07	1.05E-06	1.24E-07	1.24E-07	2.27E-08	6.24E-09	2.27E-08	2.27E-08	1.53E-08	2.65E-09	1.53E-08	1.53E-08
Osborne 1 (22)	0.006967	0.008828	0.008851	0.00682	0.007257	0.007311	0.009147	0.007848	0.007891	0.008618	0.008072	0.007467	0.010345	0.022879	0.00952	0.009231
Osborne 2 (23)	0.015282	0.01556	0.021836	0.019351	0.015002	0.016061	0.015684	0.034713	0.024941	0.017259	0.018921	0.017957	0.02118	0.021026	0.016002	0.024719
Mod Rastrigin (24)	3.608104	3.742744	3.608104	3.608104	3.580311	2.672015	3.580311	3.580311	1.678528	4.755532	1.678528	1.678528	3.129094	3.807821	3.129094	3.129094
Mineshaft 1 (25)	0.231163	0.242054	0.140767	0.242054	0.115921	0.172595	0.050117	0.172595	0.062243	0.265864	0.052399	0.265864	0.048736	0.301216	0.186905	0.301216
Mineshaft 2 (26)	5.76E-07	0.13947	0.023587	0.13947	4.14E-10	0.102895	1.02E-08	0.102895	4.31E-11	0.150416	0.036986	0.150416	1.77E-09	0.161588	0.100782	0.161588
Mineshaft 3 (27)	0.014718	0.003121	0.014718	0.014718	0.001477	0.000509	0.001477	0.001477	0.000141	2.31E-05	0.000141	0.000141	4.60E-05	8.63E-06	4.60E-05	4.60E-05
Spherical Contours (28)	2.294222	2.178067	1.626606	1.626606	2.052156	2.48859	1.527039	1.527039	2.048794	2.291117	2.186594	1.679212	3.546397	2.74971	3.506002	3.606497
S1 (29)	6.85E-14	0.008994	2.91E-14	0.008994	2.52E-14	1.09E-05	2.82E-15	1.09E-05	2.57E-15	0.00016	0.000136	0.00016	1.66E-12	0.000478	2.73E-14	0.000478
S2 (30)	0	2.94E-12	0	0	2.12E-12	1.86E-12	2.12E-12	2.12E-12	5.79E-12	1.95E-13	5.79E-12	5.79E-12	7.61E-13	9.74E-14	7.61E-13	7.61E-13
S3 (31)	4.01E-11	3.85E-11	4.01E-11	4.01E-11	4.11E-11	2.31E-11	4.11E-11	4.11E-11	1.21E-11	3.85E-12	1.21E-11	1.21E-11	1.04E-11	2.67E-12	1.04E-11	1.04E-11
Downhill Step (32)	0	0	0	0	0	0	0	0	0.097693	0	0.097693	0.097693	0.0199	0	0.0199	0.0199
Salomon (33)	0.007252	0.007415	0.007252	0.007252	0.006812	0.005896	0.006812	0.006812	0.005151	0.007503	0.005151	0.005151	0.007224	0.00576	0.007224	0.007224
Whitley (34)	0.009421	0.012613	0.009421	0.009421	0.009409	0.010014	0.009409	0.009409	0.032538	0.011194	0.032538	0.032538	0.009375	0.008712	0.009375	0.009375
Odd Square (35)	0.000276	0.000262	0.000276	0.000276	0.000234	0.000196	0.000234	0.000234	0.000154	0.024617	0.000154	0.000154	0.000151	0.041999	0.000151	0.000151
Storn Chebyshev (36)	23.29153	5.32589	13.87507	16.28878	23.69721	1.382097	4.862997	16.53017	18.15813	18.17421	1.786396	21.46312	19.73274	19.21866	1.762901	225.828
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	12.18844	24.38087	12.18844	12.18844	35.3259	7.212145	35.3259	35.3259	18.83067	1.71E-12	18.83067	18.83067
Rosenbrock 10D (38)	217.3042	230.3305	187.9664	195.2453	267.4521	252.2162	231.2002	228.9008	217.2144	237.5201	266.3089	207.8625	219.8819	217.1602	273.8847	211.6849
Rosenbrock 30D (39)	40708.14	41318.06	29136.98	29136.98	32629.77	40425.99	29351.73	29351.73	37653.95	40321.04	37411.85	37418.67	43699.42	44570.2	45796.61	48229.69
Mod Rosenbrock 1 10D (40)	129.2781	147.4957	125.0784	123.077	118.2696	160.3991	154.5099	119.1409	117.4365	132.7173	150.6909	127.6867	111.8914	120.1281	162.935	136.4074
Mod Rosenbrock 1 30D (41)	1696.444	2114.439	1451.999	1451.999	1729.504	1894.073	1392.555	1392.555	1717.212	1732.451	2052.062	1818.887	2056.898	1987.639	1950.938	2041.206
Mod Rosenbrock 2 10D (42)	0.366734	0.136452	0.274406	0.34906	0.350406	0.122698	0.289315	0.272427	0.313261	0.214857	0.195883	0.32491	0.321779	0.311181	0.230536	0.285847
Mod Rosenbrock 2 30D (43)	0.362667	0.122393	0.277712	0.277712	0.408525	0.134203	0.289763	0.289763	0.318638	0.236065	0.306304	0.312363	0.276242	0.352676	0.285994	0.332669
Spherical Contours 10D (44)	0.111995	0.143396	0.126954	0.127931	0.107545	0.13252	0.178844	0.275017	0.114588	0.133011	0.161653	0.130383	0.14015	0.141659	0.176444	0.14273
Rastrigin 10D (45)	3.594738	5.044592	3.789704	3.756153	3.864114	4.75427	3.846435	3.863727	3.832011	5.270562	4.026834	3.216063	3.999621	4.5045	4.180427	3.994107
Rastrigin 30D (46)	12.344	16.04493	10.9809	10.9809	13.13257	19.08223	9.281153	9.281153	10.45988	14.78485	11.3366	10.90821	12.79729	12.80168	12.60066	13.05385
Schwefel 10D (47)	102.6061	160.2401	260.2953	293.2839	89.91938	163.4934	220.084	226.0334	258.8402	109.8138	186.8554	184.8625	130.2179	133.3553	165.4847	149.9314
Schwefel 30D (48)	316.9808	419.4869	478.4665	478.4665	331.3564	373.1279	370.4348	370.4348	294.6744	307.0243	494.9968	301.3789	292.8625	305.8772	350.3684	281.309
Griewangk 10D (49)	0.111057	0.124152	0.129368	0.112491	0.121069	0.146805	0.175135	0.119118	0.115619	0.12328	0.170179	0.116731	0.118151	0.1297	0.168754	0.141561
Griewangk 30D (50)	1.598808	1.841664	1.32692	1.32692	1.585077	1.829976	1.497474	1.497474	1.701158	1.784699	1.821455	1.994324	2.099479	2.180435	2.157859	2.095577
Salomon 10D (51)	0.102366	0.125539	0.112904	0.103876	0.115434	0.122558	0.119155	0.108493	0.107252	0.123347	0.140973	0.120655	0.126033	0.127279	0.141262	0.122004
Salomon 30D (52)	0.265647	0.276739	0.239194	0.239194	0.226056	0.261256	0.188108	0.188108	0.269583	0.281052	0.276435	0.222022	0.249581	0.278787	0.251496	0.381325
Odd Square 10D (53)	0.043623	0.059829	0.071698	0.081334	0.047413	0.039939	0.077091	0.078022	0.05976	0.04038	0.039152	0.082685	0.029926	0.044146	0.035168	0.052835
Whitley 10D (54)	2045522	2604460	78015538	1.11E+09	1979989	3031878	1890845	2378926	2936534	2544105	3347130	2442704	3231051	2755655	3052807	2089246
Whitley 30D (55)	2.3E+11	2.71E+11	1.31E+11	1.31E+11	1.78E+11	3.37E+11	1.72E+11	1.72E+11	2.15E+11	2.94E+11	1.99E+11	2.54E+11	1.03E+12	3.26E+11	4.37E+11	3.58E+11
Rana 10D (56)	274.4108	296.1826	262.0122	288.24	269.461	334.9216	295.1612	250.5919	414.7407	270.471	346.7622	219.8214	321.2937	270.9231	339.114	211.3331
Rana 30D (57)	586.1852	840.6589	598.4742	598.4742	643.6404	875.4546	675.713	675.713	688.3924	670.033	636.6508	455.6613	809.2824	790.6141	666.4597	402.7137

Results St. Dev. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.000892	0.0007	0.000892	0.000892	0.000712	0.0006	0.000712	0.000712	0.000651	0.000242	0.000651	0.000651	0.000455	8.30E-05	0.000455	0.000455
McCormic (2)	5.57E-07	9.07E-08	5.57E-07	5.57E-07	1.12E-07	3.68E-08	1.12E-07	1.12E-07	2.99E-08	9.00E-09	2.99E-08	2.99E-08	5.66E-08	0.001188	5.66E-08	5.66E-08
Box and Betts (3)	2.63E-08	8.78E-09	3.77E-08	3.37E-08	1.63E-05	7.84E-07	1.22E-07	2.80E-08	7.18E-07	5.32E-06	3.23E-07	4.16E-07	8.32E-06	1.43E-05	8.57E-07	8.76E-06
Goldstein (4)	2.76E-05	5.62E-06	2.76E-05	2.76E-05	9.58E-06	2.18E-06	9.58E-06	9.58E-06	2.40E-06	5.88E-07	2.40E-06	2.40E-06	1.60E-06	0.994924	1.60E-06	1.60E-06
Easom (5)	0.001258	0.001342	0.001258	0.001258	0.001167	0.000814	0.001167	0.001167	0.0007	0.000204	0.0007	0.0007	9.87E-05	0.00044	9.87E-05	9.87E-05
Mod Rosenbrock 1 (6)	0.024712	0.026213	0.024712	0.024712	0.022918	0.024242	0.022918	0.022918	0.029122	0.014398	0.029122	0.029122	0.017028	0.008522	0.017028	0.017028
Mod Rosenbrock 2 (7)	0.435033	0.498186	0.435033	0.435033	0.477272	0.453939	0.477272	0.477272	0.404079	0.300321	0.404079	0.404079	0.321657	0.219133	0.321657	0.321657
Bohachevsky (8)	0.401672	0.399887	0.401672	0.401672	0.476496	0.47449	0.476496	0.476496	0.464999	0.451321	0.464999	0.464999	0.422849	0.361141	0.422849	0.422849
Powell (9)	80956.55	80956.55	44689.17	32878.24	65628.22	65628.22	62374.06	16269.15	57478.98	57478.98	71223.02	22621.22	74617.33	74617.33	77902.69	59704.09
Wood (10)	224420.2	224420.2	139136.6	58572.81	223095.7	223095.7	127207.9	21477	129266	129266	188994.6	27027.12	233777.9	233777.9	211481.5	69057.25
Beale (11)	0.163398	0.299022	0.163398	0.163398	0.173182	0.267431	0.173182	0.173182	0.412107	0.170216	0.412107	0.412107	0.237717	0.133734	0.237717	0.237717
Engvall (12)	1.156952	0.586544	1.156952	1.156952	0.749216	0.702731	0.749216	0.749216	0.688756	0.515231	0.688756	0.688756	0.777355	0.400089	0.777355	0.777355
DeJong (13)	5.97E-06	4.16E-06	5.97E-06	5.97E-06	4.95E-06	9.76E-07	4.95E-06	4.95E-06	1.30E-06	1.72E-07	1.30E-06	1.30E-06	3.21E-07	8.76E-08	3.21E-07	3.21E-07
Rastrigin (14)	0.001337	0.00142	0.001337	0.001337	0.001571	0.000485	0.001571	0.001571	0.000429	0.271455	0.000429	0.000429	0.092507	0.174911	0.092507	0.092507
Schwefel (15)	0.00787	0.00562	0.00787	0.00787	0.007058	0.007524	0.007058	0.007058	0.013885	0.010008	0.013885	0.013885	0.017196	0.008227	0.017196	0.017196
Griewangk (16)	0.003249	0.00333	0.003249	0.003249	0.003455	0.003691	0.003455	0.003455	0.003188	0.003034	0.003188	0.003188	0.003181	0.003443	0.003181	0.003181
Ackley (17)	0.014723	0.016165	0.014723	0.014723	0.013292	0.014224	0.013292	0.013292	0.014369	0.009091	0.014369	0.014369	0.01264	0.004928	0.01264	0.01264
Langerman (18)	0.002712	0.002524	0.00263	0.012626	0.002954	0.002769	0.002526	0.002708	0.003642	0.003099	0.003205	0.002999	0.00576	0.005711	0.004772	0.004368
Michaelewicz (19)	0.338875	0.368919	0.461271	0.403581	0.355222	0.35811	0.472902	0.284473	0.514795	0.411831	0.355446	0.33442	0.50195	0.430386	0.425366	0.30778
Branin (20)	5.99E-06	2.83E-06	5.99E-06	5.99E-06	5.07E-06	8.32E-07	5.07E-06	5.07E-06	2.59E-06	2.03E-07	2.59E-06	2.59E-06	2.73E-07	0.00717	2.73E-07	2.73E-07
Six Hump Camel (21)	9.88E-07	2.56E-07	9.88E-07	9.88E-07	3.21E-07	1.04E-06	3.21E-07	3.21E-07	1.25E-06	1.20E-08	1.25E-06	1.25E-06	2.91E-08	0.003717	2.91E-08	2.91E-08
Osborne 1 (22)	0.008925	0.010007	0.010951	0.006834	0.009075	0.00877	0.009498	0.008342	0.017881	0.017827	0.010539	0.009825	0.093544	0.094714	0.015308	0.094326
Osborne 2 (23)	0.020571	0.019502	0.0282	0.02793	0.018231	0.015695	0.060216	0.035756	0.028602	0.022475	0.027094	0.028951	0.024509	0.02482	0.024635	0.02517
Mod Rastrigin (24)	4.122239	3.199692	4.122239	4.122239	3.337975	2.913914	3.337975	3.337975	1.552534	4.732321	1.552534	1.552534	3.081965	3.855279	3.081965	3.081965
Mineshaft 1 (25)	0.234497	0.254499	0.13651	0.254499	0.107506	0.206555	0.100915	0.206555	0.073973	0.30293	0.114148	0.30293	0.05391	0.189157	0.2804	0.189157
Mineshaft 2 (26)	1.20E-06	0.161451	0.043187	0.161451	2.10E-08	0.150362	0.020201	0.150362	2.96E-09	0.179539	0.075701	0.179539	0.061514	0.165509	0.14433	0.165509
Mineshaft 3 (27)	0.026798	0.053059	0.026798	0.026798	0.002601	0.004215	0.002601	0.002601	0.000268	0.077309	0.000268	0.000268	7.48E-05	2.08E-05	7.48E-05	7.48E-05
Spherical Contours (28)	2.408062	2.25145	2.591679	2.591679	2.43838	2.349727	2.103314	2.103314	2.731663	2.734428	2.778085	2.814104	3.510566	3.510566	3.510566	3.510566
S1 (29)	3.20E-13	0.009055	4.15E-14	0.009055	7.51E-14	0.00056	2.41E-14	0.00056	7.54E-14	0.000838	0.000136	0.000838	0.000186	0.000497	0.000244	0.000497
S2 (30)	9.31E-15	1.70E-11	9.31E-15	9.31E-15	1.88E-11	1.19E-11	1.88E-11	1.88E-11	1.10E-11	1.30E-12	1.10E-11	1.10E-11	2.81E-12	6.03E-13	2.81E-12	2.81E-12
S3 (31)	2.59E-10	1.70E-10	2.59E-10	2.59E-10	1.88E-10	1.04E-10	1.88E-10	1.88E-10	7.60E-11	1.81E-11	7.60E-11	7.60E-11	6.64E-11	1.42E-10	6.64E-11	6.64E-11
Downhill Step (32)	0	0	0	0	0	0	0	0	0.097693	0	0.097693	0.097693	0.053395	0.098	0.053395	0.053395
Salomon (33)	0.012135	0.01765	0.012135	0.012135	0.012303	0.015345	0.012303	0.012303	0.0133	0.016653	0.0133	0.0133	0.015685	0.009848	0.015685	0.015685
Whitley (34)	0.034366	0.037956	0.034366	0.034366	0.018611	0.025462	0.018611	0.018611	0.04172	0.02812	0.04172	0.04172	0.027055	0.022832	0.027055	0.027055
Odd Square (35)	0.000454	0.00041	0.000454	0.000454	0.000391	0.00036	0.000391	0.000391	0.000247	0.026334	0.000247	0.000247	0.000305	0.063943	0.000305	0.000305
Storn Chebyshev (36)	48.73319	28.7751	199.6604	199.8315	57.85623	17.15709	11.94083	45.53729	56.75597	42.60021	6.441301	51.19568	230.2133	233.0608	46.03653	227.5482
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	25.35	37.62126	25.35	25.35	35.3259	25.13706	35.3259	35.3259	20.27776	1.71E-12	20.27776	20.27776
Rosenbrock 10D (38)	284.8383	289.3597	247.6124	259.651	304.2992	300.8082	355.3829	284.9356	286.8768	338.1465	347.3763	284.1646	330.9361	330.3748	334.8182	330.936
Rosenbrock 30D (39)	45593.8	43649.16	30995.13	30995.13	42469.04	48641.51	38683.54	38683.54	53385.05	53746.87	66205.65	57058.38	134491.9	134491.9	134491.9	134491.9
Mod Rosenbrock 1 10D (40)	161.5512	180.3157	146.2791	143.0111	138.7644	167.4008	197.3603	139.1205	143.2768	158.5406	182.6547	155.1589	139.4441	139.4441	136.4818	139.4379
Mod Rosenbrock 1 30D (41)	1798.98	2071.999	2153.2	2153.2	1748.455	2151.346	1934.071	1934.071	2269.815	2235.279	2322.952	2223.539	2485.18	2485.18	2485.18	2485.18
Mod Rosenbrock 2 10D (42)	0.499738	0.293972	0.791636	0.408584	0.425607	0.227746	0.365852	0.573034	0.412722	0.312479	0.264457	0.382242	0.372579	0.47091	0.361937	0.397217
Mod Rosenbrock 2 30D (43)	0.420045	0.217618	0.365454	0.365454	0.524899	0.192412	0.372847	0.372847	0.432123	0.406833	0.431531	0.384377	0.451947	0.420668	0.382122	0.423355
Spherical Contours 10D (44)	0.141386	0.154384	0.151406	0.143766	0.12978	0.144622	0.205694	0.282181	0.135641	0.144342	0.217199	0.158328	0.17976	0.17976	0.179456	0.179764
Rastrigin 10D (45)	3.869324	5.353355	3.634232	3.845253	4.398545	5.905813	4.608282	4.100082	4.559658	5.273722	4.16451	3.563552	4.7124	4.952679	4.128964	4.507885
Rastrigin 30D (46)	13.27247	18.85622	13.17759	13.17759	15.35699	16.09938	9.921238	9.921238	16.244	15.86687	17.04705	12.42004	17.11753	14.77319	18.59447	15.66477
Schwefel 10D (47)	105.112	172.309	280.7609	311.3574	110.001	175.3687	236.2462	210.8006	256.2289	130.3961	200.1186	187.634	163.0751	161.1087	188.4526	179.4041
Schwefel 30D (48)	309.6716	433.5593	477.6605	477.6605	346.2096	400.9804	431.8627	431.8627	316.9911	317.6489	515.2796	281.0295	280.5243	259.5301	374.807	331.5292
Griewangk 10D (49)	0.127522	0.142961	0.169779	0.143659	0.145794	0.166076	0.201359	0.140929	0.143727	0.142537	0.217165	0.145977	0.151756	0.151756	0.151756	0.151756
Griewangk 30D (50)	1.596109	1.947614	2.022026	2.022026	1.61286	1.674982	1.741391	1.741391	2.071118	2.044763	2.049339	2.092102	2.63062	2.63062	2.63062	2.63062
Salomon 10D (51)	0.118277	0.115143	0.117949	0.112761	0.134314	0.136106	0.138114	0.114969	0.131674	0.121421	0.156915	0.125453	0.150451	0.148201	0.141927	0.146842
Salomon 30D (52)	0.300953	0.291094	0.295412	0.295412	0.321708	0.264818	0.256001	0.256001	0.277122	0.308518	0.30298	0.306927	0.471675	0.472002	0.46989	0.469892
Odd Square 10D (53)	0.025522	0.027953	0.075782	0.076681	0.024314	0.031462	0.05046	0.070144	0.030375	0.029223	0.027991	0.063687	0.022193	0.031208	0.029075	0.012388
Whitley 10D (54)	4329180	4832354	1.11E+09	1.11E+09	3933838	5326752	3772875	4602860	4989607	5235485	4929947	4325134	5549899	5601020	5804289	5600566
Whitley 30D (55)	3.37E+11	3.31E+11	1.57E+11	1.57E+11	2.9E+11	4.28E+11	1.96E+11	1.96E+11	4.9E+11	4.42E+11	4.67E+11	2.1E+12	1.99E+12	2.39E+12	2.72E+12	1.88E+12
Rana 10D (56)	308.2025	326.2391	251.9518	293.8413	340.1329	346.4717	298.1214	231.592	448.5402	357.2937	331.4433	212.3585	369.3153	380.8446	367.4422	227.941
Rana 30D (57)	579.1798	776.9028	618.8116	618.8116	637.327	739.8505	598.3164	598.3164	749.1405	810.5776	679.3851	468.1727	813.2817	824.4177	596.7946	340.5216

Results St. Dev. (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.003351	0.00371	0.003351	0.003351	0.00353	0.003587	0.00353	0.00353	0.016458	0.002232	0.016458	0.016458	0.004011	0.002941	0.004011	0.004011
McCormic (2)	2.97E-06	7.22E-07	2.97E-06	2.97E-06	7.91E-06	2.46E-07	7.91E-06	7.91E-06	6.50E-07	0.002864	6.50E-07	6.50E-07	4.60E-06	0.025841	4.60E-06	4.60E-06
Box and Betts (3)	8.92E-06	2.16E-06	1.23E-06	2.00E-07	1.63E-05	7.87E-06	2.76E-06	8.14E-06	6.19E-06	1.81E-05	9.11E-06	1.07E-06	3.10E-05	3.00E-05	2.13E-05	1.35E-05
Goldstein (4)	0.000217	0.000151	0.000217	0.000217	0.000271	3.614992	0.000271	0.000271	0.001045	1.788556	0.001045	0.001045	0.853179	2.965234	0.853179	0.853179
Easom (5)	0.00716	0.007695	0.00716	0.00716	0.009262	0.005547	0.009262	0.009262	0.008372	0.00675	0.008372	0.008372	0.031074	0.025686	0.031074	0.031074
Mod Rosenbrock 1 (6)	0.090207	0.092136	0.090207	0.090207	0.087196	0.068508	0.087196	0.087196	0.082421	0.058726	0.082421	0.082421	0.094245	0.13082	0.094245	0.094245
Mod Rosenbrock 2 (7)	0.945759	0.941672	0.945759	0.945759	0.834742	0.757661	0.834742	0.834742	0.83375	0.670334	0.83375	0.83375	0.934187	1.253961	0.934187	0.934187
Bohachevsky (8)	1.668626	1.525826	1.668626	1.668626	1.098133	1.9884	1.098133	1.098133	1.660346	1.660346	1.660346	1.660346	1.96593	1.96593	1.96593	1.96593
Powell (9)	272380.1	272380.1	194569.9	413263.4	357388.9	357388.9	315280.6	259969.6	339245.7	339245.7	340090.9	341577.3	384226.9	384226.9	384226.9	384226.9
Wood (10)	931193.6	931193.6	627732.2	433811.9	849174	849174	700168.8	614009.3	2096928	2096928	2101353	2097904	1258769	1258769	1258769	1258769
Beale (11)	3.680284	6.546745	3.680284	3.680284	3.509965	4.036273	3.509965	3.509965	9.627236	7.913539	9.627236	9.627236	28.06499	28.06499	28.06499	28.06499
Engvall (12)	8.125644	4.744431	8.125644	8.125644	3.218156	3.825397	3.218156	3.218156	5.514785	5.517071	5.514785	5.514785	4.101723	4.101723	4.101723	4.101723
DeJong (13)	3.08E-05	2.07E-05	3.08E-05	3.08E-05	2.50E-05	5.56E-06	2.50E-05	2.50E-05	7.01E-06	1.85E-06	7.01E-06	7.01E-06	1.44E-05	0.004572	1.44E-05	1.44E-05
Rastrigin (14)	0.008669	0.008323	0.008669	0.008669	0.005903	0.007679	0.005903	0.005903	0.076243	0.719393	0.076243	0.076243	0.484122	0.714999	0.484122	0.484122
Schwefel (15)	0.077186	0.093307	0.077186	0.077186	0.071113	0.366878	0.071113	0.071113	0.123635	3.15282	0.123635	0.123635	0.21028	0.21028	0.21028	0.21028
Griewangk (16)	0.005521	0.006364	0.005521	0.005521	0.005221	0.005471	0.005221	0.005221	0.006528	0.006442	0.006528	0.006528	0.005568	0.005568	0.005568	0.005568
Ackley (17)	0.040271	0.044498	0.040271	0.040271	0.039701	0.037941	0.039701	0.039701	0.034117	0.381666	0.034117	0.034117	0.040351	0.035427	0.040351	0.040351
Langerman (18)	0.010019	0.009415	0.008157	0.068201	0.081411	0.081366	0.048328	0.078802	0.051596	0.051596	0.051596	0.05161	0.065795	0.065795	0.065795	0.065795
Michaelewicz (19)	0.374456	0.479419	0.64218	0.514902	0.354524	0.46527	0.566423	0.36165	0.593487	0.574367	0.592506	0.328586	0.341035	0.341035	0.341035	0.341035
Branin (20)	3.97E-05	1.81E-05	3.97E-05	3.97E-05	3.28E-05	4.09E-06	3.28E-05	3.28E-05	7.59E-06	3.19E-06	7.59E-06	7.59E-06	1.03E-05	0.007201	1.03E-05	1.03E-05
Six Hump Camel (21)	7.82E-06	4.94E-06	7.82E-06	7.82E-06	2.50E-05	1.08E-06	2.50E-05	2.50E-05	1.82E-06	0.00678	1.82E-06	1.82E-06	0.009545	0.02913	0.009545	0.009545
Osborne 1 (22)	0.10423	0.026561	0.07722	0.076414	0.077857	0.086835	0.106546	0.057226	0.058789	0.058807	0.058787	0.058805	0.142104	0.142104	0.142104	0.142104
Osborne 2 (23)	0.037971	0.036672	0.041729	0.036044	0.057931	0.057856	0.066041	0.062046	0.070409	0.070409	0.070409	0.070409	0.268505	0.268505	0.268505	0.268505
Mod Rastrigin (24)	3.836512	2.513368	3.836512	3.836512	2.274385	2.408909	2.274385	2.274385	1.661451	4.435406	1.661451	1.661451	2.407466	2.738888	2.407466	2.407466
Mineshaft 1 (25)	0.207792	0.249713	0.160201	0.249713	0.081897	0.236123	0.118727	0.236123	0.119335	0.110797	0.211364	0.110797	0.201267	0.016905	0.123995	0.016905
Mineshaft 2 (26)	0.002695	0.197476	0.05896	0.197476	0.000752	0.178724	0.101407	0.178724	0.096204	0.170511	0.175209	0.170511	0.147828	0.160723	0.16423	0.160723
Mineshaft 3 (27)	0.047576	0.180189	0.047576	0.047576	0.008493	0.674361	0.008493	0.008493	0.696338	0.705041	0.696338	0.696338	1.248096	2.466138	1.248096	1.248096
Spherical Contours (28)	3.881627	3.932576	3.932635	3.932635	4.687166	4.687166	4.687166	4.687166	8.536318	8.536318	8.536318	8.536318	30.41852	30.41852	30.41852	30.41852
S1 (29)	1.33E-11	0.036352	2.41E-12	0.036352	8.30E-12	0.006813	0.000394	0.006813	8.81E-06	0.00102	0.000854	0.00102	0.000297	0.000494	0.000478	0.000494
S2 (30)	5.16E-10	2.75E-08	5.16E-10	5.16E-10	4.26E-10	2.07E-10	4.26E-10	4.26E-10	1.93E-09	1.91E-08	1.93E-09	1.93E-09	6.47E-10	4.91E-10	6.47E-10	6.47E-10
S3 (31)	1.60E-08	1.94E-08	1.60E-08	1.60E-08	1.13E-06	2.79E-09	1.13E-06	1.13E-06	1.54E-08	0.006519	1.54E-08	1.54E-08	0.000451	0.0044	0.000451	0.000451
Downhill Step (32)	0	0	0	0	0	0.101705	0	0	0.136715	0.219463	0.136715	0.136715	0.140513	0.174711	0.140513	0.140513
Salomon (33)	0.036696	0.033982	0.036696	0.036696	0.033505	0.034957	0.033505	0.033505	0.036331	0.03669	0.036331	0.036331	0.035645	0.037488	0.035645	0.035645
Whitley (34)	0.217441	0.170997	0.217441	0.217441	0.162739	0.159986	0.162739	0.162739	0.170306	0.170309	0.170306	0.170306	0.192486	0.200334	0.192486	0.192486
Odd Square (35)	0.001003	0.001191	0.001003	0.001003	0.001174	0.000701	0.001174	0.001174	0.001068	0.090886	0.001068	0.001068	0.043293	0.106424	0.043293	0.043293
Storn Chebyshev (36)	292.5495	311.4895	367.3218	351.2086	273.184	266.3224	335.3326	304.5303	2959.976	2959.976	2959.646	2959.623	2709.907	2709.907	2709.907	2709.907
Rana (37)	24.79684	46.58653	24.79684	24.79684	53.84518	56.73861	53.84518	53.84518	35.3259	35.3259	35.3259	35.3259	20.27776	20.27776	20.27776	20.27776
Rosenbrock 10D (38)	540.4067	515.8669	581.4181	408457.7	570.2309	570.2309	569.7199	570.2309	1579.246	1579.246	1579.246	1579.246	1719.795	1719.795	1719.795	1719.795
Rosenbrock 30D (39)	1756885	1757268	1758909	1758909	505050	504834.9	504834.9	504834.9	3287020	3287020	3287020	3287020	14520913	14520913	14520913	14520913
Mod Rosenbrock 1 10D (40)	224.5054	219.9974	239.046	217.1349	208.3191	208.5737	208.5737	208.4543	275.0985	275.0985	275.0985	275.0985	399.4616	399.4616	399.4616	399.4616
Mod Rosenbrock 1 30D (41)	2800.592	2818.703	2910.547	2910.547	5560.662	5560.662	5560.662	5560.662	18166.14	18166.14	18166.14	18166.14	17195.34	17195.34	17195.34	17195.34
Mod Rosenbrock 2 10D (42)	0.986514	0.721361	1.010997	0.957996	0.790669	0.664453	0.913418	0.801535	0.891816	0.982384	0.911703	0.959474	0.883104	0.883104	0.883104	0.883104
Mod Rosenbrock 2 30D (43)	1.0153	0.667337	0.93516	0.93516	0.986059	0.926619	0.836993	0.836993	0.793268	0.739447	0.799809	0.813932	1.015218	1.015218	1.015218	1.015218
Spherical Contours 10D (44)	0.217506	0.226473	0.249506	0.225105	0.285347	0.285347	0.285347	0.284869	0.280287	0.280287	0.280287	0.280287	0.747876	0.747876	0.747876	0.747876
Rastrigin 10D (45)	4.574538	5.77205	5.244224	5.491665	5.271861	6.484666	5.989547	5.352133	7.903638	7.903638	7.903638	7.903638	6.99626	6.99626	6.99626	6.99626
Rastrigin 30D (46)	16.71133	21.27324	18.80427	18.80427	26.19195	20.30815	24.58501	24.58501	28.07731	28.18518	27.39898	25.76213	31.80102	31.80102	31.80102	31.80102
Schwefel 10D (47)	115.2902	214.4069	321.302	322.9689	167.4295	207.9802	272.1125	208.9884	200.665	189.0501	227.15	185.3078	172.0348	172.0348	172.0348	172.0348
Schwefel 30D (48)	328.6991	461.652	523.4439	523.4439	387.135	554.2985	434.978	434.978	366.853	384.4306	451.4802	263.9187	261.1423	261.1423	261.1423	261.1423
Griewangk 10D (49)	0.191766	0.224213	0.278913	0.236337	0.230225	0.230225	0.235835	0.230225	1.002004	1.002004	1.002004	1.002004	0.522338	0.522338	0.522338	0.522338
Griewangk 30D (50)	2.721659	2.739612	2.741282	2.741282	5.193139	5.193139	5.193139	5.193139	8.931615	8.931615	8.931615	8.931615	20.86054	20.86054	20.86054	20.86054
Salomon 10D (51)	0.161748	0.163882	0.177408	0.153915	0.18758	0.19322	0.186931	0.191023	0.183994	0.183994	0.183994	0.183994	0.364181	0.364181	0.364181	0.364181
Salomon 30D (52)	0.395756	0.398025	0.384203	0.384203	0.447699	0.447699	0.447699	0.447699	0.973472	0.973472	0.973472	0.973472	1.561221	1.561221	1.561221	1.561221
Odd Square 10D (53)	0.054685	0.042378	0.045685	0.0287	0.072463	0.06792	0.067244	0.07968	0.073057	0.067651	0.072242	0.073778	0.057783	0.057783	0.057783	0.057783
Whitley 10D (54)	23084616	1.13E+09	1.13E+09	1.13E+09	21247497	21247497	21247497	21247497	41082708	41082708	41082708	41082708	4.66E+08	4.66E+08	4.66E+08	4.66E+08
Whitley 30D (55)	4.79E+14	4.79E+14	4.79E+14	4.79E+14	8.28E+12	7.6E+12	7.58E+12	7.58E+12	8.87E+15	8.87E+15	8.87E+15	8.87E+15	1.93E+16	1.93E+16	1.93E+16	1.93E+16
Rana 10D (56)	297.5336	361.0028	349.7266	316.6317	365.07	344.5898	410.8291	235.1095	456.6926	436.0398	385.3431	218.5789	152.1538	152.1538	152.1538	152.1538
Rana 30D (57)	522.7446	888.3637	678.861	678.861	666.3398	791.4651	645.2509	645.2509	934.641	779.1152	706.3862	495.0364	337.288	337.288	337.288	337.288

APPENDIX F3: AVG. RUNTIMES FOR SMOA-HTDE

Average Times (s) for 1M	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	5.137005	4.552051	5.253422	5.489247	5.235702	4.494236	5.008756	5.742168	2.514963	2.255432	2.708359	2.885365	2.853003	2.340293	1.595046	1.40089
McCormic (2)	4.583351	3.789861	4.234716	4.279078	4.327839	4.080495	4.392119	4.049833	1.478484	1.420914	1.841833	1.653171	1.621927	1.925569	0.942396	0.792376
Box and Betts (3)	4.695495	4.809293	5.086439	6.070614	4.600651	4.486554	4.894906	5.800486	4.192746	4.102282	4.535706	4.498019	4.560929	4.773994	3.444234	3.287372
Goldstein (4)	4.047974	2.702686	4.61912	4.481856	4.074423	2.583453	4.150939	4.444992	1.527027	1.287321	1.868324	1.85944	1.689676	1.992737	0.854625	0.780234
Easom (5)	6.543013	5.137826	5.826938	6.249456	6.491741	5.181233	6.330997	5.978192	3.058039	2.665551	3.665894	3.80724	4.017641	4.043819	2.079643	2.018318
Mod Rosenbrock 1 (6)	4.891942	4.462742	4.78749	4.96982	5.411506	4.659208	4.923176	5.230455	2.982665	2.113253	3.485753	3.403329	3.248508	2.424491	1.610688	1.399974
Mod Rosenbrock 2 (7)	5.036161	4.572534	5.093888	5.05449	5.2271	5.066094	5.239577	4.936567	3.091774	2.134905	3.263056	3.346761	3.413435	2.628636	1.518562	1.460247
Bohachevsky (8)	4.905461	4.268757	4.966692	4.481617	5.075306	4.686755	5.080093	4.72505	3.019517	2.261254	3.124544	3.349118	3.289507	2.933981	1.582133	1.468669
Powell (9)	6.90513	7.030611	8.863599	14.6021	8.594887	8.537152	10.32332	15.87853	7.81971	7.442155	8.27717	10.53515	9.188424	7.982653	6.063819	5.992888
Wood (10)	6.576728	6.923763	9.109118	14.41621	8.702214	8.36405	10.14451	16.27448	8.507971	7.368459	7.669791	10.41444	8.31315	7.267315	5.593912	5.487931
Beale (11)	5.087991	4.244122	5.110121	5.358655	5.186951	4.425664	5.072162	5.585294	3.196515	2.687697	2.908177	3.380237	3.524153	2.463295	1.627668	1.428005
Engvall (12)	5.429905	4.807636	5.081404	5.408579	5.438391	4.720885	5.55295	5.26981	3.513997	2.926896	3.248152	3.933608	3.332946	2.616399	1.847934	1.796525
DeJong (13)	4.737428	4.251908	4.785593	4.688712	5.026892	4.105815	5.140767	4.662183	2.600248	1.951848	2.405992	3.077316	1.845799	1.270085	0.896824	0.815215
Rastrigin (14)	4.797865	4.162963	4.947812	4.610824	4.911218	4.496597	4.754779	4.585584	2.323735	2.844407	2.598036	3.237591	3.06977	2.065991	1.329061	1.321774
Schwefel (15)	5.4793	4.56263	5.056451	4.527353	5.499778	4.794027	5.593806	4.425639	2.781199	2.880969	3.095014	3.394007	2.969043	2.347745	1.676479	1.493203
Griewangk (16)	4.832792	4.560965	4.931155	3.646352	4.613634	4.54468	4.565154	3.87779	2.83828	2.691422	2.846197	3.131112	2.575875	1.809171	1.396322	1.34381
Ackley (17)	5.210304	4.722881	4.774872	3.998377	4.858554	4.468401	4.815671	4.002204	3.059909	2.821103	2.851675	3.966729	2.632326	2.103324	1.65514	1.553267
Langerman (18)	7.45276	8.347467	10.19157	13.4416	9.314455	10.73709	11.05986	18.70675	9.665211	9.927661	11.74081	17.99563	7.926134	9.251336	6.855858	7.497412
Michaelewicz (19)	12.78154	16.71203	19.25941	16.95564	17.1179	17.19292	25.11868	24.50723	30.97017	19.24759	26.86137	58.96068	33.31386	32.51529	19.06731	66.7926
Branin (20)	3.586372	3.063027	3.06423	2.422842	3.205306	3.188164	2.611048	2.426592	2.602603	1.644895	2.85429	2.3786	1.527097	1.24141	1.087653	1.0229
Six Hump Camel (21)	3.523853	3.037644	2.660457	2.362398	2.985029	2.786544	2.426161	2.406394	2.21909	1.67871	2.617881	2.031679	1.502608	1.324143	1.059503	1.061809
Osborne 1 (22)	10.38629	10.98001	11.09799	12.42748	10.59585	11.72597	10.64414	18.70488	12.79394	13.3211	15.07269	16.34591	10.60624	10.10149	10.15469	12.24398
Osborne 2 (23)	23.11558	26.26514	30.08904	32.00731	25.76992	26.18239	38.56139	40.52324	41.36403	33.62696	40.13239	45.24274	27.44743	27.24694	25.78562	39.24073
Mod Rastrigin (24)	2.897573	2.531055	3.450325	3.903207	3.139737	2.746584	4.181224	2.714968	3.783254	3.391578	3.853968	2.536609	1.966933	2.127475	1.970901	2.446081
Mineshaft 1 (25)	2.440304	1.829529	2.557116	2.582444	2.252706	1.793866	2.20554	1.637691	2.130109	2.033221	1.845524	1.577752	1.257389	1.405016	1.239615	1.523266
Mineshaft 2 (26)	1.799796	1.215052	1.873064	1.693103	1.624835	1.045492	1.333226	0.804104	1.444854	1.363434	1.225858	0.941899	0.666794	0.796979	0.644855	0.891579
Mineshaft 3 (27)	2.666331	2.04218	3.253279	3.297169	3.246543	2.128943	2.736106	1.910689	3.082376	2.171181	2.672335	2.302553	1.262383	1.398354	1.296663	1.651788
Spherical Contours (28)	12.64126	14.87585	23.63306	20.73664	22.16054	16.3394	30.31087	24.95189	44.59645	24.10345	44.56954	41.13185	8.634501	9.174907	8.463388	11.52819
S1 (29)	1.670219	1.323564	1.05277	0.865784	1.320941	1.345267	0.450227	0.380853	1.819132	1.586903	0.979316	0.501362	0.771432	0.781362	0.546905	0.816303
S2 (30)	2.848662	2.475921	1.971679	1.967257	2.231832	2.751914	1.293404	1.050069	3.860041	2.696855	2.349247	1.501899	1.481059	1.153121	1.056965	1.516734
S3 (31)	2.710686	2.458247	1.931591	1.670554	1.8264	2.74044	1.303761	1.056265	3.239812	2.284646	1.926334	1.599161	1.223802	1.126539	0.876001	1.160315
Downhill Step (32)	3.954004	3.199316	2.271622	2.018653	2.40682	3.619025	1.686091	1.351892	4.107755	3.787683	2.692029	1.976933	2.666894	2.227219	1.989088	2.732195
Salomon (33)	3.202048	2.755761	1.663199	1.414354	2.128113	2.650775	1.371932	1.101712	3.392696	3.115317	2.302242	1.642846	1.935118	1.231023	1.579236	2.053274
Whitley (34)	3.616463	3.201523	2.203679	1.689845	2.466672	2.590288	1.593141	1.287316	3.393437	3.342736	2.405604	2.065562	2.343175	1.481873	2.067243	2.268986
Odd Square (35)	3.199497	3.351758	2.270953	1.567686	2.422953	2.37936	1.497253	1.207276	3.582239	3.165766	2.219508	1.983405	2.091454	1.521335	1.784997	2.023248
Storn Chebyshev (36)	252.2229	254.3541	255.7747	256.7247	252.5929	253.969	259.8318	267.2906	285.4269	280.2726	278.0609	307.1094	286.0823	292.3806	304.0718	352.5867
Rana (37)	1.770989	1.23909	2.204125	2.527941	2.229914	1.7334	2.802129	3.425296	2.205009	2.024439	2.44744	3.240183	2.474556	2.448777	3.443942	3.356903
Rosenbrock 10D (38)	3.822117	4.97825	9.754972	11.19069	6.084679	5.525055	16.76031	23.95811	14.64021	7.754681	11.03525	42.34362	15.70698	15.66681	16.24077	45.61261
Rosenbrock 30D (39)	9.731469	11.39312	22.00995	23.05516	17.67635	12.56632	38.86815	38.94507	32.48303	17.81403	42.18111	57.7366	14.84544	14.67845	17.57973	23.0754
Mod Rosenbrock 1 10D (40)	5.604841	7.28337	13.72412	15.21645	8.881453	8.18401	20.30658	24.67599	15.48887	9.900896	13.41694	44.03514	17.35932	16.07661	16.15077	42.71884
Mod Rosenbrock 1 30D (41)	14.79305	17.23031	29.19406	28.9644	24.83514	18.67349	43.41972	42.23994	37.28104	21.25507	48.24943	60.97	15.14532	16.15207	17.48826	19.80758
Mod Rosenbrock 2 10D (42)	7.231622	9.689696	14.87883	15.71334	12.54243	11.96002	21.51402	23.94244	22.56945	13.17307	20.87708	58.53273	35.31508	34.91563	33.46021	71.63413
Mod Rosenbrock 2 30D (43)	17.96745	22.12913	30.83086	30.69546	27.76362	24.05872	45.70426	43.60008	54.37651	27.22048	87.20567	108.2949	67.20873	57.48668	126.8183	176.2705
Spherical Contours 10D (44)	6.099187	8.681031	12.54969	14.00307	9.473322	9.318685	14.78078	18.75544	18.86774	8.878497	14.56805	40.10755	18.86389	17.35906	15.9448	38.25932
Rastrigin 10D (45)	6.706994	10.36899	14.64107	13.43445	10.25885	10.69509	17.05619	22.40043	23.63069	10.81986	20.08355	47.17474	25.78591	24.61435	23.74083	54.30936
Rastrigin 30D (46)	16.01402	18.72402	25.59953	25.19822	24.39075	20.3415	38.28574	40.40892	55.53461	24.13286	70.99758	71.03026	57.94482	47.53077	62.35519	76.54511
Schwefel 10D (47)	9.250793	11.54784	13.19552	13.07474	15.46193	13.25761	20.0422	23.46278	33.796	22.20759	28.34194	58.16141	50.22638	54.61525	34.18832	72.49173
Schwefel 30D (48)	19.22478	21.44053	25.36844	24.75748	27.55049	23.46745	43.01677	44.16345	62.56976	34.18334	93.81514	105.3932	85.7524	76.26891	120.046	185.0893
Griewangk 10D (49)	7.536459	9.354778	11.66157	12.05205	9.055846	10.6452	18.59755	23.24253	22.95049	12.58265	16.8349	37.34796	21.62374	19.50855	14.59121	34.36495
Griewangk 30D (50)	15.80169	18.70828	23.30225	23.15126	21.62767	18.38161	37.29846	40.40899	47.19388	25.08746	51.58739	44.47505	13.86065	14.64478	14.20175	14.41743
Salomon 10D (51)	6.504143	9.253777	10.76897	11.16371	7.816335	8.95507	18.41681	25.76391	22.08967	12.07024	14.98269	29.07828	20.46353	19.83951	16.32883	33.85312
Salomon 30D (52)	13.85872	15.65485	21.43224	22.55352	18.9888	16.12439	39.0835	36.38547	50.16623	23.35964	50.95356	47.28359	18.28539	19.5542	20.96534	20.90218
Odd Square 10D (53)	7.904704	9.098642	12.54418	13.25748	9.753709	9.640848	21.8266	21.38627	29.11435	14.88114	16.20447	38.85592	28.44263	25.42133	25.61443	49.35801
Whitley 10D (54)	14.56971	15.84509	20.20175	19.75798	15.42906	15.48878	26.40732	26.14669	29.42538	19.31252	19.04229	44.9718	25.50299	25.35538	22.45512	37.35468
Whitley 30D (55)	78.01788	78.96122	87.69994	88.06825	85.27144	79.43632	93.44947	87.78199	108.3686	89.54307	118.9342	118.7315	85.16195	83.75699	79.22356	90.12601
Rana 10D (56)	10.23518	12.25526	15.92256	16.46043	16.8396	16.36624	17.80854	18.18527	28.06264	33.25582	27.95997	48.46168	44.581	50.07174	27.60092	97.08578
Rana 30D (57)	22.10531	26.07532	33.08109	33.31221	32.24091	27.48733	37.54896	36.01805	72.18537	48.90884	93.48063	90.56017	92.09171	79.66618	111.6399	189.029

Average Times (s) for 500k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	1.321064	1.07438	1.291351	1.212067	1.315264	0.953844	0.95793	1.287055	1.123246	0.819984	1.163992	1.367368	0.726504	0.740145	1.186186	0.961095
McCormic (2)	1.222931	0.922784	1.190412	1.330711	1.132278	0.685683	0.810924	1.073997	0.590415	0.613955	0.64944	0.75158	0.502574	0.687459	0.830568	0.631929
Box and Betts (3)	2.592627	2.284292	2.717758	3.286025	2.183596	1.928897	2.277462	2.683903	1.912829	1.93743	1.958876	2.097227	1.794901	2.103171	2.072813	2.000007
Goldstein (4)	1.328101	0.884473	1.294535	1.609769	1.063267	0.614154	1.029662	1.086702	0.639804	0.583365	0.761554	0.739008	0.498556	0.674878	0.62988	0.679556
Easom (5)	1.878701	1.250502	1.839248	2.144844	1.650371	0.944871	1.542848	1.653559	1.280436	1.157497	1.658	1.605495	1.204406	1.297059	1.449577	1.569739
Mod Rosenbrock 1 (6)	1.554987	1.101266	1.562462	1.761132	1.458621	0.88386	1.267701	1.320394	1.122362	0.934694	1.298477	1.384336	0.793187	0.779254	1.025884	1.042789
Mod Rosenbrock 2 (7)	1.563609	1.109795	1.735378	1.553252	1.456342	1.052445	1.330991	1.332001	1.208124	0.910235	1.357138	1.469804	0.797465	0.779334	1.113848	1.056554
Bohachevsky (8)	1.538068	1.136326	1.761859	1.44815	1.351362	1.120275	1.303655	1.367363	1.240869	0.948464	1.38816	1.446526	0.907202	0.9449	1.211176	1.075634
Powell (9)	2.584514	2.127031	3.446593	4.653894	2.649489	2.421444	3.001876	4.567075	3.006948	2.944615	3.757022	4.317736	2.005673	2.38041	3.380392	3.42255
Wood (10)	2.526476	1.933075	2.991302	4.630286	2.498196	2.17007	3.047423	4.396428	2.884004	3.001658	3.655105	4.227172	1.987055	2.618333	3.129184	3.492117
Beale (11)	1.644961	1.088789	1.514807	1.610772	1.387077	0.959346	1.460437	1.449075	1.335558	1.028237	1.472392	1.542702	0.979615	1.155552	1.242928	1.17818
Engvall (12)	1.774757	1.271899	1.653128	1.620465	1.446822	1.063938	1.56454	1.534314	1.409154	1.226631	1.586578	1.595111	1.035892	1.277446	1.179354	1.221387
DeJong (13)	1.517823	1.007893	1.425853	1.365142	1.22301	0.779052	1.252057	1.225156	0.90811	0.827746	1.093662	1.063421	0.542736	0.75573	0.643205	0.631418
Rastrigin (14)	1.547445	1.11578	1.444518	1.355277	1.190994	0.776003	1.247735	1.260025	1.26997	1.259248	1.253856	1.211095	0.853491	1.158658	1.188843	1.025487
Schwefel (15)	1.70114	1.171287	1.549015	1.475135	1.243081	0.880561	1.299665	1.368559	1.535552	1.181402	1.554843	1.436103	0.993163	1.262953	1.404851	1.225858
Griewangk (16)	1.535422	1.104088	1.387184	1.338029	1.143918	0.813541	1.199243	1.192068	1.276886	1.049528	1.344441	1.198311	0.807454	1.02107	1.124492	0.990598
Ackley (17)	1.735374	1.255691	1.536133	1.34401	1.304657	1.046628	1.367773	1.325919	1.539851	1.286496	1.45979	1.235673	0.947412	1.138542	1.269602	1.13673
Langerman (18)	2.969164	2.526724	3.735521	5.044129	2.707479	2.480406	3.990071	6.467907	4.33925	4.192114	4.281898	4.931392	2.016937	2.895527	3.032131	3.690438
Michaelewicz (19)	5.957485	6.379442	7.909499	8.005717	6.251473	4.846793	10.92853	13.15471	14.54651	9.904489	9.970675	23.25333	13.82768	18.90766	13.90213	38.32188
Branin (20)	1.555353	1.170982	1.380875	1.247746	1.087401	0.593846	1.332386	1.290017	1.000019	0.815744	0.736984	0.845263	0.588274	0.812365	0.670863	0.703241
Six Hump Camel (21)	1.551474	1.160918	1.317374	1.231489	1.063192	0.591117	1.251839	1.281017	0.855686	0.810251	0.624879	0.73406	0.606715	0.95691	0.693146	0.740089
Osborne 1 (22)	5.183854	4.811195	5.573236	6.611902	4.702756	3.869756	6.051826	8.616217	5.232651	5.669877	5.185887	6.105534	4.0374	5.467409	5.229124	5.721205
Osborne 2 (23)	12.60464	13.74796	14.15175	14.00977	12.2228	10.8111	16.74432	15.74141	13.05258	12.43817	13.24046	14.86718	10.22338	11.95016	11.60448	11.03701
Mod Rastrigin (24)	1.824583	1.428372	1.323057	1.325235	1.473706	0.905267	1.638366	1.027167	1.122108	1.115446	1.197725	1.138531	1.106258	1.628187	1.337216	0.985875
Mineshaft 1 (25)	1.555872	0.98397	0.941689	0.812812	0.98662	0.623715	0.938597	0.64268	0.727435	0.743895	0.680559	0.695965	0.717528	1.048921	0.838228	0.643038
Mineshaft 2 (26)	1.213564	0.63824	0.62006	0.452321	0.671531	0.312336	0.592843	0.340791	0.521742	0.398418	0.385764	0.356561	0.398349	0.73873	0.525834	0.337605
Mineshaft 3 (27)	1.723544	1.150494	1.201647	1.137533	1.16277	0.607009	1.298445	0.841703	1.012509	0.645957	0.823389	0.798461	0.750327	1.208372	0.88719	0.656243
Spherical Contours (28)	6.628037	7.597568	9.569988	9.436679	7.147883	5.508473	14.11621	10.73785	3.868559	3.67536	3.7643	3.960355	3.284712	3.891748	3.939191	3.862656
S1 (29)	0.908074	0.713958	0.462085	0.443053	0.433325	0.28349	0.483684	0.276635	0.434094	0.449343	0.317742	0.291591	0.34318	0.524655	0.512105	0.31996
S2 (30)	1.497824	1.273929	0.974451	1.065201	0.909803	0.617905	1.124504	0.691671	0.862967	0.661491	0.745566	0.706933	0.538992	0.637749	0.823028	0.50136
S3 (31)	1.459978	1.293579	0.933704	1.025854	0.870176	0.600402	1.054661	0.684902	0.646109	0.604678	0.533753	0.572118	0.546377	0.715386	0.770441	0.496124
Downhill Step (32)	2.257383	1.914025	1.332722	1.383247	1.072433	0.811089	1.336888	0.92602	1.229087	1.160065	1.061257	1.113183	1.217065	1.590484	1.815898	1.161183
Salomon (33)	1.826728	1.572816	1.029544	1.095833	0.79252	0.667029	1.044925	0.725537	1.01028	0.873966	0.845309	0.91109	0.824172	1.077079	1.102558	0.751638
Whitley (34)	1.817853	1.630084	1.072316	1.100739	0.901648	0.913354	1.17628	0.834568	1.139455	0.990426	0.966959	1.035887	0.95117	1.225693	1.207532	0.856404
Odd Square (35)	1.60478	1.540002	1.065618	1.063886	0.858011	0.863956	1.155384	0.790866	1.175831	0.977986	0.974407	0.97134	0.795718	1.373851	1.055139	0.715882
Storn Chebyshev (36)	144.599	138.8338	138.8995	139.9093	137.841	139.5736	141.2271	144.4693	140.8265	139.7323	139.4009	148.1628	142.9621	144.7218	140.2199	143.0246
Rana (37)	1.284336	0.938755	1.213651	1.319755	1.358983	1.193023	1.097864	1.087576	1.053387	0.784648	1.133789	1.231987	1.324847	0.881007	1.112674	0.868742
Rosenbrock 10D (38)	2.620482	2.84236	4.818595	5.298554	3.554572	3.808362	5.205007	7.28776	5.507198	3.038344	4.684254	10.26589	2.227725	1.712431	2.075025	2.002368
Rosenbrock 30D (39)	5.802996	5.84004	9.618094	9.800119	8.035785	7.252823	11.7918	11.93351	4.525242	4.40998	5.383931	6.104791	3.896802	3.168986	3.414511	3.781523
Mod Rosenbrock 1 10D (40)	3.238273	3.338005	5.754609	5.728325	4.014937	4.69547	5.839147	8.089959	6.649966	4.388305	5.167303	11.25127	2.798728	2.12802	2.298875	2.459962
Mod Rosenbrock 1 30D (41)	7.717166	7.571152	11.54796	11.29697	9.582508	9.017944	12.59661	13.304	5.973539	5.807636	6.28698	6.889917	5.73305	4.851616	5.260492	5.466527
Mod Rosenbrock 2 10D (42)	3.695968	3.909499	5.915849	6.09215	4.758489	5.804297	7.647892	8.211905	9.530698	7.642297	8.516539	21.98116	14.24236	9.236125	11.0646	19.81993
Mod Rosenbrock 2 30D (43)	9.039557	8.857327	12.66361	13.55136	12.16982	10.99738	18.43537	17.6458	23.13251	13.89325	32.95036	41.92508	31.22254	19.44656	28.5439	48.85569
Spherical Contours 10D (44)	2.810364	2.827545	5.22662	5.775626	3.792031	3.897365	5.30698	6.498552	5.683811	3.64089	4.500678	11.18326	1.943192	1.345942	1.47524	1.749399
Rastrigin 10D (45)	3.245301	3.317312	6.004686	6.032069	4.546055	4.672549	5.995985	7.39124	8.370136	5.355207	8.247322	19.56674	9.269666	4.906375	5.850919	10.3934
Rastrigin 30D (46)	7.228148	6.945181	11.66615	11.8435	10.37032	8.709999	14.4078	13.38548	17.72763	11.70933	21.15941	24.69476	7.897984	6.5181	7.483907	8.471523
Schwefel 10D (47)	4.579816	3.957586	6.34737	6.546571	6.742433	6.085701	7.071029	9.04819	14.63605	9.952811	11.25251	24.03289	18.29148	14.96304	13.18784	20.68795
Schwefel 30D (48)	9.455304	8.157348	12.87732	12.61921	12.95513	10.65305	16.51982	18.2768	29.18643	16.54244	39.2936	45.75252	32.25493	25.56645	38.68872	60.36636
Griewangk 10D (49)	3.484982	3.227146	5.911942	5.879368	4.092101	4.352254	4.956792	7.743518	7.10553	5.145132	6.233026	8.406622	2.158607	1.827551	1.957636	1.584742
Griewangk 30D (50)	7.51088	6.739337	10.98928	11.28079	9.183103	7.563437	11.30549	13.21161	5.577863	5.415369	5.863259	5.03913	4.691462	4.073723	4.379283	3.804952
Salomon 10D (51)	3.171996	3.262408	5.509359	5.974083	4.022306	3.373075	5.507579	8.278493	8.316546	4.910815	6.302024	9.775395	2.712902	1.799834	2.484499	1.688419
Salomon 30D (52)	6.524193	6.324276	10.50304	10.05187	8.785951	5.868856	12.52493	13.55855	6.6493	6.107655	6.883171	6.084823	3.808849	2.974116	3.719619	2.966692
Odd Square 10D (53)	3.64808	3.826179	6.110667	5.070686	5.061258	3.355657	6.353106	9.130513	11.56457	6.782168	8.275059	13.11993	9.347309	5.307211	6.390063	7.457047
Whitley 10D (54)	6.846946	7.034119	8.818609	7.769658	7.373351	6.152676	9.358062	13.22357	11.38254	8.520047	8.801332	12.34211	5.563482	5.416589	4.918306	4.403943
Whitley 30D (55)	38.59721	37.8107	37.6756	37.85276	36.47771	35.18681	45.49653	47.68785	38.19151	39.07805	39.11732	36.64853	33.12055	33.45312	30.13282	29.31724
Rana 10D (56)	5.514152	6.053682	5.646198	6.20018	5.64812	6.671182	10.7521	13.54888	14.20506	14.44531	13.07665	20.10834	12.66482	17.05454	10.56812	21.02874
Rana 30D (57)	12.05436	12.42148	13.07102	13.7644	13.37257	12.62976	24.00137	25.5405	31.37807	22.31562	36.40063	42.98	30.59899	29.92013	35.13403	61.7419

Average Times (s) for 100k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.145142	0.107823	0.129616	0.12578	0.1369	0.130985	0.149547	0.177979	0.15612	0.081843	0.093376	0.125757	0.111409	0.116497	0.111392	0.138737
McCormic (2)	0.131339	0.081758	0.123377	0.110243	0.102063	0.094812	0.102396	0.128706	0.134536	0.080198	0.082739	0.10766	0.110983	0.115352	0.115337	0.140325
Box and Betts (3)	0.362134	0.327311	0.368755	0.369969	0.346522	0.356357	0.362565	0.41009	0.400948	0.338619	0.346049	0.374954	0.390068	0.374692	0.37864	0.398268
Goldstein (4)	0.133532	0.074206	0.114713	0.104647	0.094015	0.088556	0.1064	0.125166	0.12328	0.077745	0.080559	0.112673	0.107461	0.11137	0.097161	0.114785
Easom (5)	0.198513	0.134047	0.180135	0.164609	0.1904	0.168327	0.220999	0.258272	0.235567	0.137666	0.154333	0.200521	0.11823	0.120694	0.109319	0.124385
Mod Rosenbrock 1 (6)	0.159608	0.113398	0.16393	0.125502	0.150792	0.135242	0.170253	0.199256	0.152688	0.095141	0.118124	0.143272	0.126264	0.122176	0.123434	0.128139
Mod Rosenbrock 2 (7)	0.157076	0.115269	0.18154	0.132473	0.148929	0.139449	0.169875	0.207737	0.168587	0.095692	0.136445	0.142027	0.132951	0.139472	0.120352	0.128424
Bohachevsky (8)	0.169196	0.121762	0.173025	0.128527	0.153309	0.141394	0.161521	0.199768	0.163762	0.103756	0.128968	0.128148	0.128999	0.149782	0.127436	0.135997
Powell (9)	0.296228	0.24791	0.340189	0.378724	0.294182	0.305492	0.330682	0.531547	0.268141	0.194844	0.227512	0.261503	0.199142	0.223835	0.21327	0.235249
Wood (10)	0.287496	0.228558	0.309954	0.370554	0.292882	0.292729	0.345915	0.474767	0.244574	0.185303	0.197221	0.237229	0.185795	0.200506	0.191797	0.209042
Beale (11)	0.184053	0.131035	0.16864	0.142505	0.187266	0.157623	0.19705	0.232104	0.189633	0.127906	0.128848	0.146824	0.136759	0.127868	0.106821	0.125929
Engvall (12)	0.212195	0.165669	0.205578	0.16783	0.202345	0.180189	0.232347	0.244576	0.200095	0.162695	0.152562	0.171444	0.17418	0.165032	0.147089	0.167569
DeJong (13)	0.161919	0.116818	0.154086	0.114819	0.156266	0.107095	0.178687	0.203785	0.143142	0.10784	0.103409	0.128983	0.139146	0.120473	0.099276	0.121526
Rastrigin (14)	0.166724	0.118355	0.168236	0.122545	0.149003	0.123847	0.182574	0.213602	0.146987	0.145931	0.110027	0.130316	0.133106	0.123388	0.096378	0.119715
Schwefel (15)	0.186507	0.132062	0.169646	0.129047	0.175761	0.165849	0.201293	0.24471	0.196962	0.144549	0.149378	0.174679	0.125296	0.124104	0.100665	0.121527
Griewangk (16)	0.167139	0.122654	0.142116	0.117937	0.146861	0.141113	0.168253	0.204873	0.147734	0.114907	0.116907	0.134198	0.123916	0.128154	0.102521	0.125203
Ackley (17)	0.197715	0.145967	0.179333	0.153126	0.191978	0.170465	0.200278	0.239502	0.177092	0.147912	0.155791	0.16136	0.146157	0.13565	0.118724	0.142768
Langerman (18)	0.350983	0.30307	0.396102	0.476706	0.362976	0.33576	0.408244	0.531054	0.283218	0.252991	0.273	0.30218	0.265794	0.263088	0.260968	0.329214
Michaelewicz (19)	0.832994	0.833746	1.140012	1.089713	1.073676	1.024578	1.630278	2.103016	2.094608	1.434979	1.707712	2.815171	0.722663	0.733691	0.819137	0.922074
Branin (20)	0.167494	0.110894	0.148463	0.136779	0.13602	0.111238	0.196236	0.187372	0.135077	0.106728	0.116215	0.122662	0.114871	0.110854	0.143369	0.13189
Six Hump Camel (21)	0.174063	0.105988	0.166046	0.147376	0.117083	0.116865	0.166314	0.175394	0.144638	0.118362	0.108465	0.130587	0.126884	0.12209	0.153859	0.142216
Osborne 1 (22)	0.736332	0.656137	0.810244	0.871108	0.679676	0.736484	0.87403	0.95598	0.701607	0.66669	0.653546	0.73883	0.655679	0.65086	0.705592	0.72641
Osborne 2 (23)	2.004572	1.997116	2.085494	2.068888	1.879266	1.929739	1.965867	2.018839	2.013656	2.000162	1.968153	2.051293	2.110336	2.165464	2.284096	2.364895
Mod Rastrigin (24)	0.2181	0.173437	0.220389	0.220852	0.186626	0.164315	0.220537	0.215201	0.189758	0.198839	0.154645	0.186451	0.157597	0.159756	0.171035	0.170108
Mineshaft 1 (25)	0.181402	0.130489	0.155721	0.144402	0.132183	0.138461	0.151863	0.159416	0.171108	0.144947	0.139641	0.16368	0.145418	0.150932	0.167182	0.160689
Mineshaft 2 (26)	0.099107	0.066722	0.090576	0.079221	0.075809	0.07617	0.089702	0.100537	0.09666	0.080422	0.078641	0.103843	0.083599	0.089562	0.102307	0.109981
Mineshaft 3 (27)	0.166661	0.124899	0.184211	0.195012	0.147227	0.125402	0.16566	0.19323	0.170383	0.148465	0.152978	0.187456	0.104095	0.114745	0.123969	0.132794
Spherical Contours (28)	0.581358	0.567882	0.611317	0.613562	0.555626	0.576096	0.589011	0.637258	0.734003	0.722154	0.713263	0.78756	1.057826	1.100576	1.229479	1.466327
S1 (29)	0.072422	0.05748	0.065721	0.08287	0.06449	0.062591	0.062738	0.074212	0.096441	0.09085	0.064372	0.09275	0.081002	0.082535	0.092245	0.099281
S2 (30)	0.143852	0.116146	0.148901	0.173836	0.13562	0.105109	0.139395	0.160563	0.129697	0.117137	0.09273	0.123194	0.102743	0.10195	0.118581	0.119292
S3 (31)	0.133534	0.112399	0.143143	0.159516	0.0991	0.097653	0.113406	0.135529	0.127992	0.127355	0.098062	0.120358	0.114843	0.113063	0.146093	0.1307
Downhill Step (32)	0.197899	0.161619	0.204914	0.230482	0.177715	0.17949	0.217106	0.270796	0.217028	0.20416	0.171806	0.205008	0.119663	0.109824	0.143409	0.133369
Salomon (33)	0.143813	0.125982	0.160569	0.164102	0.123776	0.142249	0.147459	0.178719	0.136204	0.12601	0.107937	0.12079	0.116291	0.106986	0.143362	0.131945
Whitley (34)	0.166198	0.147347	0.195952	0.189338	0.141996	0.163671	0.17382	0.208841	0.15982	0.149375	0.132583	0.143673	0.133002	0.12968	0.173993	0.152481
Odd Square (35)	0.174146	0.136695	0.201905	0.185606	0.1433	0.133149	0.172844	0.202394	0.13303	0.148095	0.112452	0.131628	0.115775	0.117631	0.149596	0.134482
Storn Chebyshev (36)	27.59002	27.24412	27.11504	27.30901	26.89669	27.01529	27.78643	27.15805	27.03105	26.98041	27.21695	27.6689	27.73851	27.79281	27.63348	27.78882
Rana (37)	0.204868	0.195255	0.18589	0.178969	0.176918	0.143321	0.193608	0.186017	0.152336	0.176615	0.165724	0.189498	0.143886	0.159803	0.198336	0.158028
Rosenbrock 10D (38)	0.365174	0.409928	0.484061	0.4693	0.256016	0.254036	0.27069	0.274789	0.272904	0.332027	0.325012	0.406178	0.346922	0.444809	0.56932	0.57037
Rosenbrock 30D (39)	0.629002	0.634323	0.64308	0.624925	0.583592	0.582146	0.598557	0.587011	0.651057	0.724421	0.749716	0.802898	1.028598	1.027295	1.261197	1.33937
Mod Rosenbrock 1 10D (40)	0.470064	0.525041	0.588475	0.601897	0.378154	0.379991	0.384268	0.418563	0.412892	0.405229	0.410582	0.482526	0.486747	0.522371	0.672496	0.626872
Mod Rosenbrock 1 30D (41)	0.980704	0.973847	0.978549	0.943954	0.948512	0.973096	0.993465	0.982176	1.064127	1.028715	1.096804	1.160467	1.407471	1.379035	1.647035	1.591271
Mod Rosenbrock 2 10D (42)	0.583069	0.69503	0.878653	0.81091	0.74079	0.806434	1.068855	1.230204	0.791269	0.740805	0.7548	1.020828	0.486153	0.524976	0.651529	0.595177
Mod Rosenbrock 2 30D (43)	1.446515	1.592602	1.976965	1.974385	1.843326	1.907962	2.231976	2.491531	1.938452	1.760966	1.973952	2.19743	1.378873	1.446447	1.669359	1.574886
Spherical Contours 10D (44)	0.327689	0.349263	0.469247	0.463985	0.267767	0.297591	0.231467	0.265766	0.295209	0.306288	0.284599	0.341076	0.346814	0.446876	0.477165	0.438544
Rastrigin 10D (45)	0.436599	0.514185	0.662659	0.677953	0.553485	0.603721	0.507222	0.663252	0.381392	0.401787	0.390831	0.454936	0.398124	0.500346	0.487366	0.479055
Rastrigin 30D (46)	0.997923	1.047677	1.234839	1.265416	0.847135	0.903851	0.831131	0.879515	0.843409	0.840814	0.900504	0.938232	1.214901	1.244733	1.181626	1.257576
Schwefel 10D (47)	0.617484	0.72669	0.866283	1.002093	1.041907	1.10332	1.073901	1.646215	1.421482	1.28088	1.632451	2.435297	0.474328	0.599702	0.482354	0.496499
Schwefel 30D (48)	1.358421	1.488464	1.82553	2.035051	2.066367	1.824996	2.706219	3.058296	3.245401	2.259548	3.693174	4.535466	1.307974	1.374633	1.256827	1.292307
Griewangk 10D (49)	0.404279	0.485505	0.514186	0.603393	0.338517	0.356391	0.298152	0.333755	0.364435	0.335614	0.387064	0.394393	0.533588	0.57791	0.538741	0.502214
Griewangk 30D (50)	0.75785	0.781752	0.778775	0.857536	0.754545	0.830913	0.729997	0.759198	0.890473	0.892553	0.925494	0.92629	1.380214	1.364342	1.270631	1.34098
Salomon 10D (51)	0.352088	0.428257	0.52458	0.667042	0.27192	0.323595	0.255466	0.31594	0.27812	0.306127	0.330022	0.32822	0.439972	0.485779	0.407814	0.463137
Salomon 30D (52)	0.622183	0.654924	0.629138	0.736568	0.551641	0.605863	0.549458	0.589776	0.639366	0.748424	0.72543	0.730017	1.126471	1.126759	0.982481	1.163914
Odd Square 10D (53)	0.440881	0.527532	0.630463	0.831916	0.553008	0.554788	0.5364	0.773043	0.473547	0.590413	0.536664	0.610345	0.444783	0.516294	0.407785	0.465006
Whitley 10D (54)	1.012741	1.052502	1.101937	1.233354	0.933359	0.954601	0.871256	0.984588	0.96297	1.050752	0.975525	1.013145	1.138631	1.186894	1.038999	1.054571
Whitley 30D (55)	6.495211	6.410774	6.417957	6.526914	6.381701	6.565553	6.335453	6.541301	6.655445	6.805314	6.706384	6.747725	7.078806	6.934548	6.52093	6.580525
Rana 10D (56)	0.730889	0.822201	1.058313	1.10906	1.129757	1.051486	1.326839	2.099134	1.816733	1.400693	1.750145	3.03632	0.540079	0.563748	0.575167	0.620068
Rana 30D (57)	1.799796	1.873612	2.371836	2.467835	2.657554	2.181111	3.607653	3.672297	4.311984	2.853654	4.634592	6.433595	1.501042	1.476021	1.540907	1.683317

APPENDIX G1: AVG. RESULTS FOR SMOA-HTDER

Average Results (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.00118	0.001963	0.00118	0.00118	0.001708	0.002037	0.001708	0.001708	0.001633	0.000338	0.001633	0.001633	0.000527	0.000211	0.000527	0.000527	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.9133
Box and Betts (3)	9.78E-09	5.37E-09	1.16E-08	5.02E-09	3.67E-09	1.79E-09	6.37E-09	2.48E-09	7.21E-10	4.24E-10	2.06E-09	2.33E-09	6.83E-10	2.80E-10	6.80E-10	1.07E-09	0
Goldstein (4)	3.000105	3.000024	3.000105	3.000105	3.00004	3.000006	3.00004	3.00004	3.000008	3.000001	3.000008	3.000008	3.000001	3	3.000001	3.000001	3
Easom (5)	-0.99895	-0.99903	-0.99895	-0.99895	-0.99878	-0.99998	-0.99878	-0.99878	-0.99994	-1	-0.99994	-0.99994	-1	-0.99997	-1	-1	-1
Mod Rosenbrock 1 (6)	0.026581	0.059274	0.026581	0.026581	0.061145	0.054269	0.061145	0.061145	0.064743	0.032093	0.064743	0.064743	0.036395	0.021505	0.036395	0.036395	0
Mod Rosenbrock 2 (7)	0.162579	0.584654	0.162579	0.162579	0.484816	0.600774	0.484816	0.484816	0.938474	0.808533	0.938474	0.938474	0.688182	0.663308	0.688182	0.688182	0
Bohachevsky (8)	0	0	0	0	0	0	0	0	0.072536	0	0.072536	0.072536	0	0	0	0	0
Powell (9)	170430.1	170430.1	21026.33	42686.97	183127.9	183127.9	16596.59	681.9996	155027.1	155027.1	70334.26	244.6674	34874.42	34874.42	131168.5	469.47	0
Wood (10)	108.6366	108.6366	1318.427	71514.39	47.77747	47.77747	1449.504	613.8804	79146.82	79146.82	1716.503	995.153	3512.64	3512.64	84529.13	73.98778	0
Beale (11)	0.120924	0.312957	0.120924	0.120924	0.261296	0.148773	0.261296	0.261296	0.522186	0.006964	0.522186	0.522186	0.004569	0.0023	0.004569	0.004569	0
Engvall (12)	0.701066	0.992378	0.701066	0.701066	1.151315	0.813806	1.151315	1.151315	1.229318	0.008098	1.229318	1.229318	0.000705	0.00358	0.000705	0.000705	0
DeJong (13)	0	9.88E-06	0	0	0	5.17E-06	0	0	5.89E-06	5.50E-07	5.89E-06	5.89E-06	6.38E-07	1.16E-07	6.38E-07	6.38E-07	0
Rastrigin (14)	0	0.002674	0	0	0	0.001001	0	0	0.000991	0.017253	0.000991	0.000991	0.002814	0.003221	0.002814	0.002814	0
Schwefel (15)	-837.957	-837.951	-837.957	-837.957	-837.954	-837.959	-837.954	-837.954	-837.958	-837.963	-837.958	-837.958	-837.964	-837.963	-837.964	-837.964	-837.9658
Griewangk (16)	0	0	0	0	0	0	0	0	0.000452	0	0.000452	0.000452	0	0	0	0	0
Ackley (17)	0.016576	0.038504	0.016576	0.016576	0.030779	0.01414	0.030779	0.030779	0.008472	0.000494	0.008472	0.008472	0.000275	0.000748	0.000275	0.000275	0
Langerman (18)	-1.4697	-1.47368	-1.48118	-1.47377	-1.46907	-1.47267	-1.48075	-1.47823	-1.47276	-1.46937	-1.48112	-1.48345	-1.4722	-1.46961	-1.473	-1.48349	-1.5
Michaelewicz (19)	-7.58771	-8.44024	-7.86807	-7.70546	-7.4985	-8.4693	-8.01958	-7.70517	-7.9018	-8.3781	-8.12113	-7.70042	-7.82982	-8.02734	-8.08687	-7.76299	-9.66
Branin (20)	0.397899	0.397897	0.397899	0.397899	0.397902	0.397891	0.397902	0.397902	0.397891	0.397888	0.397891	0.397891	0.397888	0.397887	0.397888	0.397888	0.397887
Six Hump Camel (21)	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.016712	0.014477	0.014996	0.013731	0.015756	0.015241	0.015447	0.013935	0.013093	0.014889	0.015689	0.015147	0.01679	0.015046	0.015403	0.016364	5.46E-05
Osborne 2 (23)	0.079119	0.075537	0.074272	0.074922	0.081406	0.07593	0.072221	0.076098	0.07842	0.079795	0.072803	0.076797	0.079778	0.080685	0.076129	0.078507	0.0402
Mod Rastrigin (24)	74.99509	79.03455	74.99509	74.99509	78.52584	79.52507	78.52584	78.52584	83.48374	81.07565	83.48374	83.48374	79.20761	80.21579	79.20761	79.20761	58
Mineshaft 1 (25)	1.688819	1.790769	1.76291	1.790769	1.69088	1.718212	1.717999	1.718212	1.770505	1.535744	1.675662	1.535744	1.690357	1.56655	1.65992	1.56655	1.3805
Mineshaft 2 (26)	-1.41632	-1.4099	-1.41635	-1.4099	-1.41635	-1.40842	-1.41635	-1.40842	-1.41635	-1.41635	-1.41635	-1.41635	-1.41635	-1.41635	-1.41635	-1.41635	-1.4163535
Mineshaft 3 (27)	-6.95361	-6.99091	-6.95361	-6.95361	-6.98989	-6.99857	-6.98989	-6.98989	-6.99912	-6.99983	-6.99912	-6.99912	-6.99988	-6.99997	-6.99988	-6.99988	-7
Spherical Contours (28)	5.017588	4.935578	4.957613	4.957613	4.96196	4.962489	4.976174	4.976174	5.093355	5.090472	5.093651	5.096461	5.068457	5.068457	5.068457	5.068457	0
S1 (29)	4.54E-13	4.38E-15	7.56E-14	4.38E-15	3.54E-14	8.91E-16	8.20E-15	8.91E-16	1.70E-14	7.95E-17	6.10E-16	7.95E-17	3.06E-15	1.76E-15	1.49E-15	1.76E-15	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528874	0.528877	0.528874	0.528874	0.528875	0.528879	0.528875	0.528875	0.528894	0.528874	0.528894	0.528894	0.528874	0.528873	0.528874	0.528874	0.5289
Downhill Step (32)	9	9	9	9	9	9	9	9	9.004	9	9.004	9.004	9	9	9	9	9
Salomon (33)	0	0	0	0	0	0	0	0	0.003123	0	0.003123	0.003123	0	0.010899	0	0	0
Whitley (34)	0.05741	0.109915	0.05741	0.05741	0.103598	0.128489	0.103598	0.103598	0.083531	0.016637	0.083531	0.083531	0.00913	0.004568	0.00913	0.00913	0
Odd Square (35)	-1.0073	-1.00713	-1.0073	-1.0073	-1.0073	-1.00731	-1.0073	-1.0073	-1.0074	-1.00707	-1.0074	-1.0074	-1.00709	-1.00159	-1.00709	-1.00709	-1.14383
Storn Chebyshev (36)	730.7176	16.89865	235.0258	344.8421	833.2391	0.4216	3.161147	370.6897	227.1316	64.41778	0.611657	561.3491	109.2363	290.9435	1.829988	408.9871	0
Rana (37)	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.3	-1023.42	-1023.3	-1023.3	-1023.42	-1023.42	-1023.42	-1023.42	-1023.416
Rosenbrock 10D (38)	478.617	428.121	434.6118	422.5374	484.7882	429.6711	377.339	456.0653	485.3015	462.3768	334.3834	443.4731	506.3692	480.5738	360.5908	452.6657	0
Rosenbrock 30D (39)	14042.32	13624.31	13742.31	13742.31	13952.64	13263.02	13922.4	13922.4	14192.64	14237.53	14018.93	14118.08	14120.29	14120.29	14120.29	14120.29	0
Mod Rosenbrock 1 10D (40)	521.5259	465.811	461.4683	451.5674	524.9901	471.8231	413.8174	485.5767	520.3914	500.5015	357.8158	496.5315	527.0212	527.1152	389.9275	505.6972	0
Mod Rosenbrock 1 30D (41)	4790.163	4728.693	4723.203	4723.203	4810.229	4760.5	4750.39	4750.39	4828.46	4824.563	4826.545	4822.196	4845.711	4845.711	4845.711	4845.711	0
Mod Rosenbrock 2 10D (42)	0.652445	0.301073	1.638542	1.963279	1.179155	0.227889	0.810261	1.97902	1.306212	0.451465	0.552973	2.281802	1.424377	0.95484	0.598904	1.908168	0
Mod Rosenbrock 2 30D (43)	1.755361	0.55406	2.784127	2.784127	3.733262	0.597232	3.077879	3.077879	3.941941	1.81128	2.321232	3.642788	5.551905	5.551905	5.539793	5.551905	0
Spherical Contours 10D (44)	0.466736	0.399289	0.37894	0.369804	0.451702	0.392949	0.26746	0.382838	0.431991	0.429501	0.235845	0.401866	0.437653	0.441069	0.244927	0.380566	0
Rastrigin 10D (45)	22.86941	22.72524	25.02623	25.6396	19.95856	22.64112	24.79237	24.95329	20.16988	22.72441	24.19165	25.44912	21.70722	21.76318	23.82429	24.5026	0
Rastrigin 30D (46)	175.7191	172.8277	173.5111	173.5111	174.3333	174.3309	175.2487	175.2487	175.1944	175.0817	175.5024	175.5186	175.9331	175.9331	175.9331	175.9331	0
Schwefel 10D (47)	-3828.14	-3914.07	-3919.63	-3914.53	-3829.62	-3912.54	-3933.03	-3892.17	-3818.26	-3845.19	-3884.87	-3825.37	-3796.24	-3794.36	-3837.18	-3804.37	-4189.829
Schwefel 30D (48)	-9174.98	-9100.41	-9185.83	-9185.83	-9197.45	-9039.14	-8903.06	-8903.06	-9100.87	-9126.53	-8640.55	-8390.59	-8127.33	-8123.42	-8014.57	-7869.95	-12569.487
Griewangk 10D (49)	1.396995	1.33616	1.300048	1.319783	1.413333	1.333872	1.192612	1.33439	1.392877	1.378872	1.155673	1.365529	1.39332	1.385863	1.221663	1.361396	0
Griewangk 30D (50)	5.066762	5.04582	5.079776	5.079776	5.09071	4.984438	5.068621	5.068621	5.089583	5.081756	5.107441	5.090928	5.093065	5.093065	5.093065	5.093065	0
Salomon 10D (51)	0.972052	0.931639	0.924616	0.926851	0.945686	0.938847	0.924162	0.920335	0.983336	0.972963	0.901585	0.930155	0.954421	0.93471	0.916497	0.932915	0
Salomon 30D (52)	3.907234	3.649887	3.345409	3.345409	4.137515	4.136229	4.109498	4.109498	5.35295	5.35295	5.35295	5.35295	6.987675	6.987675	6.987675	6.987675	0
Odd Square 10D (53)	-0.15807	-0.277	-0.344	-0.34764	-0.15547	-0.28138	-0.33336	-0.28968	-0.20426	-0.24985	-0.37148	-0.2569	-0.22859	-0.24624	-0.34538	-0.289	-1.14383
Whitley 10D (54)	2246176	1807260	1946986	2321567	2229374	2139231	1758569	2520468	1969835	2097502	1538574	1829967	1988760	2270443	1660588	2012265	0
Whitley 30D (55)	4.15E+09	3.92E+09	3.65E+09	3.65E+09	4.09E+09	3.75E+09	3.63E+09	3.63E+09	3.87E+09	3.91E+09	3.84E+09	3.86E+09	3.86E+09	3.86E+09	3.86E+09	3.86E+09	0
Rana 10D (56)	-4412.85	-4059.69	-3760.27	-3743.84	-4527.8	-4293.46	-3914.77	-3724.01	-4211.29	-4583.6	-4238.72	-3689.41	-4408.73	-4540.19	-4468.44	-3700.03	-5117.08
Rana 30D (57)	-8152.8	-8155.65	-7851.34	-7851.34	-8386.05	-8072.99	-7790.63	-7790.63	-8097.77	-8268.93	-7631.7	-7613.05	-8125.41	-8240.98	-7790.25	-7579.54	-15351.24

Average Results (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.002266	0.003918	0.002266	0.002266	0.003678	0.003128	0.003678	0.003678	0.003788	0.000877	0.003788	0.003788	0.001531	0.000472	0.001531	0.001531	0
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.9133
Box and Betts (3)	1.62E-08	8.63E-09	2.16E-08	1.04E-08	6.32E-09	2.87E-09	1.05E-08	5.39E-09	1.42E-09	8.19E-10	3.39E-09	4.04E-09	1.24E-09	7.74E-10	1.49E-09	2.45E-09	0
Goldstein (4)	3.000198	3.000051	3.000198	3.000198	3.000094	3.000015	3.000094	3.000094	3.000018	3.000002	3.000018	3.000018	3.000003	3.000001	3.000003	3.000003	3
Easom (5)	-0.99721	-0.99532	-0.99721	-0.99721	-0.99688	-0.99977	-0.99688	-0.99688	-0.99992	-0.99997	-0.99992	-0.99992	-0.99999	-0.99994	-0.99999	-0.99999	-1
Mod Rosenbrock 1 (6)	0.057858	0.104704	0.057858	0.057858	0.105895	0.097273	0.105895	0.105895	0.097693	0.061463	0.097693	0.097693	0.058608	0.03175	0.058608	0.058608	0
Mod Rosenbrock 2 (7)	0.256394	0.732078	0.256394	0.256394	0.680044	0.742608	0.680044	0.680044	1.10451	1.066653	1.10451	1.10451	1.121945	0.876985	1.121945	1.121945	0
Bohachevsky (8)	0	0	0	0	0	0	0	0	0.20255	0	0.20255	0.20255	0	0	0	0	0
Powell (9)	292836.5	292836.5	58189.09	77759.11	311293.5	311293.5	53451.55	6282.639	284419.3	284419.3	153613	755.2244	80320.49	80320.49	208120.7	2594.894	0
Wood (10)	6955.575	6955.575	16387.84	109081.5	4451.272	4451.272	9414.276	5494.109	125702.2	125702.2	8700.557	2540.483	27867.97	27867.97	129087.3	802.7852	0
Beale (11)	0.205802	0.3967	0.205802	0.205802	0.334438	0.254331	0.334438	0.334438	0.714542	0.025049	0.714542	0.714542	0.02026	0.010842	0.02026	0.02026	0
Engvall (12)	1.073532	1.522368	1.073532	1.073532	1.848405	1.41314	1.848405	1.848405	1.516531	0.217317	1.516531	1.516531	0.098661	0.033971	0.098661	0.098661	0
DeJong (13)	0	2.45E-05	0	0	0	1.14E-05	0	0	1.22E-05	1.16E-06	1.22E-05	1.22E-05	1.61E-06	2.42E-07	1.61E-06	1.61E-06	0
Rastrigin (14)	0	0.00511	0	0	0	0.001838	0	0	0.001973	0.064553	0.001973	0.001973	0.011786	0.023084	0.011786	0.011786	0
Schwefel (15)	-837.946	-837.94	-837.946	-837.946	-837.94	-837.952	-837.94	-837.94	-837.946	-837.959	-837.946	-837.946	-837.961	-837.962	-837.961	-837.961	-837.9658
Griewangk (16)	0	0	0	0	0	0	0	0	0.000965	0	0.000965	0.000965	0	0	0	0	0
Ackley (17)	0.038031	0.062198	0.038031	0.038031	0.06141	0.03118	0.06141	0.06141	0.012685	0.001573	0.012685	0.012685	0.000511	0.001609	0.000511	0.000511	0
Langerman (18)	-1.45634	-1.46267	-1.4731	-1.46039	-1.4536	-1.45743	-1.47145	-1.46445	-1.45417	-1.45115	-1.46604	-1.47352	-1.45072	-1.44989	-1.45455	-1.47078	-1.5
Michaelewicz (19)	-7.42424	-8.27848	-7.74129	-7.54463	-7.37437	-8.35603	-7.92271	-7.5461	-7.72023	-8.22164	-7.9521	-7.5447	-7.56801	-7.71835	-7.81527	-7.5672	-9.66
Branin (20)	0.397911	0.397913	0.397911	0.397911	0.39792	0.397894	0.39792	0.39792	0.397894	0.397888	0.397894	0.397894	0.397888	0.397887	0.397888	0.397888	0.397887
Six Hump Camel (21)	-1.03162	-1.03163	-1.03162	-1.03162	-1.03162	-1.03163	-1.03162	-1.03162	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.021955	0.020981	0.020267	0.017831	0.020514	0.020622	0.019032	0.019746	0.017852	0.018696	0.020641	0.019518	0.021964	0.020213	0.021028	0.020955	5.46E-05
Osborne 2 (23)	0.086208	0.082495	0.079698	0.080875	0.08746	0.080988	0.078425	0.084057	0.087186	0.088963	0.080622	0.086041	0.088857	0.089259	0.088598	0.089229	0.0402
Mod Rastrigin (24)	76.51321	80.77593	76.51321	76.51321	80.63758	81.06458	80.63758	80.63758	84.23679	82.25467	84.23679	84.23679	80.60137	81.83354	80.60137	80.60137	58
Mineshaft 1 (25)	1.735548	1.834731	1.815268	1.834731	1.744323	1.743098	1.757116	1.743098	1.804196	1.627846	1.720658	1.627846	1.734348	1.777222	1.72236	1.777222	1.3805
Mineshaft 2 (26)	-1.41631	-1.40686	-1.41635	-1.40686	-1.41635	-1.4083	-1.41635	-1.4083	-1.41635	-1.41111	-1.41635	-1.41111	-1.41635	-1.40105	-1.41232	-1.40105	-1.4163535
Mineshaft 3 (27)	-6.91328	-6.9793	-6.91328	-6.91328	-6.98082	-6.99662	-6.98082	-6.98082	-6.99812	-6.9997	-6.99812	-6.99812	-6.99981	-6.99996	-6.99981	-6.99981	-7
Spherical Contours (28)	5.260358	5.250284	5.277656	5.277656	5.237491	5.173011	5.227998	5.227998	5.377304	5.377304	5.377304	5.377304	5.515747	5.515747	5.515747	5.515747	0
S1 (29)	2.36E-12	6.07E-11	3.08E-13	6.07E-11	7.43E-13	4.68E-15	7.33E-14	4.68E-15	6.86E-14	6.31E-07	2.43E-13	6.31E-07	3.31E-14	4.16E-06	4.56E-14	4.16E-06	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528878	0.528885	0.528878	0.528878	0.52888	0.528888	0.52888	0.52888	0.528904	0.528878	0.528904	0.528904	0.528877	0.528874	0.528877	0.528877	0.5289
Downhill Step (32)	9	9	9	9	9	9	9	9	9.004	9	9.004	9.004	9	9	9	9	9
Salomon (33)	0	0	0	0	0	0	0	0	0.004938	0	0.004938	0.004938	0	0.020473	0	0	0
Whitley (34)	0.141732	0.256802	0.141732	0.141732	0.2193	0.264695	0.2193	0.2193	0.173166	0.054595	0.173166	0.173166	0.02222	0.012296	0.02222	0.02222	0
Odd Square (35)	-1.00662	-1.00642	-1.00662	-1.00662	-1.00654	-1.00682	-1.00654	-1.00654	-1.00675	-1.00574	-1.00675	-1.00675	-1.00457	-0.98474	-1.00457	-1.00457	-1.14383
Storn Chebyshev (36)	1359.767	68.39458	978.1601	544.3246	1550.725	29.7812	11.15233	823.6612	664.7304	246.2975	3.94381	1263.294	450.9182	973.6535	17.05832	722.4364	0
Rana (37)	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1022.28	-1023.42	-1022.28	-1022.28	-1023.42	-1023.42	-1023.42	-1023.42	-1023.416
Rosenbrock 10D (38)	593.7031	505.957	528.2964	520.205	559.5871	536.9574	499.1025	550.6291	607.7638	602.5409	430.7954	542.4769	590.0575	582.6906	465.9005	547.3427	0
Rosenbrock 30D (39)	15474.31	14910.15	14928.02	14928.02	15317.31	14893.96	15302.65	15302.65	15685.04	15685.04	15685.04	15685.04	16050.09	16050.09	16050.09	16050.09	0
Mod Rosenbrock 1 10D (40)	561.8873	513.3145	508.9183	493.5649	566.479	511.6469	448.7573	534.1354	568.0482	538.0934	408.6619	544.4727	579.3032	589.239	470.6704	551.4269	0
Mod Rosenbrock 1 30D (41)	5009.487	4980.236	4894.653	4894.653	5028.437	4977.209	5019.532	5019.532	5141.706	5141.706	5141.706	5141.706	5116.782	5116.782	5116.782	5116.782	0
Mod Rosenbrock 2 10D (42)	1.296067	0.415321	1.972357	2.481433	1.992101	0.369083	1.051424	2.530131	2.128051	0.901941	0.771988	2.953039	2.274753	1.499985	0.981292	2.512127	0
Mod Rosenbrock 2 30D (43)	3.574261	1.364662	3.874715	3.874715	5.62066	1.374816	4.486057	4.486057	7.125039	7.125039	7.125039	7.125039	7.756101	7.756101	7.756101	7.756101	0
Spherical Contours 10D (44)	0.534625	0.471415	0.442565	0.410165	0.524977	0.450403	0.323706	0.424796	0.49207	0.498666	0.295146	0.453583	0.499936	0.506957	0.336297	0.412909	0
Rastrigin 10D (45)	25.38698	25.65122	27.46699	28.42689	24.1466	25.03139	27.29302	26.82843	25.94804	26.20653	26.73795	27.91317	26.86494	26.88665	26.82588	27.1792	0
Rastrigin 30D (46)	180.9232	180.6594	179.4881	179.4881	182.066	181.7981	181.3573	181.3573	183.0511	183.0511	183.0511	183.0511	183.1268	183.1268	183.1268	183.1268	0
Schwefel 10D (47)	-3768.87	-3873.47	-3871.03	-3855.02	-3775.34	-3861.55	-3877.99	-3814.51	-3730.43	-3749.89	-3783.92	-3727.95	-3674.38	-3669.39	-3696.16	-3648.2	-4189.829
Schwefel 30D (48)	-9004.02	-8769.99	-8733.52	-8733.52	-8970.99	-8742.93	-8390.02	-8390.02	-7763.74	-7966.43	-7747.38	-7689.54	-7449.68	-7449.68	-7449.68	-7449.68	-12569.487
Griewangk 10D (49)	1.454026	1.384839	1.344692	1.376038	1.469534	1.401462	1.24814	1.372619	1.441301	1.434186	1.211078	1.402946	1.460214	1.44502	1.308014	1.392046	0
Griewangk 30D (50)	5.32597	5.267298	5.300655	5.300655	5.276388	5.239341	5.230821	5.230821	5.34236	5.34236	5.34236	5.34236	5.340704	5.340704	5.340704	5.340704	0
Salomon 10D (51)	1.024335	0.99269	0.985363	0.999169	1.006546	0.992118	0.971492	0.997175	1.03058	1.024238	0.986752	1.006454	1.032125	1.017615	1.000533	1.017423	0
Salomon 30D (52)	4.46734	4.41335	4.372628	4.372628	5.295711	5.295711	5.295711	5.295711	7.645154	7.645154	7.645154	7.645154	10.82576	10.82576	10.82576	10.82576	0
Odd Square 10D (53)	-0.13547	-0.24061	-0.25738	-0.24693	-0.13536	-0.24593	-0.29278	-0.23886	-0.17383	-0.21917	-0.3186	-0.22566	-0.18592	-0.20128	-0.27977	-0.27103	-1.14383
Whitley 10D (54)	4109849	3325642	3725424	3534118	3452475	3301542	2640610	3616567	3675500	3365634	2699588	3489554	3302121	3281029	2918702	3062982	0
Whitley 30D (55)	5.12E+09	4.91E+09	4.77E+09	4.77E+09	4.92E+09	4.85E+09	4.9E+09	4.9E+09	5.28E+09	5.28E+09	5.28E+09	5.28E+09	5.92E+09	5.92E+09	5.92E+09	5.92E+09	0
Rana 10D (56)	-4267.21	-3923.15	-3687.31	-3664.33	-4332.54	-4132.1	-3797.64	-3619.32	-3976.03	-4350.71	-3976.98	-3570.76	-4044.87	-4182.68	-4000.23	-3583.59	-5117.08
Rana 30D (57)	-7749.49	-7569.38	-7428.2	-7428.2	-7746.42	-7505.21	-7415.85	-7415.85	-7693.11	-7844.61	-7317.1	-7374.69	-6980.08	-6980.08	-6980.08	-6980.08	-15351.24

Average Result (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4	True Minima
Rosenbrock (1)	0.017976	0.021199	0.017976	0.017976	0.020451	0.018809	0.020451	0.020451	0.02051	0.010449	0.02051	0.02051	0.010003	0.003991	0.010003	0.010003	0
McCormic (2)	-1.9132	-1.91322	-1.9132	-1.9132	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91309	-1.91322	-1.91322	-1.9133
Box and Betts (3)	4.63E-08	2.91E-08	8.47E-08	5.77E-08	1.81E-08	1.11E-08	3.26E-08	2.73E-08	2.79E-07	1.38E-08	1.83E-08	2.55E-08	4.17E-08	1.34E-07	2.38E-07	3.04E-08	0
Goldstein (4)	3.001525	3.000258	3.001525	3.001525	3.000524	3.000083	3.000524	3.000524	3.000122	3.000032	3.000122	3.000122	3.028198	3.000018	3.028198	3.028198	3
Easom (5)	-0.9633	-0.92818	-0.9633	-0.9633	-0.95036	-0.98267	-0.95036	-0.95036	-0.99489	-0.99736	-0.99489	-0.99489	-0.99844	-0.99487	-0.99844	-0.99844	-1
Mod Rosenbrock 1 (6)	0.239373	0.332224	0.239373	0.239373	0.336474	0.338402	0.336474	0.336474	0.242956	0.234733	0.242956	0.242956	0.251772	0.111348	0.251772	0.251772	0
Mod Rosenbrock 2 (7)	0.639221	1.014522	0.639221	0.639221	0.928807	1.037006	0.928807	0.928807	2.129543	2.314427	2.129543	2.129543	2.684706	1.791417	2.684706	2.684706	0
Bohachevsky (8)	0	0	0	0	0	0	0	0	4.336853	0.003644	4.336853	4.336853	0.855291	0.004897	0.855291	0.855291	0
Powell (9)	1142773	1142773	375133.1	216460.7	1236784	1236784	411899.9	63929.93	924843.3	924843.3	784706.5	47304.82	1160370	1160370	1151578	1160370	0
Wood (10)	199826	199826	177059.9	405001.7	163730.3	163730.3	189825.2	28970.3	352205.2	352205.2	310805.8	48393.65	378064.2	378064.2	378064.2	377237.6	0
Beale (11)	0.507235	2.629043	0.507235	0.507235	1.937508	2.209315	1.937508	1.937508	5.62301	0.227535	5.62301	5.62301	0.353335	0.246918	0.353335	0.353335	0
Engvall (12)	2.513811	2.649915	2.513811	2.513811	2.740555	2.335795	2.740555	2.740555	17.32629	1.142389	17.32629	17.32629	9.134579	0.431369	9.134579	9.134579	0
DeJong (13)	0	0.000113	0	0	0	5.33E-05	0	0	5.01E-05	6.60E-06	5.01E-05	5.01E-05	1.44E-05	2.09E-06	1.44E-05	1.44E-05	0
Rastrigin (14)	0	0.027197	0	0	0.001813	0.012106	0.001813	0.001813	0.024149	0.336771	0.024149	0.024149	0.181907	0.147435	0.181907	0.181907	0
Schwefel (15)	-837.844	-837.803	-837.844	-837.844	-837.831	-837.86	-837.831	-837.831	-837.841	-837.883	-837.841	-837.841	-837.84	-837.877	-837.84	-837.84	-837.9658
Griewangk (16)	0	0	0	0	0	0.000291	0	0	0.008977	0	0.008977	0.008977	0.006571	0.000319	0.006571	0.006571	0
Ackley (17)	0.141271	0.156624	0.141271	0.141271	0.16675	0.126567	0.16675	0.16675	0.043369	0.031977	0.043369	0.043369	0.018785	0.022166	0.018785	0.018785	0
Langerman (18)	-1.37033	-1.38352	-1.40881	-1.38788	-1.37015	-1.3578	-1.39918	-1.37276	-1.32864	-1.33296	-1.34149	-1.35127	-1.30604	-1.30604	-1.30604	-1.30604	-1.5
Michaelewicz (19)	-7.06752	-7.79838	-7.40684	-7.1842	-7.02607	-7.75061	-7.42171	-7.17146	-7.05273	-7.05273	-7.05273	-7.05273	-7.14763	-7.14763	-7.14763	-7.14763	-9.66
Branin (20)	0.398082	0.398021	0.398082	0.398082	0.398115	0.397923	0.398115	0.398115	0.39792	0.397892	0.39792	0.39792	0.397896	0.397889	0.397896	0.397896	0.397887
Six Hump Camel (21)	-1.03159	-1.03162	-1.03159	-1.03159	-1.03161	-1.03163	-1.03161	-1.03161	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.0316
Osborne 1 (22)	0.039336	0.037618	0.03647	0.036849	0.040199	0.041472	0.038751	0.036996	0.043949	0.04426	0.044611	0.041072	0.057228	0.057228	0.057228	0.057228	5.46E-05
Osborne 2 (23)	0.108854	0.104763	0.104603	0.104715	0.111296	0.110467	0.111049	0.111358	0.115115	0.115115	0.115115	0.115115	0.125839	0.125839	0.125839	0.125839	0.0402
Mod Rastrigin (24)	81.24453	85.23218	81.24453	81.24453	85.75552	84.55958	85.75552	85.75552	86.87364	86.29148	86.87364	86.87364	85.73123	85.74229	85.73123	85.73123	58
Mineshaft 1 (25)	1.88072	1.935903	1.939768	1.935903	1.922456	1.8336	1.878938	1.8336	1.877641	1.89896	1.832186	1.89896	1.845641	2.108908	1.884736	2.108908	1.3805
Mineshaft 2 (26)	-1.41532	-1.39545	-1.41631	-1.39545	-1.41294	-1.39051	-1.41059	-1.39051	-1.41635	-1.32876	-1.41573	-1.32876	-1.40877	-1.31232	-1.37677	-1.31232	-1.4163535
Mineshaft 3 (27)	-6.66494	-6.93091	-6.66494	-6.66494	-6.93107	-6.98201	-6.93107	-6.93107	-6.98895	-6.99679	-6.98895	-6.98895	-6.99788	-6.91528	-6.99788	-6.99788	-7
Spherical Contours (28)	5.997541	5.997541	5.997541	5.997541	6.067851	6.067851	6.067851	6.067851	7.129421	7.129421	7.129421	7.129421	9.313409	9.313409	9.313409	9.313409	0
S1 (29)	8.66E-11	4.49E-07	2.21E-11	4.49E-07	8.34E-11	7.18E-05	9.30E-11	7.18E-05	2.72E-11	0.000173	2.84E-10	0.000173	6.64E-11	9.87E-05	3.85E-07	9.87E-05	0
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528939	0.528967	0.528939	0.528939	0.528944	0.528952	0.528944	0.528944	0.528964	0.5289	0.528964	0.528964	0.52891	0.528885	0.52891	0.52891	0.5289
Downhill Step (32)	9	9	9	9	9	9.006	9	9	9.011	9.008	9.011	9.011	9.023	9.048	9.023	9.023	9
Salomon (33)	0	0	0	0	0	0.001999	0	0	0.022786	0	0.022786	0.022786	0.010496	0.037853	0.010496	0.010496	0
Whitley (34)	0.705982	0.841495	0.705982	0.705982	0.746988	0.795271	0.746988	0.746988	0.681681	0.378471	0.681681	0.681681	0.37388	0.222871	0.37388	0.37388	0
Odd Square (35)	-1.00117	-1.00114	-1.00117	-1.00117	-1.00217	-0.99805	-1.00217	-1.00217	-0.99809	-0.97247	-0.99809	-0.99809	-0.95254	-0.85534	-0.95254	-0.95254	-1.14383
Storn Chebyshev (36)	5844.71	1187.966	2649.822	3368.645	6096.527	2094.043	834.2014	3848.335	6408.074	6408.074	6408.074	6408.074	6521.228	6521.228	6521.228	6521.228	0
Rana (37)	-1023.42	-1023.42	-1023.42	-1023.42	-1023.42	-1023.16	-1023.42	-1023.42	-1018.53	-1022.66	-1018.53	-1018.53	-1022.4	-1023.16	-1022.4	-1022.4	-1023.416
Rosenbrock 10D (38)	953.1685	876.3786	845.605	816.788	940.9371	892.7971	842.1785	875.3141	931.0364	931.0364	931.0364	931.0364	868.0349	868.0349	868.0349	868.0349	0
Rosenbrock 30D (39)	19232.23	19232.23	19232.23	19232.23	19668.47	19668.47	19668.47	19668.47	25444.81	25444.81	25444.81	25444.81	34524.46	34524.46	34524.46	34524.46	0
Mod Rosenbrock 1 10D (40)	715.2077	666.6784	623.8601	609.4136	701.9684	668.1008	626.1108	654.047	711.8594	711.8594	711.8594	711.8594	710.7683	710.7683	710.7683	710.7683	0
Mod Rosenbrock 1 30D (41)	5666.674	5666.674	5666.674	5666.674	5704.082	5704.082	5704.082	5704.082	6564.919	6564.919	6564.919	6564.919	7509.809	7509.809	7509.809	7509.809	0
Mod Rosenbrock 2 10D (42)	4.371043	1.557425	3.190135	4.034954	4.502846	1.598326	2.444696	4.635661	6.137072	6.137072	6.137072	6.137072	6.016969	6.016969	6.016969	6.016969	0
Mod Rosenbrock 2 30D (43)	14.32416	13.9431	13.9431	13.9431	15.38689	15.38689	15.38689	15.38689	15.57241	15.57241	15.57241	15.57241	15.18482	15.18482	15.18482	15.18482	0
Spherical Contours 10D (44)	0.730558	0.684939	0.587823	0.607819	0.70231	0.649067	0.551944	0.562596	0.679581	0.679581	0.679581	0.679581	0.677224	0.677224	0.677224	0.677224	0
Rastrigin 10D (45)	34.81851	33.94557	36.61333	37.54691	34.6593	31.87635	34.10838	35.04713	34.73096	34.73096	34.73096	34.73096	33.86389	33.86389	33.86389	33.86389	0
Rastrigin 30D (46)	199.7876	199.7876	199.7876	199.7876	200.3187	200.3187	200.3187	200.3187	206.3459	206.3459	206.3459	206.3459	210.6346	210.6346	210.6346	210.6346	0
Schwefel 10D (47)	-3555.58	-3643.24	-3595.36	-3577.33	-3516.35	-3505.96	-3521.89	-3486.52	-3280.59	-3280.59	-3280.59	-3280.59	-3168.92	-3168.92	-3168.92	-3168.92	-4189.829
Schwefel 30D (48)	-7690.24	-7479.11	-7274.36	-7274.36	-7073.35	-7073.35	-7073.35	-7073.35	-7048.17	-7048.17	-7048.17	-7048.17	-7084.15	-7084.15	-7084.15	-7084.15	-12569.487
Griewangk 10D (49)	1.637453	1.576796	1.483626	1.512189	1.632512	1.575232	1.498718	1.519243	1.597706	1.597706	1.597706	1.597706	1.60176	1.60176	1.60176	1.60176	0
Griewangk 30D (50)	6.028609	6.028609	6.028609	6.028609	5.926295	5.926295	5.926295	5.926295	6.579206	6.579206	6.579206	6.579206	7.793015	7.793015	7.793015	7.793015	0
Salomon 10D (51)	1.196801	1.180715	1.183702	1.181075	1.189045	1.171673	1.180918	1.190735	1.242659	1.242659	1.242659	1.242659	1.255865	1.255865	1.255865	1.255865	0
Salomon 30D (52)	8.985719	8.985719	8.985719	8.985719	12.80663	12.80663	12.80663	12.80663	16.06182	16.06182	16.06182	16.06182	16.63137	16.63137	16.63137	16.63137	0
Odd Square 10D (53)	-0.09342	-0.1564	-0.17142	-0.16029	-0.08984	-0.14521	-0.19021	-0.16113	-0.05992	-0.05992	-0.05992	-0.05992	-0.06794	-0.06794	-0.06794	-0.06794	-1.14383
Whitley 10D (54)	13980963	13457202	12682191	11657157	11540554	10224428	9846913	10390321	11794321	11794321	11794321	11794321	10607619	10607619	10607619	10607619	0
Whitley 30D (55)	9.85E+09	9.85E+09	9.85E+09	9.85E+09	1.03E+10	1.03E+10	1.03E+10	1.03E+10	2.39E+10	2.39E+10	2.39E+10	2.39E+10	6.75E+10	6.75E+10	6.75E+10	6.75E+10	0
Rana 10D (56)	-3835.22	-3544.51	-3474.57	-3440.65	-3672.3	-3551	-3413.6	-3357.56	-3268.06	-3268.06	-3268.06	-3268.06	-3261.9	-3261.9	-3261.9	-3261.9	-5117.08
Rana 30D (57)	-6930.56	-6786.22	-6865.42	-6865.42	-6553.17	-6553.17	-6553.17	-6553.17	-6763.16	-6763.16	-6763.16	-6763.16	-6879.56	-6879.56	-6879.56	-6879.56	-15351.24

APPENDIX G2: ST. DEV. FOR SMOA-HTDER

Results St. Dev. (1M)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.001535	0.002126	0.001535	0.001535	0.002008	0.002906	0.002008	0.002008	0.001807	0.000551	0.001807	0.001807	0.0013	0.000376	0.0013	0.0013
McCormic (2)	2.93E-06	4.57E-07	2.93E-06	2.93E-06	5.73E-07	9.12E-08	5.73E-07	5.73E-07	1.61E-07	1.63E-08	1.61E-07	1.61E-07	2.75E-08	5.22E-09	2.75E-08	2.75E-08
Box and Betts (3)	7.43E-09	3.75E-09	1.23E-08	1.20E-08	2.85E-09	1.39E-09	5.29E-09	6.16E-09	6.23E-10	2.70E-10	1.51E-09	2.55E-09	3.48E-09	2.06E-10	4.73E-10	8.34E-10
Goldstein (4)	0.000141	4.25E-05	0.000141	0.000141	3.87E-05	6.76E-06	3.87E-05	3.87E-05	9.12E-06	1.30E-06	9.12E-06	9.12E-06	1.50E-06	3.15E-07	1.50E-06	1.50E-06
Easom (5)	0.003992	0.002524	0.003992	0.003992	0.004685	0.000101	0.004685	0.004685	0.000243	1.51E-05	0.000243	0.000243	5.11E-06	0.000249	5.11E-06	5.11E-06
Mod Rosenbrock 1 (6)	0.039878	0.050458	0.039878	0.039878	0.051825	0.049519	0.051825	0.051825	0.046001	0.030479	0.046001	0.046001	0.030921	0.019003	0.030921	0.030921
Mod Rosenbrock 2 (7)	0.235421	0.385012	0.235421	0.235421	0.377835	0.37325	0.377835	0.377835	0.394134	0.474594	0.394134	0.394134	0.405574	0.377416	0.405574	0.405574
Bohachevsky (8)	0	0	0	0	0	0	0	0	0.34335	0	0.34335	0.34335	0	0	0	0
Powell (9)	168478.8	168478.8	43104.42	67841.3	173639.2	173639.2	25767.55	3688.74	162024.3	162024.3	111869.2	1038.892	62607.6	62607.6	170091.2	815.9443
Wood (10)	456.4668	456.4668	4797.916	69005.54	50.13177	50.13177	5302.087	4408.74	66695.79	66695.79	13709.16	6589.756	15212.11	15212.11	75443.48	150.0496
Beale (11)	0.14294	0.156549	0.14294	0.14294	0.172639	0.174725	0.172639	0.172639	2.111848	0.015087	2.111848	2.111848	0.010203	0.006848	0.010203	0.010203
Engvall (12)	0.935875	0.980587	0.935875	0.935875	1.105556	1.006013	1.105556	1.105556	1.295703	0.042667	1.295703	1.295703	0.001837	0.023171	0.001837	0.001837
DeJong (13)	0	1.29E-05	0	0	0	5.74E-06	0	0	5.85E-06	8.86E-07	5.85E-06	5.85E-06	1.27E-06	1.67E-07	1.27E-06	1.27E-06
Rastrigin (14)	0	0.004371	0	0	0	0.001067	0	0	0.000905	0.045205	0.000905	0.000905	0.00675	0.007588	0.00675	0.00675
Schwefel (15)	0.013005	0.019749	0.013005	0.013005	0.014874	0.012242	0.014874	0.014874	0.009821	0.00839	0.009821	0.009821	0.009557	0.0089	0.009557	0.009557
Griewangk (16)	0	0	0	0	0	0	0	0	0.001977	0	0.001977	0.001977	0	0	0	0
Ackley (17)	0.021652	0.035303	0.021652	0.021652	0.023227	0.025919	0.023227	0.023227	0.015954	0.000871	0.015954	0.015954	0.000413	0.001568	0.000413	0.000413
Langerman (18)	0.018782	0.015065	0.013852	0.018965	0.019563	0.019109	0.014186	0.015363	0.018386	0.02123	0.01546	0.01237	0.018803	0.021322	0.020408	0.013323
Michaelewicz (19)	0.283942	0.358754	0.400757	0.306951	0.263508	0.332388	0.322249	0.242594	0.36647	0.338561	0.347398	0.237328	0.378423	0.356291	0.362095	0.2423
Branin (20)	2.80E-05	1.33E-05	2.80E-05	2.80E-05	2.14E-05	3.97E-06	2.14E-05	2.14E-05	4.38E-06	4.59E-07	4.38E-06	4.38E-06	5.50E-07	8.86E-08	5.50E-07	5.50E-07
Six Hump Camel (21)	2.33E-06	1.25E-06	2.33E-06	2.33E-06	1.71E-06	2.20E-07	1.71E-06	1.71E-06	4.32E-07	3.02E-08	4.32E-07	4.32E-07	2.39E-08	5.84E-09	2.39E-08	2.39E-08
Osborne 1 (22)	0.006899	0.005515	0.006677	0.005186	0.006063	0.006386	0.007819	0.006127	0.005846	0.006489	0.007137	0.007092	0.006817	0.007289	0.005841	0.006944
Osborne 2 (23)	0.009346	0.009874	0.010198	0.010303	0.010551	0.009569	0.009891	0.008796	0.009135	0.010635	0.009778	0.009712	0.009124	0.010102	0.008877	0.008857
Mod Rastrigin (24)	4.13496	4.211056	4.13496	4.13496	4.221483	3.717513	4.221483	4.221483	2.53504	5.760824	2.53504	2.53504	4.07556	4.502935	4.07556	4.07556
Mineshaft 1 (25)	0.311961	0.190221	0.208867	0.190221	0.209932	0.110271	0.144316	0.110271	0.083202	0.076733	0.095991	0.076733	0.078409	0.127628	0.070633	0.127628
Mineshaft 2 (26)	0.000156	0.038958	9.42E-07	0.038958	8.78E-07	0.055585	1.58E-08	0.055585	2.66E-09	3.18E-12	1.58E-10	3.18E-12	1.34E-10	7.04E-09	6.65E-11	7.04E-09
Mineshaft 3 (27)	0.100986	0.019523	0.100986	0.100986	0.013075	0.003103	0.013075	0.013075	0.001894	0.000335	0.001894	0.001894	0.000301	5.95E-05	0.000301	0.000301
Spherical Contours (28)	0.460694	0.47206	0.535224	0.535224	0.461247	0.568857	0.4563	0.4563	0.357818	0.35882	0.358044	0.360123	0.404981	0.404981	0.404981	0.404981
S1 (29)	3.47E-12	1.24E-14	2.40E-13	1.24E-14	1.37E-13	2.64E-15	2.37E-14	2.64E-15	4.14E-14	2.60E-16	1.31E-15	2.60E-16	7.65E-15	7.24E-15	4.64E-15	7.24E-15
S2 (30)	0	2.84E-10	0	0	3.43E-11	1.01E-10	3.43E-11	3.43E-11	1.00E-10	4.01E-11	1.00E-10	1.00E-10	1.05E-11	2.73E-12	1.05E-11	1.05E-11
S3 (31)	4.78E-06	1.10E-05	4.78E-06	4.78E-06	1.18E-05	1.02E-05	1.18E-05	1.18E-05	1.81E-05	3.54E-06	1.81E-05	1.81E-05	4.22E-06	1.10E-06	4.22E-06	4.22E-06
Downhill Step (32)	0	0	0	0	0	0	0	0	0.039799	0	0.039799	0.039799	0	0	0	0
Salomon (33)	0	0	0	0	0	0	0	0	0.013537	0	0.013537	0.013537	0	0.019054	0	0
Whitley (34)	0.133469	0.129597	0.133469	0.133469	0.146069	0.192983	0.146069	0.146069	0.122125	0.054184	0.122125	0.122125	0.02382	0.021764	0.02382	0.02382
Odd Square (35)	0.000878	0.000921	0.000878	0.000878	0.000857	0.001064	0.000857	0.000857	0.000822	0.001663	0.000822	0.000822	0.002067	0.015069	0.002067	0.002067
Storn Chebyshev (36)	704.3446	76.42764	380.9293	394.0454	1072.226	2.254202	10.15719	403.1021	363.1849	254.0967	3.430919	522.8217	242.2333	500.7421	6.803576	532.6443
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	0.911258	1.71E-12	0.911258	0.911258	1.71E-12	1.71E-12	1.71E-12	1.71E-12
Rosenbrock 10D (38)	134.817	166.6966	182.1913	184.3677	142.8843	180.4204	181.049	150.2939	146.4931	152.9129	174.7464	154.8893	147.6819	158.5814	158.6047	139.8227
Rosenbrock 30D (39)	2204.656	2366.375	2286.582	2286.582	2128.901	2359.939	2055.351	2055.351	2470.167	2424.834	2360.162	2405.429	2121.745	2121.745	2121.745	2121.745
Mod Rosenbrock 1 10D (40)	70.77495	124.857	129.7581	135.6121	94.22384	125.1941	136.6705	99.13623	73.16039	96.46217	127.3485	90.52279	83.91005	81.7738	112.3573	97.29659
Mod Rosenbrock 1 30D (41)	371.849	446.8857	340.6215	340.6215	330.5321	433.7967	341.3486	341.3486	348.2605	344.3787	334.637	338.1215	353.5814	353.5814	353.5814	353.5814
Mod Rosenbrock 2 10D (42)	0.91104	0.28045	0.938448	1.022834	1.221632	0.151901	0.45682	0.855459	0.864451	0.388351	0.31143	0.948919	0.878505	0.798031	0.307207	0.896632
Mod Rosenbrock 2 30D (43)	2.261682	0.402094	1.847763	1.847763	2.729069	0.521168	1.731415	1.731415	2.06657	1.368198	1.655003	1.897825	2.565859	2.565859	2.549917	2.565859
Spherical Contours 10D (44)	0.093477	0.147751	0.176424	0.160702	0.102772	0.153837	0.169932	0.147953	0.086011	0.11064	0.141902	0.127267	0.109365	0.095789	0.125117	0.127397
Rastrigin 10D (45)	5.981363	5.270788	4.254455	3.792791	5.473856	5.233896	4.16683	4.256614	6.380222	5.457837	4.230481	4.881737	5.765302	5.390312	3.783574	4.205051
Rastrigin 30D (46)	10.3009	11.12155	11.36395	11.36395	7.997565	10.99246	12.15865	12.15865	12.93572	12.1329	12.5042	11.62222	8.968027	8.968027	8.968027	8.968027
Schwefel 10D (47)	82.79409	89.24183	72.71473	105.2314	71.99247	98.34577	72.34656	80.56621	83.79058	78.58828	93.39986	101.9382	79.49069	80.71872	107.5572	87.39455
Schwefel 30D (48)	254.109	336.3631	337.7006	337.7006	256.6241	315.0441	378.0413	378.0413	275.9847	251.3999	428.9624	416.0503	541.823	503.5052	415.4819	271.8466
Griewangk 10D (49)	0.08319	0.186884	0.210552	0.19107	0.084382	0.194007	0.209486	0.138925	0.094014	0.12308	0.176751	0.111962	0.116963	0.088167	0.166081	0.121043
Griewangk 30D (50)	0.359704	0.439003	0.322741	0.322741	0.380961	0.441743	0.359551	0.359551	0.312625	0.299727	0.311694	0.311483	0.380928	0.380928	0.380928	0.380928
Salomon 10D (51)	0.11625	0.113517	0.114355	0.1059	0.10985	0.119326	0.122243	0.11985	0.098964	0.093938	0.131175	0.104238	0.088666	0.108038	0.121179	0.096036
Salomon 30D (52)	0.424921	0.325445	0.29886	0.29886	0.280154	0.323069	0.281647	0.281647	0.45302	0.45302	0.45302	0.45302	0.673355	0.673355	0.673355	0.673355
Odd Square 10D (53)	0.050632	0.072049	0.08883	0.083557	0.048927	0.070415	0.06813	0.073195	0.058571	0.061665	0.077502	0.073041	0.067964	0.063261	0.072924	0.06787
Whitley 10D (54)	1974791	1689507	1927003	1970565	1733443	1835033	1676172	2027995	1596225	1488746	1559757	1310864	1595070	2253271	1586333	2162501
Whitley 30D (55)	1.58E+09	1.63E+09	1.66E+09	1.66E+09	1.56E+09	1.27E+09	1.45E+09	1.45E+09	1.38E+09	1.39E+09	1.38E+09	1.38E+09	1.42E+09	1.42E+09	1.42E+09	1.42E+09
Rana 10D (56)	270.0457	324.7485	174.0058	172.8288	339.6368	373.6113	342.7529	105.3346	352.4235	415.825	449.108	148.312	399.7777	434.3407	396.1101	203.2779
Rana 30D (57)	546.1197	1087.043	612.0489	612.0489	611.6564	769.8392	514.7955	514.7955	540.5837	683.5092	472.7576	431.2703	667.3334	636.8651	593.5733	368.732

Results St. Dev. (500k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.002871	0.003945	0.002871	0.002871	0.004553	0.003713	0.004553	0.004553	0.004685	0.001208	0.004685	0.004685	0.002983	0.000917	0.002983	0.002983
McCormic (2)	5.90E-06	8.14E-07	5.90E-06	5.90E-06	1.34E-06	1.51E-07	1.34E-06	1.34E-06	3.66E-07	3.33E-08	3.66E-07	3.66E-07	7.43E-08	9.52E-09	7.43E-08	7.43E-08
Box and Betts (3)	1.23E-08	6.30E-09	2.10E-08	2.13E-08	4.97E-09	2.15E-09	7.77E-09	1.03E-08	1.12E-09	5.76E-10	2.31E-09	3.92E-09	3.48E-09	1.08E-09	1.06E-09	1.79E-09
Goldstein (4)	0.000244	6.88E-05	0.000244	0.000244	9.38E-05	1.94E-05	9.38E-05	9.38E-05	1.97E-05	2.67E-06	1.97E-05	1.97E-05	4.47E-06	1.06E-06	4.47E-06	4.47E-06
Easom (5)	0.00645	0.01455	0.00645	0.00645	0.007625	0.001503	0.007625	0.007625	0.000285	8.50E-05	0.000285	0.000285	3.07E-05	0.000257	3.07E-05	3.07E-05
Mod Rosenbrock 1 (6)	0.074786	0.085947	0.074786	0.074786	0.091992	0.075905	0.091992	0.091992	0.080471	0.049886	0.080471	0.080471	0.048099	0.025863	0.048099	0.048099
Mod Rosenbrock 2 (7)	0.309255	0.357689	0.309255	0.309255	0.355769	0.34197	0.355769	0.355769	0.622092	0.593731	0.622092	0.622092	0.639715	0.424837	0.639715	0.639715
Bohachevsky (8)	0	0	0	0	0	0	0	0	1.119491	0	1.119491	1.119491	0	0	0	0
Powell (9)	270973.6	270973.6	95985.92	143595.2	302387.3	302387.3	95772.8	54877.05	287658.3	287658.3	198996.4	2752.072	138252	138252	268234.3	11290.45
Wood (10)	25545.09	25545.09	44759.11	104044.6	21480.46	21480.46	27496.77	34972.51	108426.3	108426.3	29662.48	12190.39	57658.3	57658.3	101083.7	2575.206
Beale (11)	0.173322	0.281931	0.173322	0.173322	0.19497	0.255994	0.19497	0.19497	2.245146	0.061279	2.245146	2.245146	0.046305	0.026522	0.046305	0.046305
Engvall (12)	1.138516	1.178383	1.138516	1.138516	1.174979	1.290473	1.174979	1.174979	1.361002	0.725809	1.361002	1.361002	0.466281	0.298993	0.466281	0.466281
DeJong (13)	0	3.81E-05	0	0	0	1.43E-05	0	0	1.19E-05	2.00E-06	1.19E-05	1.19E-05	2.41E-06	3.43E-07	2.41E-06	2.41E-06
Rastrigin (14)	0	0.008543	0	0	0	0.001954	0	0	0.001773	0.150494	0.001773	0.001773	0.024994	0.107389	0.024994	0.024994
Schwefel (15)	0.026615	0.031303	0.026615	0.026615	0.037551	0.020451	0.037551	0.037551	0.025722	0.021406	0.025722	0.025722	0.018008	0.010576	0.018008	0.018008
Griewangk (16)	0	0	0	0	0	0	0	0	0.003775	0	0.003775	0.003775	0	0	0	0
Ackley (17)	0.04536	0.049222	0.04536	0.04536	0.042703	0.043927	0.042703	0.042703	0.025769	0.004298	0.025769	0.025769	0.000729	0.003057	0.000729	0.000729
Langerman (18)	0.025808	0.021183	0.019533	0.032361	0.02619	0.028548	0.022307	0.025383	0.030097	0.030826	0.026746	0.021974	0.033742	0.030997	0.02926	0.02352
Michaelewicz (19)	0.30833	0.426714	0.434735	0.318477	0.251379	0.367821	0.361072	0.254249	0.414664	0.374297	0.375935	0.212407	0.352728	0.375398	0.361517	0.256043
Branin (20)	4.09E-05	4.30E-05	4.09E-05	4.09E-05	4.02E-05	7.63E-06	4.02E-05	4.02E-05	7.79E-06	1.21E-06	7.79E-06	7.79E-06	1.22E-06	2.08E-07	1.22E-06	1.22E-06
Six Hump Camel (21)	7.11E-06	2.61E-06	7.11E-06	7.11E-06	3.93E-06	4.81E-07	3.93E-06	3.93E-06	6.89E-07	6.92E-08	6.89E-07	6.89E-07	1.01E-07	1.99E-08	1.01E-07	1.01E-07
Osborne 1 (22)	0.008946	0.007717	0.00791	0.007447	0.00738	0.007561	0.009043	0.00736	0.007559	0.007416	0.009296	0.008591	0.008762	0.008331	0.008551	0.009297
Osborne 2 (23)	0.009907	0.01196	0.011056	0.01111	0.012036	0.011412	0.011324	0.014694	0.010181	0.01117	0.013261	0.011023	0.00994	0.009473	0.01	0.009471
Mod Rastrigin (24)	4.509093	4.359478	4.509093	4.509093	4.713608	3.899839	4.713608	4.713608	2.717603	5.953839	2.717603	2.717603	4.525594	4.690497	4.525594	4.525594
Mineshaft 1 (25)	0.331415	0.197057	0.206998	0.197057	0.219402	0.107694	0.150255	0.107694	0.076045	0.140912	0.10472	0.140912	0.059647	0.183781	0.076858	0.183781
Mineshaft 2 (26)	0.000191	0.055395	4.48E-06	0.055395	1.33E-06	0.05558	2.18E-08	0.05558	9.73E-06	0.036801	3.88E-10	0.036801	9.57E-09	0.06085	0.040123	0.06085
Mineshaft 3 (27)	0.169961	0.043347	0.169961	0.169961	0.023728	0.008041	0.023728	0.023728	0.004321	0.00048	0.004321	0.004321	0.000378	7.78E-05	0.000378	0.000378
Spherical Contours (28)	0.507731	0.513851	0.565897	0.565897	0.46157	0.58342	0.466689	0.466689	0.416601	0.416601	0.416601	0.416601	0.475357	0.475357	0.475357	0.475357
S1 (29)	1.01E-11	6.03E-10	8.91E-13	6.03E-10	2.61E-12	1.14E-14	1.75E-13	1.14E-14	1.79E-13	6.28E-06	2.26E-12	6.28E-06	7.94E-14	2.91E-05	2.43E-13	2.91E-05
S2 (30)	0	1.78E-09	0	0	3.08E-10	9.30E-10	3.08E-10	3.08E-10	7.35E-10	7.49E-11	7.35E-10	7.35E-10	1.04E-10	1.38E-11	1.04E-10	1.04E-10
S3 (31)	1.73E-05	2.66E-05	1.73E-05	1.73E-05	1.88E-05	2.07E-05	1.88E-05	1.88E-05	3.00E-05	7.26E-06	3.00E-05	3.00E-05	7.68E-06	2.69E-06	7.68E-06	7.68E-06
Downhill Step (32)	0	0	0	0	0	0	0	0	0.039799	0	0.039799	0.039799	0	0	0	0
Salomon (33)	0	0	0	0	0	0	0	0	0.018671	0	0.018671	0.018671	0	0.032567	0	0
Whitley (34)	0.201367	0.27588	0.201367	0.201367	0.287983	0.325329	0.287983	0.287983	0.228301	0.146256	0.228301	0.228301	0.050889	0.033605	0.050889	0.050889
Odd Square (35)	0.001196	0.001531	0.001196	0.001196	0.001272	0.001517	0.001272	0.001272	0.001354	0.003609	0.001354	0.001354	0.008794	0.047894	0.008794	0.008794
Storn Chebyshev (36)	1313.641	311.341	3898.649	615.9036	1496.109	128.9443	37.10956	834.1565	949.4005	693.1318	11.84859	1125.033	718.6482	1217.136	45.65408	827.3912
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	4.813627	1.71E-12	4.813627	4.813627	1.71E-12	1.71E-12	1.71E-12	1.71E-12
Rosenbrock 10D (38)	186.0309	207.8547	221.131	231.2546	178.8887	214.3152	228.5191	197.2512	173.592	179.9646	215.8666	183.3707	173.8143	178.839	194.0604	169.552
Rosenbrock 30D (39)	2315.556	1914.612	2440.065	2440.065	2482.7	2736.46	2403.248	2403.248	2637.014	2637.014	2637.014	2637.014	2585.243	2585.243	2585.243	2585.243
Mod Rosenbrock 1 10D (40)	88.9385	138.048	154.9755	152.8104	103.2908	139.0944	151.5032	120.1306	90.02063	107.8662	159.2196	113.9755	85.4283	84.2616	132.5182	105.6266
Mod Rosenbrock 1 30D (41)	413.9458	371.5997	366.9629	366.9629	364.9426	472.1319	365.565	365.565	366.1108	366.1108	366.1108	366.1108	373.7269	373.7269	373.7269	373.7269
Mod Rosenbrock 2 10D (42)	1.580329	0.35339	1.295859	1.24765	1.798267	0.280564	0.64416	1.260813	1.367449	0.779636	0.5378	1.291733	1.416137	1.117541	0.631377	1.285517
Mod Rosenbrock 2 30D (43)	3.189255	1.899724	2.707768	2.707768	3.265023	1.33275	2.764204	2.764204	3.250536	3.250536	3.250536	3.250536	3.561087	3.561087	3.561087	3.561087
Spherical Contours 10D (44)	0.105307	0.165185	0.204857	0.181045	0.112631	0.166264	0.197704	0.167706	0.109044	0.118406	0.168836	0.152586	0.113037	0.115452	0.163235	0.138118
Rastrigin 10D (45)	5.787411	5.358289	4.083043	4.36584	5.863421	5.318693	4.22498	4.470282	6.296628	4.997673	4.334661	4.870476	4.76843	4.974622	4.6523	4.945509
Rastrigin 30D (46)	11.84699	11.9145	12.981	12.981	11.04003	11.273	12.19564	12.19564	12.49263	12.49263	12.49263	12.49263	9.390574	9.390574	9.390574	9.390574
Schwefel 10D (47)	83.82031	102.4727	91.01066	123.4298	85.72526	112.2289	91.14551	122.2816	101.7289	91.63692	101.4346	109.9992	102.8388	110.5938	108.5171	117.4006
Schwefel 30D (48)	255.4313	345.7044	396.7284	396.7284	282.3158	373.2352	366.9573	366.9573	426.7822	567.9326	376.3481	297.5916	248.5979	248.5979	248.5979	248.5979
Griewangk 10D (49)	0.103055	0.191249	0.22073	0.207482	0.102033	0.199499	0.21696	0.155322	0.111234	0.137242	0.186176	0.129855	0.111558	0.109859	0.173454	0.138003
Griewangk 30D (50)	0.375629	0.433146	0.343289	0.343289	0.41994	0.477232	0.440559	0.440559	0.363393	0.363393	0.363393	0.363393	0.404966	0.404966	0.404966	0.404966
Salomon 10D (51)	0.133292	0.129189	0.138173	0.130678	0.112273	0.119484	0.119494	0.135615	0.107543	0.10914	0.14012	0.112802	0.112122	0.110588	0.109195	0.109456
Salomon 30D (52)	0.419429	0.424431	0.48411	0.48411	0.6816	0.6816	0.6816	0.6816	0.946258	0.946258	0.946258	0.946258	1.537085	1.537085	1.537085	1.537085
Odd Square 10D (53)	0.043962	0.075334	0.073103	0.076902	0.047602	0.071109	0.076011	0.068338	0.060306	0.053729	0.080523	0.073712	0.057613	0.057468	0.076151	0.064699
Whitley 10D (54)	3751131	2896202	3303232	3247748	2687152	2532396	2411923	2931035	2729435	2387982	2594970	2613078	3052711	2947417	3197551	2979094
Whitley 30D (55)	1.91E+09	2.04E+09	1.92E+09	1.92E+09	1.92E+09	2E+09	1.86E+09	1.86E+09	2.03E+09	2.03E+09	2.03E+09	2.03E+09	2.52E+09	2.52E+09	2.52E+09	2.52E+09
Rana 10D (56)	276.6442	333.7942	200.2541	193.0394	347.443	401.6331	354.036	119.4547	309.0401	429.4278	372.4965	162.9642	367.0623	466.613	373.1006	224.5529
Rana 30D (57)	610.4538	911.0715	555.9184	555.9184	636.1564	578.3394	561.0284	561.0284	570.7185	701.7923	433.9555	407.6243	292.7167	292.7167	292.7167	292.7167

Results St. Dev. (100k)	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.02976	0.024083	0.02976	0.02976	0.022974	0.021195	0.022974	0.022974	0.020493	0.011049	0.020493	0.020493	0.012931	0.005497	0.012931	0.012931
McCormic (2)	3.13E-05	5.33E-06	3.13E-05	3.13E-05	8.20E-06	1.01E-06	8.20E-06	8.20E-06	1.77E-06	4.05E-06	1.77E-06	1.77E-06	3.87E-07	0.00131	3.87E-07	3.87E-07
Box and Betts (3)	3.65E-08	2.04E-08	7.19E-08	8.62E-08	1.27E-08	1.33E-08	2.18E-08	3.98E-08	2.55E-06	3.28E-08	1.34E-08	2.25E-08	1.58E-07	4.20E-07	2.12E-06	5.12E-08
Goldstein (4)	0.002085	0.000278	0.002085	0.002085	0.000571	8.71E-05	0.000571	0.000571	0.00011	0.000126	0.00011	0.00011	0.280259	7.68E-05	0.280259	0.280259
Easom (5)	0.055782	0.093037	0.055782	0.055782	0.074297	0.055471	0.074297	0.074297	0.028414	0.010923	0.028414	0.028414	0.006936	0.024062	0.006936	0.006936
Mod Rosenbrock 1 (6)	0.208185	0.248503	0.208185	0.208185	0.228074	0.247319	0.228074	0.228074	0.189062	0.18505	0.189062	0.189062	0.188506	0.083809	0.188506	0.188506
Mod Rosenbrock 2 (7)	0.400902	0.615139	0.400902	0.400902	0.206056	0.809991	0.206056	0.206056	1.569938	1.087878	1.569938	1.569938	1.225984	0.811936	1.225984	1.225984
Bohachevsky (8)	0	0	0	0	0	0	0	0	8.747788	0.036258	8.747788	8.747788	3.006824	0.037544	3.006824	3.006824
Powell (9)	938585.2	938585.2	548133.3	398158.6	1003706	1003706	546102.2	258811.5	876975.7	876975.7	881781.6	116763.1	785596.1	785596.1	773200.3	785596.1
Wood (10)	258508.6	258508.6	232803.7	1209820	197381	197381	229422.8	87578.04	275888.9	275888.9	264694.9	114045.9	253432.5	253432.5	253432.5	251481.4
Beale (11)	0.909022	4.323421	0.909022	0.909022	3.601457	4.317251	3.601457	3.601457	14.1321	0.566432	14.1321	14.1321	0.827442	0.548008	0.827442	0.827442
Engvall (12)	0.9849	0.79324	0.9849	0.9849	0.693817	1.110293	0.693817	0.693817	81.39629	1.390137	81.39629	81.39629	38.17994	0.939318	38.17994	38.17994
DeJong (13)	0	0.000159	0	0	0	6.12E-05	0	0	4.76E-05	6.79E-06	4.76E-05	4.76E-05	1.60E-05	2.21E-06	1.60E-05	1.60E-05
Rastrigin (14)	0	0.047	0	0	0.010161	0.012061	0.010161	0.010161	0.140002	0.439586	0.140002	0.140002	0.268672	0.282458	0.268672	0.268672
Schwefel (15)	0.152712	0.208106	0.152712	0.152712	0.145261	0.140293	0.145261	0.145261	0.161676	0.147418	0.161676	0.161676	0.23564	0.179004	0.23564	0.23564
Griewangk (16)	0	0	0	0	0	0.002899	0	0	0.01645	0	0.01645	0.01645	0.012379	0.002013	0.012379	0.012379
Ackley (17)	0.110357	0.113169	0.110357	0.110357	0.102537	0.108517	0.102537	0.102537	0.097323	0.053025	0.097323	0.097323	0.045625	0.027432	0.045625	0.045625
Langerman (18)	0.081948	0.091212	0.062212	0.085795	0.078161	0.096395	0.073157	0.133196	0.088179	0.092458	0.087795	0.092722	0.124128	0.124128	0.124128	0.124128
Michaelewicz (19)	0.367571	0.572999	0.463941	0.323852	0.309551	0.468815	0.469116	0.332454	0.302737	0.302737	0.302737	0.302737	0.278512	0.278512	0.278512	0.278512
Branin (20)	0.000237	0.000149	0.000237	0.000237	0.000241	3.90E-05	0.000241	0.000241	3.43E-05	5.98E-06	3.43E-05	3.43E-05	8.93E-06	1.75E-06	8.93E-06	8.93E-06
Six Hump Camel (21)	4.22E-05	1.02E-05	4.22E-05	4.22E-05	1.54E-05	2.51E-06	1.54E-05	1.54E-05	2.98E-06	4.58E-07	2.98E-06	2.98E-06	4.90E-07	1.82E-07	4.90E-07	4.90E-07
Osborne 1 (22)	0.015107	0.016069	0.016487	0.016329	0.016891	0.019559	0.015675	0.017279	0.018187	0.018383	0.018705	0.017967	0.061544	0.061544	0.061544	0.061544
Osborne 2 (23)	0.016786	0.01817	0.018715	0.018772	0.02115	0.020491	0.020574	0.020462	0.018592	0.018592	0.018592	0.018592	0.021323	0.021323	0.021323	0.021323
Mod Rastrigin (24)	5.496776	3.923383	5.496776	5.496776	3.523375	3.540462	3.523375	3.523375	2.40692	5.959777	2.40692	2.40692	4.518048	4.135191	4.518048	4.518048
Mineshaft 1 (25)	0.327098	0.189307	0.193638	0.189307	0.200538	0.12306	0.133478	0.12306	0.065106	0.161471	0.098022	0.161471	0.080799	0.216105	0.131519	0.216105
Mineshaft 2 (26)	0.004736	0.076593	0.000283	0.076593	0.033547	0.085643	0.043263	0.085643	9.72E-06	0.142103	0.006119	0.142103	0.044691	0.143819	0.103563	0.143819
Mineshaft 3 (27)	0.485385	0.114655	0.485385	0.485385	0.089643	0.035878	0.089643	0.089643	0.014298	0.015531	0.014298	0.014298	0.003449	0.703688	0.003449	0.003449
Spherical Contours (28)	0.634097	0.634097	0.634097	0.634097	0.61913	0.61913	0.61913	0.61913	0.745879	0.745879	0.745879	0.745879	1.121056	1.121056	1.121056	1.121056
S1 (29)	3.15E-10	4.44E-06	6.59E-11	4.44E-06	6.60E-10	0.000555	8.62E-10	0.000555	2.21E-10	0.000833	2.79E-09	0.000833	5.92E-10	0.000275	3.26E-06	0.000275
S2 (30)	7.28E-09	4.55E-08	7.28E-09	7.28E-09	1.42E-08	2.21E-08	1.42E-08	1.42E-08	1.58E-08	4.70E-09	1.58E-08	1.58E-08	4.19E-09	1.61E-09	4.19E-09	4.19E-09
S3 (31)	0.00012	0.000142	0.00012	0.00012	0.000122	7.50E-05	0.000122	0.000122	7.09E-05	2.12E-05	7.09E-05	7.09E-05	2.53E-05	8.22E-06	2.53E-05	2.53E-05
Downhill Step (32)	0	0	0	0	0	0.059699	0	0	0.079869	0.070257	0.079869	0.079869	0.091493	0.136	0.091493	0.091493
Salomon (33)	0	0	0	0	0	0.013996	0	0	0.039908	0	0.039908	0.039908	0.028849	0.04404	0.028849	0.028849
Whitley (34)	0.562101	0.534164	0.562101	0.562101	0.549675	0.577484	0.549675	0.549675	0.625571	0.513191	0.625571	0.625571	0.48536	0.420175	0.48536	0.48536
Odd Square (35)	0.006212	0.005898	0.006212	0.006212	0.005658	0.015632	0.005658	0.005658	0.019574	0.058058	0.019574	0.019574	0.070165	0.101961	0.070165	0.070165
Storn Chebyshev (36)	4891.182	2072.02	5023.403	6637.171	5167.63	3390.438	1813.324	4249.807	5040.131	5040.131	5040.131	5040.131	4355.599	4355.599	4355.599	4355.599
Rana (37)	1.71E-12	1.71E-12	1.71E-12	1.71E-12	1.71E-12	2.531343	1.71E-12	1.71E-12	10.26132	4.29954	10.26132	10.26132	4.997838	2.507464	4.997838	4.997838
Rosenbrock 10D (38)	314.2113	363.5015	381.9863	348.5963	320.9108	313.7478	359.2991	322.9034	278.5185	278.5185	278.5185	278.5185	258.8279	258.8279	258.8279	258.8279
Rosenbrock 30D (39)	3200.956	3200.956	3200.956	3200.956	3305.561	3305.561	3305.561	3305.561	3566.943	3566.943	3566.943	3566.943	6323.958	6323.958	6323.958	6323.958
Mod Rosenbrock 1 10D (40)	133.5534	177.7896	208.2604	208.3699	103.775	165.0763	190.6193	147.7449	104.6836	104.6836	104.6836	104.6836	114.3402	114.3402	114.3402	114.3402
Mod Rosenbrock 1 30D (41)	461.5575	461.5575	461.5575	461.5575	424.7642	424.7642	424.7642	424.7642	1684.201	1684.201	1684.201	1684.201	766.7308	766.7308	766.7308	766.7308
Mod Rosenbrock 2 10D (42)	3.034502	1.50872	2.306903	2.44856	2.791013	1.645568	1.610476	2.533975	2.280365	2.280365	2.280365	2.280365	2.819627	2.819627	2.819627	2.819627
Mod Rosenbrock 2 30D (43)	7.42338	6.780266	6.780266	6.780266	6.916187	6.916187	6.916187	6.916187	6.277924	6.277924	6.277924	6.277924	6.414046	6.414046	6.414046	6.414046
Spherical Contours 10D (44)	0.163341	0.195671	0.271921	0.255999	0.144558	0.199633	0.268343	0.222713	0.157022	0.157022	0.157022	0.157022	0.170749	0.170749	0.170749	0.170749
Rastrigin 10D (45)	6.31617	6.116666	5.905702	6.986135	5.447586	5.875704	5.572089	5.944444	6.135906	6.135906	6.135906	6.135906	5.327044	5.327044	5.327044	5.327044
Rastrigin 30D (46)	13.65801	13.65801	13.65801	13.65801	12.97823	12.97823	12.97823	12.97823	14.22287	14.22287	14.22287	14.22287	13.36935	13.36935	13.36935	13.36935
Schwefel 10D (47)	110.7594	144.3073	146.5535	170.2008	126.4321	164.6917	145.0204	158.1528	124.7879	124.7879	124.7879	124.7879	130.9228	130.9228	130.9228	130.9228
Schwefel 30D (48)	677.0864	541.7205	437.6374	437.6374	329.0539	329.0539	329.0539	329.0539	241.0282	241.0282	241.0282	241.0282	246.4223	246.4223	246.4223	246.4223
Griewangk 10D (49)	0.155218	0.215932	0.261437	0.244016	0.14047	0.187629	0.252551	0.2072	0.139674	0.139674	0.139674	0.139674	0.13161	0.13161	0.13161	0.13161
Griewangk 30D (50)	0.433366	0.433366	0.433366	0.433366	0.494363	0.494363	0.494363	0.494363	0.550467	0.550467	0.550467	0.550467	0.762799	0.762799	0.762799	0.762799
Salomon 10D (51)	0.143336	0.154527	0.166677	0.153749	0.15046	0.154028	0.156942	0.143285	0.130508	0.130508	0.130508	0.130508	0.173484	0.173484	0.173484	0.173484
Salomon 30D (52)	1.538881	1.538881	1.538881	1.538881	2.032719	2.032719	2.032719	2.032719	1.820409	1.820409	1.820409	1.820409	1.532779	1.532779	1.532779	1.532779
Odd Square 10D (53)	0.039306	0.055402	0.063176	0.063708	0.037807	0.055485	0.072758	0.061031	0.032053	0.032053	0.032053	0.032053	0.040724	0.040724	0.040724	0.040724
Whitley 10D (54)	10313952	12380847	11757820	10346131	8639041	7433516	8064585	8841941	9650838	9650838	9650838	9650838	8064770	8064770	8064770	8064770
Whitley 30D (55)	3.67E+09	3.67E+09	3.67E+09	3.67E+09	4.24E+09	4.24E+09	4.24E+09	4.24E+09	1.11E+10	1.11E+10	1.11E+10	1.11E+10	5.97E+10	5.97E+10	5.97E+10	5.97E+10
Rana 10D (56)	328.7087	261.3182	250.6862	222.3593	291.8306	336.3998	223.7605	157.7117	149.2647	149.2647	149.2647	149.2647	120	120	120	120
Rana 30D (57)	552.055	513.9056	428.9303	428.9303	339.6151	339.6151	339.6151	339.6151	357.0768	357.0768	357.0768	357.0768	319.5346	319.5346	319.5346	319.5346

APPENDIX G3: AVG. RUNTIMES FOR SMOA-HTDER

Average Times (s) for 1M	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	10.23634	8.541231	9.772463	9.05821	9.185232	7.530018	8.940131	9.762379	1.671029	1.483972	2.969924	3.023995	4.988651	5.123014	7.001314	5.867207
McCormic (2)	7.552181	7.177687	7.656273	7.652289	7.997134	7.055322	7.993776	7.521024	1.602836	1.394708	2.53453	3.116816	5.458351	4.61868	6.608141	5.089843
Box and Betts (3)	16.38615	16.26442	16.47222	15.81683	17.00464	17.17368	17.20496	18.13622	13.62016	14.43256	18.1814	19.3468	20.31954	19.87561	23.92976	25.21793
Goldstein (4)	8.22163	4.802275	8.514997	7.214019	8.200602	4.374407	8.069923	8.128547	1.943318	2.01472	3.232311	3.604539	4.696341	4.294573	5.438686	4.832337
Easom (5)	8.559842	7.207722	9.175134	8.827854	8.623471	7.349871	8.88225	8.619746	2.258562	2.443559	3.637247	4.259028	6.09332	6.001871	5.374163	4.941075
Mod Rosenbrock 1 (6)	9.84578	7.572031	9.2536	9.791123	9.491313	7.761319	9.460825	9.528188	2.78302	2.427915	4.134818	6.249691	7.924146	6.28336	5.675494	5.523286
Mod Rosenbrock 2 (7)	9.689185	7.886992	9.252569	8.989508	9.79722	8.306341	9.494578	9.2284	3.001859	2.405195	4.638446	5.317305	6.103057	5.817739	6.263978	5.281064
Bohachevsky (8)	8.310447	7.427258	9.372907	8.790315	8.449584	7.624338	9.0316	8.772778	3.070875	2.484198	6.246053	4.688635	6.732818	5.900215	5.822248	5.56016
Powell (9)	10.63264	11.43401	12.13494	16.82622	13.32679	13.91439	13.98938	18.39103	6.773233	7.272038	12.19614	12.63093	11.6695	11.76154	15.33825	17.46057
Wood (10)	13.92722	13.52487	16.27641	23.94797	16.98707	16.96837	18.20531	25.25894	9.796874	10.76071	15.14113	21.56879	15.59582	15.16445	20.64837	24.58746
Beale (11)	8.444471	7.00713	9.454671	8.591092	9.415475	7.348712	8.56288	8.957323	3.86326	3.550852	6.500004	6.031567	5.889986	5.271985	6.612158	7.063153
Engvall (12)	8.968494	8.068739	9.940247	9.888934	9.457978	7.5854	8.978848	9.972254	4.427637	3.992651	7.718733	6.90796	6.508629	5.892431	7.041122	7.148618
DeJong (13)	8.190638	7.103102	8.55535	8.460095	8.66944	6.533102	8.645103	9.023895	3.622877	3.065189	5.668636	4.978514	4.628034	4.308152	6.611015	6.262864
Rastrigin (14)	8.633603	7.998708	8.185226	8.417776	8.539731	8.053342	8.372715	7.826941	3.79763	3.255443	6.556424	6.110776	5.479957	4.813933	6.670585	6.617366
Schwefel (15)	8.992865	7.231042	8.118934	7.727953	8.440661	7.147054	8.274417	7.084172	3.888206	3.543908	5.559203	5.66386	5.638687	4.854023	6.440433	5.437769
Griewangk (16)	8.764183	7.610222	7.985585	7.320331	8.138359	7.197372	8.591415	6.392167	3.882694	3.699553	5.302678	5.3102	5.215162	5.035515	6.689991	5.03685
Ackley (17)	8.757181	8.151143	8.092748	6.859955	7.590091	7.607923	7.559128	6.44348	4.525183	5.206434	6.119086	5.840129	5.769663	5.882054	7.443683	5.182192
Langerman (18)	10.78317	13.92711	12.23732	13.22709	12.18139	15.91319	14.20558	16.9162	14.58453	14.52181	17.55077	21.11712	14.90141	16.34493	17.84552	14.05274
Michaelewicz (19)	14.97587	17.93247	16.63767	16.44236	16.162	18.27468	18.89588	19.99287	24.26595	21.28812	22.2529	36.91577	34.15269	34.48907	19.31823	35.42196
Branin (20)	4.088819	4.49665	3.997116	4.423382	4.077499	3.866506	4.544724	2.770112	6.686242	5.673167	5.480999	6.454077	6.187773	5.310666	2.766737	2.322383
Six Hump Camel (21)	4.174879	4.30835	4.75831	3.866186	4.75028	3.600213	3.815974	2.854259	7.475303	5.872895	5.321276	6.244791	5.656096	5.798517	3.121478	2.334878
Osborne 1 (22)	22.67865	24.27791	22.16367	21.79848	21.84212	24.6015	21.98183	22.79879	29.07711	29.37265	32.3612	36.81063	25.09022	26.60175	25.30636	27.97609
Osborne 2 (23)	42.05641	44.95473	45.08638	45.5986	43.22533	44.91383	48.59859	51.92121	58.07964	54.33554	55.7692	57.79783	52.77816	52.48006	52.52227	59.01802
Mod Rastrigin (24)	4.261749	2.654899	5.980029	7.252926	5.921605	4.37453	8.171478	7.296579	8.46649	5.826705	4.533215	3.893208	4.277788	3.274251	2.732622	2.541914
Mineshaft 1 (25)	3.959698	2.05161	5.059203	5.486886	5.711331	3.317165	5.329754	5.475001	5.957176	8.29825	4.076417	4.862394	5.186815	6.732942	4.289084	4.222108
Mineshaft 2 (26)	3.724058	1.105602	4.877822	3.576219	6.139616	2.009976	4.8159	4.330327	5.776331	6.569651	2.490077	3.131936	3.750231	3.64529	1.765903	1.70354
Mineshaft 3 (27)	4.634297	2.027282	6.250303	5.582752	5.751468	2.884993	6.749632	5.88495	5.530969	5.227161	2.579909	2.905721	3.462309	3.017912	1.754034	1.69587
Spherical Contours (28)	3.55069	2.517573	4.389529	4.587355	4.685964	3.734926	6.285145	5.464314	3.5739	3.86773	2.385597	3.048951	2.340394	2.180995	1.386744	1.5412
S1 (29)	5.366349	1.746706	4.457371	4.614805	6.033748	3.606616	4.613214	4.615175	4.658584	5.356363	2.156447	3.106504	3.234181	3.057187	1.405129	1.258057
S2 (30)	6.109624	2.131365	6.006861	5.677459	5.51662	4.269461	4.825176	3.735827	5.034909	3.992191	2.07498	2.733739	2.654325	2.084132	1.392405	1.304919
S3 (31)	6.013013	2.53786	5.858197	5.110456	6.129842	5.426276	5.454139	4.516646	6.149035	4.977569	2.489573	3.47115	3.1938	2.72365	1.689064	1.572327
Downhill Step (32)	6.072929	3.578028	5.060467	5.782818	5.771411	4.574396	4.586398	3.439254	5.550712	4.772938	2.438078	3.235122	3.359053	2.983049	1.896854	1.766137
Salomon (33)	6.98981	4.076352	5.922926	4.859181	5.902918	5.522639	4.727786	2.182801	4.838394	4.81128	2.553211	3.566369	3.333277	3.210308	1.963454	1.821743
Whitley (34)	7.110877	5.911237	5.643777	5.153729	5.292571	5.928243	4.029687	2.448346	5.199576	4.728521	3.072225	4.013285	2.904219	3.450418	2.352294	2.211728
Odd Square (35)	7.093775	7.892204	5.575024	4.500643	5.713313	7.283218	2.800854	2.161983	4.82444	5.227199	3.629384	4.353261	2.892053	2.845138	2.776423	2.593289
Storn Chebyshev (36)	586.7392	610.0558	612.6379	611.0844	585.4496	607.3091	615.303	615.6072	616.9281	607.9305	625.1054	632.5013	620.3544	630.2224	632.5493	655.297
Rana (37)	2.620998	2.138217	4.724226	5.295413	4.01085	2.84208	5.403179	6.14782	3.078542	2.371811	3.805909	4.989284	3.919986	4.907167	5.582344	5.653969
Rosenbrock 10D (38)	2.099481	2.25688	6.033148	6.237803	3.923616	4.460589	10.30565	12.2804	6.844273	4.568549	7.668434	22.90444	15.14674	16.41106	11.32958	33.22776
Rosenbrock 30D (39)	1.928052	1.883063	3.980833	4.396384	2.817269	2.933333	5.432755	5.36535	2.450439	2.168015	3.537592	4.623198	2.899962	2.777456	2.52043	2.880537
Mod Rosenbrock 1 10D (40)	6.520705	4.992687	11.24564	11.12396	7.391312	7.446127	13.11161	14.62334	10.63114	8.125317	10.15404	24.17196	19.71581	18.61349	15.63996	36.51663
Mod Rosenbrock 1 30D (41)	9.61987	9.180409	12.14911	12.02471	10.0195	9.784274	12.4787	12.0051	9.331732	9.824197	10.97837	12.0506	9.993001	9.930527	9.293742	10.44494
Mod Rosenbrock 2 10D (42)	5.592112	6.46357	9.666435	9.448349	8.96286	7.311899	10.54377	12.67	10.3099	8.32662	9.110703	21.38829	16.58523	16.42864	15.8585	39.45492
Mod Rosenbrock 2 30D (43)	9.149719	9.850359	11.54084	11.4823	12.38379	11.71165	13.08784	13.15063	10.91636	9.667127	12.061	15.17256	9.451161	9.853706	10.46211	10.36862
Spherical Contours 10D (44)	4.153441	3.143665	5.530575	5.971101	6.886062	7.57549	7.709497	8.56341	9.061522	5.40992	10.10202	22.43545	13.85752	15.52659	13.27172	28.36359
Rastrigin 10D (45)	5.753518	3.877844	7.177237	7.003896	8.319675	8.042029	8.406504	9.568331	11.06588	6.860355	11.37686	23.22484	16.63279	15.7772	14.13548	26.7914
Rastrigin 30D (46)	6.023349	4.736244	6.019811	6.169537	7.06686	6.813009	6.893138	6.885648	6.449832	5.316549	8.445136	9.116997	5.06946	5.216315	5.026483	4.296385
Schwefel 10D (47)	7.600958	6.500207	7.549634	7.344805	7.475923	8.61447	8.158719	9.576344	10.84558	8.331207	12.0235	23.57413	18.66963	20.17637	18.90574	25.31854
Schwefel 30D (48)	7.060871	7.090447	7.121759	7.056542	6.869109	7.073151	8.480923	7.469733	9.306261	8.337795	11.49252	17.23141	12.62595	12.69934	13.35459	17.84239
Griewangk 10D (49)	6.920863	8.19243	6.759693	6.766242	8.388798	7.049837	7.270429	8.774544	9.509786	8.981051	10.90796	23.71528	18.40625	16.66778	15.91753	20.17881
Griewangk 30D (50)	7.594399	8.005341	6.9279	6.964759	7.603811	7.832896	6.990355	6.863255	7.855264	6.649131	7.195589	8.431846	6.285464	6.423711	7.010242	5.714298
Salomon 10D (51)	4.197111	5.514641	4.815449	4.799219	5.576484	5.328785	5.262234	5.251784	12.57706	5.883342	7.601922	16.98989	13.03466	13.58815	13.97439	18.91423
Salomon 30D (52)	2.251625	3.11319	2.590337	2.704579	2.635439	2.145805	1.88674	1.581788	2.048002	1.468449	2.018145	1.808344	2.188439	2.428979	2.865362	2.04108
Odd Square 10D (53)	4.05104	6.472211	5.914468	5.676467	5.688078	6.717204	5.34459	6.339936	12.57738	7.064169	10.88531	20.261	19.56788	20.3713	13.71833	24.42746
Whitley 10D (54)	24.79297	25.5771	22.89985	22.81975	25.15665	25.44975	22.65278	22.68905	32.31505	27.42647	30.11556	34.34869	35.62896	33.52277	30.16625	45.87428
Whitley 30D (55)	114.5723	116.4813	113.8071	114.0391	112.4868	112.8098	116.9141	118.8888	121.5321	121.8418	121.4727	114.4879	119.6342	119.4002	119.2879	114.9654
Rana 10D (56)	6.835226	7.189466	10.82104	10.63455	9.953333	9.509323	16.06183	16.8634	20.99143	16.60581	14.44034	24.67378	15.70826	17.9187	17.19141	22.11757
Rana 30D (57)	12.01837	12.22096	15.32612	15.50987	14.10427	14.12275	18.83144	20.01393	19.27209	17.68199	19.10183	19.65746	20.99188	19.50787	21.21394	29.5739

Average Times (s) for 500k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	1.759337	1.235251	1.195356	1.050026	1.236654	1.269087	0.8118	1.106542	1.21668	0.627695	0.787474	0.803457	0.935855	1.195621	0.934438	0.869775
McCormic (2)	1.513775	1.108393	1.085181	1.054362	1.322385	1.12971	0.742025	0.78128	0.882406	0.595248	0.734106	0.749879	0.806012	1.025323	0.815172	0.796783
Box and Betts (3)	8.36096	7.506157	6.688479	6.852369	7.327535	7.355234	6.29771	6.272084	6.975245	6.222187	7.770662	7.274946	7.297813	7.938322	7.008238	7.392686
Goldstein (4)	2.117543	1.065444	1.011272	1.353129	1.198235	1.107162	0.97985	0.686717	0.708259	0.55538	0.978853	0.772592	1.03201	1.035255	0.694427	0.838672
Easom (5)	2.266909	1.227277	1.170747	1.192008	1.584757	1.331429	1.155387	0.845848	0.885041	0.760562	1.083248	0.91299	1.540348	1.269773	0.994281	1.208664
Mod Rosenbrock 1 (6)	2.193529	1.418084	1.298853	1.199524	1.538533	1.557819	1.321142	0.940444	1.03497	0.780738	1.058858	1.058665	1.323456	1.351645	1.044939	1.331787
Mod Rosenbrock 2 (7)	2.341432	1.384081	1.230644	1.211511	1.499768	1.533417	1.512972	0.945559	1.173839	0.781823	1.215496	1.34811	1.292353	1.412653	1.053668	1.292169
Bohachevsky (8)	2.439031	1.356739	1.201427	1.244604	1.455877	1.49765	1.557414	0.972153	1.068159	0.853866	1.340471	1.680719	1.361677	1.526496	1.110041	1.365333
Powell (9)	3.813794	2.502434	2.11597	2.940867	2.429482	3.101439	3.085615	2.403878	2.55973	2.246704	4.098147	3.688977	2.847735	3.255027	3.199171	3.847794
Wood (10)	4.825664	3.232761	2.5787	4.890341	3.755475	3.744891	3.723923	3.630034	3.262507	2.884624	5.388843	4.706099	4.106766	4.22211	4.643367	4.832431
Beale (11)	2.557746	1.523231	1.208091	1.526647	1.958584	1.368076	1.497948	1.291234	1.010823	0.860575	2.023657	1.696136	1.749282	1.412807	1.458709	1.14725
Engvall (12)	2.913407	1.759988	1.516541	1.663927	2.147283	1.656665	1.876292	1.50914	1.480541	1.129502	2.295839	1.992672	2.086532	1.662281	1.8293	1.664803
DeJong (13)	2.29435	1.216756	1.215756	1.210661	1.633375	1.221882	1.433721	1.020745	0.928621	0.668672	1.639195	1.473152	1.36021	1.12385	1.280262	1.029265
Rastrigin (14)	2.072832	1.34746	1.183832	1.444067	1.631714	1.698483	1.467045	0.992241	1.206314	0.72979	1.576364	1.689849	1.40652	1.136213	1.842664	1.175765
Schwefel (15)	1.950744	1.316383	1.348515	1.671462	1.611918	1.405322	1.396484	0.965665	1.199312	0.923824	1.43362	1.48958	1.656067	1.163342	1.848932	1.072505
Griewangk (16)	2.0807	1.324158	1.545788	1.829724	1.648718	1.204681	1.19764	0.919766	0.963884	0.992135	1.51918	1.466155	1.619904	1.136232	2.154231	1.019619
Ackley (17)	2.331443	1.56018	1.762211	2.00825	1.78723	1.432155	1.390719	1.106919	1.097483	1.172998	1.558139	1.758182	1.795241	1.40165	2.686803	1.465742
Langerman (18)	3.629895	3.287335	3.479843	4.598447	3.850067	3.570183	2.771502	4.09447	3.120384	3.322028	4.653163	6.303779	4.363553	4.251625	7.287351	5.375124
Michaelewicz (19)	5.92777	6.415566	6.197116	6.98467	6.494776	5.882315	5.579479	6.95083	6.778138	6.736944	8.041132	11.84851	8.590802	8.243812	8.208646	10.11461
Branin (20)	1.331786	1.386231	0.91958	1.712341	1.460265	0.777024	0.794013	1.056066	0.784218	0.653918	1.37527	0.962994	1.076996	0.959718	0.933157	0.821618
Six Hump Camel (21)	1.619172	1.430763	1.017503	1.730333	1.323764	0.86465	0.847848	0.984772	0.863287	0.747068	1.333519	1.091616	1.191882	1.087616	1.045054	0.855909
Osborne 1 (22)	10.4634	10.01014	9.041497	10.60807	9.18745	8.977015	8.680294	10.18148	8.727199	8.797594	10.35227	11.70724	10.44773	10.0882	10.26436	10.39091
Osborne 2 (23)	22.30535	22.2588	21.4865	21.00234	20.46762	21.91176	20.88316	21.70545	22.11658	21.96535	22.08515	25.29181	22.20003	22.76138	21.92752	23.61922
Mod Rastrigin (24)	1.987945	1.856646	1.261648	1.247969	1.8322	2.272124	1.172406	1.321309	1.897117	1.483394	1.594886	2.451894	1.707043	2.048117	1.515623	1.710948
Mineshaft 1 (25)	1.748072	1.443091	0.966689	0.968451	1.603418	1.508165	0.959856	1.164698	1.300567	2.828873	1.530812	3.225422	2.45128	3.883741	2.213051	3.016814
Mineshaft 2 (26)	1.288623	0.825279	0.552274	0.589273	1.193124	0.908895	0.522269	0.64079	0.721281	1.807547	0.73616	2.351255	1.309615	2.5862	0.904204	1.336843
Mineshaft 3 (27)	1.403379	1.007934	0.855211	1.178855	1.299154	1.075006	0.766436	0.962047	0.830996	1.330565	0.806986	1.993293	1.120499	1.6581	0.851826	0.892482
Spherical Contours (28)	1.065484	1.046003	0.949372	1.075923	1.078052	1.136802	0.938925	1.100875	0.604772	0.880073	0.617173	1.179396	1.143871	1.553961	0.912927	1.187422
S1 (29)	1.142036	0.728586	0.569894	0.657596	1.138091	1.039202	0.492132	0.641987	0.695847	1.129533	0.888041	1.947044	1.498412	1.92106	0.668141	0.664988
S2 (30)	1.41157	0.826945	0.802315	1.126389	1.27865	0.940838	0.668847	0.880939	0.683442	0.874321	0.89578	1.74603	1.22914	0.940114	0.639919	0.773205
S3 (31)	1.448653	0.884828	0.9613	1.245557	1.271328	1.01808	0.757941	1.109993	0.811668	1.346733	0.960336	1.54412	1.447162	1.273465	0.785324	0.973665
Downhill Step (32)	1.191872	0.85184	1.109923	1.322105	1.339321	0.82865	0.769174	0.915248	0.921124	1.537086	1.049744	1.46712	1.966963	1.224222	0.872348	1.077198
Salomon (33)	1.195204	0.847143	1.215054	1.471172	1.463957	0.971379	0.814501	0.911698	0.92769	1.617309	1.049005	1.460619	2.23972	1.285185	0.960057	1.009533
Whitley (34)	1.452456	1.094853	1.4662	1.5753	1.6669	1.130952	1.007192	1.188209	1.186897	1.773373	1.114554	1.672442	2.475298	1.586791	1.181124	1.238567
Odd Square (35)	1.555113	1.146033	1.829044	1.994717	1.92561	1.003617	1.066504	1.525272	1.307296	1.811784	1.191711	1.903354	3.094499	1.408592	1.344121	1.458498
Storn Chebyshev (36)	307.3451	314.725	314.8678	310.7326	301.5497	312.1171	316.2755	319.0608	321.7436	316.7832	323.6237	321.9502	323.9373	325.2715	329.9746	333.2755
Rana (37)	1.296482	1.457153	1.240989	1.765235	1.49963	2.082652	1.294627	2.727152	1.232819	1.494316	1.408113	1.645845	1.580749	1.902731	2.400871	1.454314
Rosenbrock 10D (38)	1.058028	1.522929	1.400892	2.035806	2.001041	2.442068	1.961805	4.949233	2.632216	2.472459	2.763895	7.565633	3.980996	4.257244	4.448481	7.3259
Rosenbrock 30D (39)	0.919875	1.143246	1.012163	1.266288	1.282511	1.463375	1.171246	1.967272	0.695657	0.785788	0.793458	0.960724	1.18505	1.301911	1.503931	1.30639
Mod Rosenbrock 1 10D (40)	2.555134	3.047732	2.93507	3.494698	3.468066	4.419002	3.346299	5.811128	4.037544	3.728835	4.103515	8.959584	6.64377	6.171464	6.08984	8.578491
Mod Rosenbrock 1 30D (41)	4.208142	4.349194	4.472156	4.758063	4.676343	5.029607	4.385777	4.775028	3.860132	4.160475	4.082914	4.290893	5.241219	5.2234	5.673161	5.219465
Mod Rosenbrock 2 10D (42)	2.300725	2.655358	3.086819	3.975497	3.450993	3.424087	3.118221	4.207708	3.779617	3.671748	4.120133	9.259114	5.926783	6.363221	6.088251	7.985352
Mod Rosenbrock 2 30D (43)	4.299525	4.439218	4.865459	5.335992	5.312806	4.920392	5.228756	5.097383	4.027201	4.237081	4.239687	4.554476	4.851266	5.099243	4.915172	4.670251
Spherical Contours 10D (44)	0.981777	1.169672	1.77182	2.737914	2.730925	1.997011	2.288299	2.465845	2.5935	2.708349	2.734767	7.427421	4.969622	3.683413	3.835522	7.405264
Rastrigin 10D (45)	1.573704	1.931472	2.055981	3.236005	3.417754	2.47818	2.985156	3.045917	3.215274	3.362419	3.714601	8.153348	5.209948	5.354544	4.186088	7.383084
Rastrigin 30D (46)	2.024234	2.165457	2.214869	2.571549	2.664348	2.450986	2.311635	2.232966	1.675312	1.952547	2.007325	2.108885	2.547483	2.550741	2.487716	2.65644
Schwefel 10D (47)	1.742545	1.941966	2.409713	2.998681	3.223273	3.036132	2.48283	3.264675	3.520105	4.246537	4.103684	9.336187	5.18112	6.232514	5.11055	6.973236
Schwefel 30D (48)	2.435187	2.482456	2.941154	3.061495	2.967439	2.865627	3.011251	3.017179	3.469273	3.604057	4.286439	6.013613	3.06195	3.093639	3.025826	2.812103
Griewangk 10D (49)	1.74635	1.882225	2.580195	3.030544	3.124242	2.415613	2.555983	3.185454	3.410902	3.713528	3.080313	9.15137	6.147724	6.628736	4.19258	6.96332
Griewangk 30D (50)	2.499156	2.545728	2.8499	3.085396	3.058614	2.770501	2.732471	2.775042	2.288883	2.620062	2.313394	2.918723	3.32293	3.718565	3.130894	3.235597
Salomon 10D (51)	1.25889	1.084902	1.650053	2.193791	1.728411	1.527934	1.739164	2.371035	2.299981	2.414701	1.971848	5.060459	4.284136	3.788124	2.232183	5.016346
Salomon 30D (52)	0.635925	0.591689	0.675211	0.926581	0.727663	0.560682	0.48281	0.500859	0.511912	0.676892	0.646461	0.639013	1.287677	1.058307	0.814074	1.217259
Odd Square 10D (53)	1.186897	1.393822	2.327983	2.643613	2.524893	1.914265	2.100714	3.18489	3.244291	2.735037	3.064313	7.764438	5.081461	4.782115	2.692037	7.536524
Whitley 10D (54)	9.954562	9.8152	10.58589	11.09159	11.08936	10.35975	10.89928	12.17792	12.27239	11.24631	11.35819	16.12947	15.76757	14.91856	12.26419	15.11471
Whitley 30D (55)	54.68127	55.6523	55.5832	55.60702	55.41578	55.19865	57.34775	55.52393	58.1931	58.11413	56.2366	57.21192	61.9124	61.55138	61.15555	60.10454
Rana 10D (56)	3.553663	3.59188	3.789917	4.071545	3.921007	4.258315	5.342481	5.920364	5.99907	5.671105	5.092205	8.270549	5.176431	6.165998	6.351174	8.529309
Rana 30D (57)	6.245229	6.076288	6.262245	6.498102	6.218494	6.485881	7.177246	7.224393	8.412449	7.567744	8.248132	10.42224	6.83027	7.108355	7.073558	6.806311

Average Times (s) for 100k	A50, N1	A50, N2	A50, N3	A50, N4	A100, N1	A100, N2	A100, N3	A100, N4	A250, N1	A250, N2	A250, N3	A250, N4	A500, N1	A500, N2	A500, N3	A500, N4
Rosenbrock (1)	0.163246	0.13237	0.152536	0.15124	0.274131	0.205077	0.189852	0.168855	0.180893	0.128916	0.168463	0.201751	0.19245	0.130439	0.176861	0.174744
McCormic (2)	0.151043	0.118464	0.142464	0.139955	0.241696	0.17727	0.167668	0.150616	0.129572	0.106413	0.116414	0.13737	0.163655	0.208688	0.146079	0.14666
Box and Betts (3)	1.307282	1.232332	1.183077	1.119391	1.501907	1.550808	1.377033	1.305814	1.513034	1.545289	1.494395	1.440441	1.739677	1.948843	1.764515	1.686461
Goldstein (4)	0.171534	0.10772	0.137871	0.138545	0.192201	0.172195	0.159543	0.139169	0.113342	0.098197	0.109588	0.097734	0.12978	0.170466	0.147518	0.148875
Easom (5)	0.198456	0.140982	0.156906	0.158952	0.226572	0.254388	0.19619	0.170235	0.19988	0.150373	0.218219	0.17468	0.228113	0.173248	0.229903	0.231123
Mod Rosenbrock 1 (6)	0.229708	0.158813	0.180457	0.17917	0.224291	0.2844	0.271966	0.194385	0.215734	0.151484	0.235218	0.186172	0.22627	0.136131	0.219141	0.218631
Mod Rosenbrock 2 (7)	0.234358	0.159324	0.182146	0.179162	0.22541	0.269072	0.25371	0.196306	0.217247	0.152549	0.220506	0.187388	0.211318	0.181891	0.216907	0.217321
Bohachevsky (8)	0.2388	0.158521	0.186458	0.183026	0.222564	0.314381	0.231203	0.195322	0.225137	0.17829	0.217723	0.196352	0.245421	0.25439	0.257467	0.258344
Powell (9)	0.375296	0.300406	0.324036	0.411561	0.37973	0.613549	0.44069	0.454344	0.397033	0.376847	0.513001	0.472729	0.274039	0.297485	0.295808	0.313854
Wood (10)	0.436058	0.348597	0.388205	0.530662	0.458918	0.740233	0.646724	0.580097	0.41995	0.421103	0.581579	0.564345	0.37174	0.398346	0.375946	0.435537
Beale (11)	0.238267	0.156979	0.186316	0.186544	0.212627	0.308291	0.323007	0.193543	0.184062	0.166537	0.208605	0.183523	0.21232	0.214859	0.237769	0.278292
Engvall (12)	0.303434	0.21133	0.242914	0.243127	0.275224	0.368864	0.360726	0.252895	0.251229	0.265317	0.334301	0.244445	0.285662	0.288886	0.328617	0.347936
DeJong (13)	0.211721	0.132881	0.1685	0.169056	0.187483	0.255459	0.25341	0.171081	0.182553	0.147619	0.192563	0.134821	0.114036	0.137446	0.133988	0.132784
Rastrigin (14)	0.20636	0.141999	0.161683	0.164293	0.181455	0.301017	0.244253	0.169204	0.225853	0.18556	0.230192	0.155614	0.17744	0.186152	0.205247	0.203156
Schwefel (15)	0.213718	0.142231	0.168308	0.168546	0.196432	0.227957	0.241046	0.186783	0.2486	0.200158	0.23907	0.172203	0.243025	0.187374	0.247291	0.245779
Griewangk (16)	0.205834	0.143449	0.175431	0.214805	0.196347	0.227219	0.236371	0.190445	0.21907	0.223531	0.18973	0.169509	0.233453	0.176179	0.239375	0.253444
Ackley (17)	0.225763	0.178928	0.212142	0.248121	0.239478	0.274026	0.280422	0.228604	0.255617	0.263986	0.237734	0.210802	0.273474	0.20411	0.290411	0.304638
Langerman (18)	0.433771	0.411807	0.46328	0.597154	0.508588	0.630175	0.666629	0.702472	0.527263	0.625013	0.635159	0.635756	0.394248	0.404735	0.458255	0.498405
Michaelewicz (19)	0.978397	0.979951	1.02411	1.093636	1.116478	1.183244	1.197308	1.184881	1.021131	1.078068	1.056449	1.06056	1.361887	1.264733	1.319926	1.497474
Branin (20)	0.172281	0.129102	0.155036	0.216011	0.237791	0.195812	0.257054	0.173069	0.156013	0.131201	0.145923	0.160244	0.187937	0.15631	0.119148	0.166299
Six Hump Camel (21)	0.19112	0.142087	0.172357	0.238745	0.332324	0.217952	0.2598	0.187036	0.158616	0.154312	0.153961	0.172911	0.215069	0.216697	0.150735	0.203502
Osborne 1 (22)	1.730999	1.658904	1.773545	2.006386	2.163278	1.925677	1.994373	1.927908	1.898309	1.882988	2.030844	2.125796	2.109446	1.930227	2.07199	2.186421
Osborne 2 (23)	4.24362	4.036303	4.205052	4.452542	4.508571	4.342332	4.34686	4.068225	4.658067	4.614966	4.706913	4.729609	5.46312	5.504866	5.754682	5.808963
Mod Rastrigin (24)	0.318143	0.217716	0.246378	0.370199	0.372413	0.409763	0.277145	0.234625	0.363285	0.212051	0.347954	0.307147	0.233589	0.229265	0.325868	0.304916
Mineshaft 1 (25)	0.290665	0.236103	0.200908	0.35258	0.318276	0.514826	0.230018	0.343787	0.393225	0.462894	0.500911	0.487235	0.43886	0.448403	0.603397	0.550323
Mineshaft 2 (26)	0.203164	0.110246	0.11048	0.183112	0.210345	0.255793	0.117398	0.142765	0.201269	0.182515	0.198054	0.174309	0.171626	0.168348	0.245717	0.213775
Mineshaft 3 (27)	0.255462	0.123081	0.166454	0.229312	0.251533	0.204682	0.162157	0.145479	0.196879	0.132557	0.172987	0.146646	0.147383	0.134119	0.215075	0.209083
Spherical Contours (28)	0.153616	0.098344	0.104449	0.140951	0.168709	0.166807	0.12277	0.111718	0.252007	0.21442	0.26186	0.243313	0.466403	0.462969	0.625629	0.817106
S1 (29)	0.194337	0.104696	0.101469	0.16329	0.200877	0.183097	0.120012	0.114767	0.194712	0.140789	0.159722	0.126593	0.127917	0.122016	0.137515	0.14319
S2 (30)	0.226253	0.103964	0.144002	0.193993	0.233868	0.147047	0.147764	0.132366	0.146457	0.089661	0.137472	0.114199	0.073639	0.065893	0.080019	0.08408
S3 (31)	0.245561	0.120425	0.161019	0.216665	0.235242	0.194278	0.160942	0.145896	0.135009	0.142575	0.137021	0.111335	0.094174	0.115625	0.101265	0.107247
Downhill Step (32)	0.258516	0.124899	0.16278	0.243036	0.219748	0.2079	0.161284	0.146401	0.185054	0.181555	0.18853	0.157797	0.16173	0.135547	0.173594	0.184074
Salomon (33)	0.288358	0.131469	0.179562	0.294673	0.209181	0.229355	0.177804	0.159797	0.191196	0.210363	0.200731	0.162685	0.172568	0.14794	0.184747	0.195713
Whitley (34)	0.325018	0.171359	0.220474	0.347175	0.261009	0.272589	0.220599	0.200885	0.242026	0.250779	0.250435	0.274453	0.213502	0.189887	0.229419	0.242044
Odd Square (35)	0.343885	0.179592	0.237993	0.375685	0.277997	0.271285	0.230893	0.210465	0.262746	0.227723	0.266595	0.274212	0.212836	0.130514	0.228563	0.242862
Storn Chebyshev (36)	61.60901	62.69204	65.99259	66.68914	67.10907	65.39481	64.95749	64.9171	69.94749	70.05952	69.93498	70.56983	79.95421	80.28123	80.45063	79.04224
Rana (37)	0.240832	0.273476	0.447031	0.444214	0.404172	0.312752	0.349509	0.265233	0.318037	0.247942	0.348292	0.359367	0.283785	0.31475	0.274734	0.274902
Rosenbrock 10D (38)	0.171914	0.244173	0.46775	0.469062	0.385069	0.308648	0.373165	0.451093	0.161406	0.14207	0.211672	0.229334	0.208275	0.296054	0.271083	0.319367
Rosenbrock 30D (39)	0.128111	0.142035	0.2034	0.200336	0.236134	0.200531	0.208884	0.212803	0.287535	0.246902	0.347932	0.352149	0.551795	0.6768	0.595791	0.729587
Mod Rosenbrock 1 10D (40)	0.453318	0.516612	0.763507	0.779415	0.717548	0.601092	0.652575	0.79348	0.512779	0.464314	0.591126	0.569741	0.598189	0.734738	0.657812	0.663832
Mod Rosenbrock 1 30D (41)	0.750037	0.80412	0.876882	0.893783	1.009679	0.922218	0.923336	0.9748	1.061796	1.021607	1.147457	1.156069	1.674364	1.81482	1.623787	1.762832
Mod Rosenbrock 2 10D (42)	0.419738	0.598565	0.615402	0.701031	0.64495	0.548266	0.585952	0.773199	0.499492	0.457089	0.546533	0.550093	0.719694	0.719984	0.653209	0.659763
Mod Rosenbrock 2 30D (43)	0.786379	0.877072	0.862043	0.925269	0.916664	0.873969	0.906573	0.911684	1.122966	1.103226	1.200549	1.178525	1.849012	1.853551	1.719485	1.824368
Spherical Contours 10D (44)	0.159476	0.286849	0.291005	0.393993	0.325294	0.212923	0.278411	0.464176	0.130314	0.134461	0.166202	0.176134	0.208732	0.280944	0.230013	0.276373
Rastrigin 10D (45)	0.268885	0.411485	0.425355	0.519067	0.435001	0.343191	0.411454	0.596243	0.278025	0.284733	0.301958	0.324041	0.424581	0.468485	0.385533	0.424288
Rastrigin 30D (46)	0.323221	0.392757	0.387428	0.412607	0.432456	0.398729	0.420963	0.448009	0.539886	0.543747	0.550568	0.579734	1.009331	1.089619	0.920252	1.059592
Schwefel 10D (47)	0.322425	0.45474	0.572351	0.630439	0.453319	0.380252	0.536522	0.570731	0.337189	0.34172	0.342597	0.349608	0.47973	0.578699	0.46555	0.477949
Schwefel 30D (48)	0.474898	0.570184	0.666193	0.67641	0.531337	0.486904	0.546143	0.510194	0.713788	0.708467	0.773338	0.731847	1.198409	1.233181	1.165718	1.242489
Griewangk 10D (49)	0.319823	0.473998	0.645818	0.686711	0.479555	0.386997	0.546301	0.540527	0.38882	0.343559	0.370338	0.412895	0.48322	0.515615	0.45856	0.494353
Griewangk 30D (50)	0.447905	0.521451	0.566985	0.58644	0.596791	0.575828	0.603906	0.542989	0.716538	0.691351	0.693003	0.744253	1.25498	1.18367	1.130888	1.242506
Salomon 10D (51)	0.164909	0.263611	0.396534	0.410114	0.267028	0.207209	0.30532	0.270096	0.191727	0.177331	0.16888	0.240366	0.299891	0.300902	0.260806	0.307184
Salomon 30D (52)	0.09034	0.123019	0.158742	0.159809	0.14248	0.116967	0.1543	0.112184	0.239671	0.240484	0.241077	0.295237	0.61868	0.517562	0.505243	0.665112
Odd Square 10D (53)	0.223794	0.346778	0.53231	0.545299	0.349674	0.279814	0.443029	0.424996	0.23062	0.231178	0.220468	0.300674	0.375952	0.310208	0.288283	0.351261
Whitley 10D (54)	1.91678	2.152227	2.447831	2.300031	2.247944	2.155167	2.227375	2.171333	2.234305	2.241337	2.253093	2.3516	2.682917	2.598122	2.492109	2.553731
Whitley 30D (55)	11.04204	11.94659	12.15236	11.77675	12.19444	12.26825	12.22141	12.00629	12.5967	12.75872	12.74046	12.66276	17.24234	17.2446	17.02135	17.27517
Rana 10D (56)	0.666718	0.941339	1.033789	0.967768	0.759435	0.813384	0.862097	0.963758	0.73124	0.854389	0.796262	0.837952	0.92614	1.006055	0.908833	1.111835
Rana 30D (57)	1.289323	1.508604	1.596974	1.49669	1.325935	1.338104	1.387927	1.378563	1.647375	1.803305	1.75992	1.714699	2.444779	2.517578	2.450496	2.755746

APPENDIX H1: EA AVERAGE RESULTS

	1M Evals				500k Evals				100k Evals			
Average Results	SGA	PSO	DE	HJ	SGA	PSO	DE	HJ	SGA	PSO	DE	HJ
Rosenbrock (1)	7.42E-06	0	0	1.28E-022	1.14E-05	0	0	1.28E-022	1.62E-05	0	8.08E-013	2.94E-021
McCormic (2)	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322	-1.91322
Box and Betts (3)	5.10E-17	6.29E-33	0	2.60E-025	2.08E-13	6.29E-33	0	2.60E-025	1.96E-10	6.29E-33	0	2.60E-025
Goldstein (4)	3	3	3	3	3	3	3	3	3	3	3	3
Easom (5)	-1	-1	-1	-0.96	-1	-1	-1	-0.96	-1	-1	-1	-0.96
Mod Rosenbrock 1 (6)	0.029463	0.067461	7.83E-005	0.008204	0.029463	0.067466	0.000278	0.008204	0.029463	0.068211	0.00574	0.008204
Mod Rosenbrock 2 (7)	0.554649	1.026444	0.12562	0.007147	0.554649	1.042706	0.186451	0.007147	0.554649	1.080681	0.478551	0.007147
Bohachevsky (8)	0	0	0	0	0	0	0	0	0	0	0	0
Powell (9)	0.07962	225149.3	1.37E-010	1.31E-018	2918.928	225149.3	7.65E-010	1.76E-017	36223.6	227915	32467.1	2.77E-011
Wood (10)	0.055115	1.895501	1.62E-020	4.11E-021	0.114644	1.895501	4.62E-011	4.11E-021	0.185459	2.191786	0.002877	5.83E-008
Beale (11)	0	0.104137	0	1.10E-023	0	0.104137	0	1.11E-023	0	0.133885	0	1.11E-023
Engvall (12)	0	0	0	0	0	0	0	0	0	0	0	0
DeJong (13)	0	0	5.50E-035	1.45E-023	0	6.69E-220	5.50E-035	1.45E-023	3.50E-100	5.17E-48	5.50E-035	1.45E-023
Rastrigin (14)	0	0	0	0	0	0	0	0	0	0	0	0
Schwefel (15)	-837.966	-810.725	-837.966	-837.966	-837.966	-809.541	-837.966	-837.966	-837.966	-807.172	-837.966	-837.966
Griewangk (16)	0.00076	7.40E-05	0	0.006435	0.00076	7.40E-05	0	0.006435	0.00076	0.000518	7.91E-007	0.006435
Ackley (17)	4.44E-16	4.44E-16	4.44E-016	9.05E-012	4.44E-16	4.44E-16	4.44E-016	9.05E-012	4.44E-16	4.44E-16	4.44E-016	9.05E-012
Langerman (18)	-1.5	-1.11495	-1.5	-0.84904	-1.5	-1.11495	-1.5	-0.84904	-1.5	-1.10793	-1.5	-0.84904
Michaelewicz (19)	-9.41956	-8.38134	-8.58054	-8.98162	-9.41956	-8.37332	-8.15419	-8.98162	-9.41956	-8.34146	-6.91792	-8.98162
Branin (20)	0.397887	0.397887	0.397887	0.397887	0.397887	0.397887	0.397887	0.397887	0.397887	0.397887	0.397887	0.397887
Six Hump Camel (21)	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163	-1.03163
Osborne 1 (22)	0.000431	0.500993	7.44E-005	5.46E-005	0.000576	0.500993	0.000107	5.46E-005	0.001788	0.519239	0.001054	0.000136
Osborne 2 (23)	0.040192	0.338392	0.040138	0.040138	0.041489	0.338393	0.040138	0.040138	0.049142	0.339375	0.044606	0.040192
Mod Rastrigin (24)	61.91701	66.03951	60.79753	69.65214	61.91701	66.03951	60.79753	69.65214	61.91701	66.10381	73.32614	69.65214
Mineshaft 1 (25)	2.108147	1.759376	1.833253	2.252252	2.108147	1.759376	1.976885	2.252252	2.108147	1.759376	2.191939	2.252252
Mineshaft 2 (26)	-1.41635	-1.40803	-1.41635	-1.3539	-1.41635	-1.40803	-1.41635	-1.3539	-1.41635	-1.40803	-1.41635	-1.3539
Mineshaft 3 (27)	-6.19856	-5.78	-6.9423	-7	-6.19856	-5.72	-6.9064	-7	-6.19856	-5.68	-6.86802	-7
Spherical Contours (28)	1.73E-142	0.00139	4.29E-031	7.06E-021	1.55E-70	0.00139	4.29E-031	7.06E-021	1.44E-13	0.001593	6.23E-007	0.000428
S1 (29)	0	0	0	3.11E-025	0	0	0	3.11E-025	0	0	0	3.11E-025
S2 (30)	2	2	2	2	2	2	2	2	2	2	2	2
S3 (31)	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872	0.528872
Downhill Step (32)	9	9	9	9	9	9	9	9	9	9	9	9
Salomon (33)	0.000999	0	0	0.056928	0.000999	0	0	0.056928	0.000999	0	2.59E-016	0.056928
Whitley (34)	0.002368	0.004735	0	0	0.002368	0.00513	0	0	0.002368	0.005919	0	0
Odd Square (35)	-1.00847	-1.00847	-1.00847	-0.82579	-1.00847	-1.00847	-1.00847	-0.82579	-1.00847	-1.00847	-1.00847	-0.82578
Storn Chebyshev (36)	48.48605	0	0.000633	0	48.48605	0	0.30974	0	48.48605	0	82.10315	0
Rana (37)	-999.075	-1009.3	-1023.42	-1004.01	-1000.53	-1009.3	-1023.42	-1004.01	-1000.05	-1009.3	-1023.42	-1004.01
Rosenbrock 10D (38)	3.271653	32.03413	0.018428	2.47E-019	5.091197	32.03421	0.337704	8.70E-017	6.834324	32.45678	4.487699	0.018188
Rosenbrock 30D (39)	27.83797	1130.247	0.005003	3.28E-006	30.34245	1130.463	9.016813	0.098478	36.58164	1134.681	26.41671	43.38633
Mod Rosenbrock 1 10D (40)	9.328353	118.1656	7.866659	0.724829	9.328353	118.1656	8.025103	0.74089	9.328464	127.4822	8.368693	0.804974
Mod Rosenbrock 1 30D (41)	55.65867	520.0627	28.07968	21.173	55.65867	520.087	28.29864	21.24531	55.66621	546.9679	32.35948	214.8782
Mod Rosenbrock 2 10D (42)	0.48398	0.869415	0.124351	0.007811	0.48398	0.883733	0.176551	0.007811	0.48398	0.983523	0.542867	0.008661
Mod Rosenbrock 2 30D (43)	0.533107	0.859063	0.118276	0.007532	0.533107	0.861324	0.172092	0.007572	0.533107	1.017408	0.504374	0.605776
Spherical Contours 10D (44)	0	0	4.50E-032	1.27E-021	1.24E-165	5.97E-214	4.50E-032	1.27E-021	3.82E-32	7.28E-46	5.25E-032	2.08E-017
Rastrigin 10D (45)	2.706289	16.22776	11.91103	1.591934	2.706289	16.25761	14.67694	1.591934	2.706414	16.51629	22.75599	1.591934
Rastrigin 30D (46)	22.82435	100.5741	161.7422	9.591405	22.82435	100.5752	169.8472	9.591405	22.85317	100.576	198.794	9.741842
Schwefel 10D (47)	-3881.3	-2813.98	-2815.25	-3598.4	-3881.3	-2813.98	-2719.13	-3598.4	-3881.3	-2812.78	-2465.1	-3598.4
Schwefel 30D (48)	-9057.22	-6954.17	-4831.07	-9361.55	-9057.22	-6954.17	-4681.46	-9361.55	-9055.4	-6954.12	-4305.95	-9352.97
Griewangk 10D (49)	0.008468	0.137772	0.132389	0.000222	0.008468	0.138289	0.177611	0.000222	0.008468	0.139594	0.273462	0.000222
Griewangk 30D (50)	0.00037	0.073024	0	0	0.00037	0.073024	0	0	0.00037	0.083133	0.001387	0.072802
Salomon 10D (51)	0.099873	0.184873	0.099873	0.687873	0.099873	0.184873	0.099873	0.687873	0.099873	0.185873	0.099873	0.687873
Salomon 30D (52)	0.217893	2.068873	0.121959	2.458873	0.217893	2.068873	0.153587	2.458873	0.217893	2.069873	0.501882	3.467081
Odd Square 10D (53)	-0.73712	-0.48034	-0.74049	-0.02058	-0.73712	-0.48033	-0.74026	-0.02058	-0.73712	-0.48027	-0.7395	-0.02058
Whitley 10D (54)	26.1428	30.44494	38.86195	0	26.19969	30.44989	42.90359	0	26.48996	30.45603	51.15253	3.38E-010
Whitley 30D (55)	275.6891	7844.236	590.4345	0	276.0691	7844.236	625.7617	0	277.5687	8342.14	733.4363	967.7335
Rana 10D (56)	-3040.95	-3615.7	-5114.47	-4502.87	-3109.41	-3612.96	-5114.29	-4501.14	-2970.85	-3585.25	-5076.73	-4382.1
Rana 30D (57)	-5973.06	-8415.67	-13998.6	-11992.9	-6177.16	-8402.75	-12901.2	-11772.6	-5781.02	-8333.76	-8053.51	-9601.04

APPENDIX H2: EA ST. DEV. OF RESULTS

	1M Evals				500k Evals				100k Evals			
Results St. Dev.	SGA	PSO	DE	HJ	SGA	PSO	DE	HJ	SGA	PSO	DE	HJ
Rosenbrock (1)	0.000063	0	0	1.58E-022	0.000096	0	0	1.58E-022	0.000137	0	1.47E-012	3.51E-021
McCormic (2)	0	4.00E-15	4.00E-015	4.00E-015	0	4.00E-15	4.00E-015	4.00E-015	0	4.00E-15	4.00E-015	4.00E-015
Box and Betts (3)	0	2.66E-32	0	1.85E-025	0	2.66E-32	0	1.85E-025	0	2.66E-32	0	1.85E-025
Goldstein (4)	0	9.01E-16	8.88E-016	3.66E-015	0	8.98E-16	8.88E-016	3.66E-015	0	8.68E-16	8.88E-016	3.66E-015
Easom (5)	0	0	0	0.195943	0	0	0	0.195943	0	0	0	0.195943
Mod Rosenbrock 1 (6)	0.044651	0.252745	5.70E-005	0.01338	0.044651	0.252744	0.000209	0.01338	0.044651	0.253561	0.004461	0.01338
Mod Rosenbrock 2 (7)	0.324284	2.067343	0.054968	0.01077	0.324284	2.090583	0.07273	0.01077	0.324284	2.166156	0.215632	0.01077
Bohachevsky (8)	0	0	0	0	0	0	0	0	0	0	0	0
Powell (9)	0.794879	2145012	1.03E-010	3.55E-018	17907.51	2145012	5.45E-010	4.93E-017	138455.9	2146120	28471.41	5.84E-011
Wood (10)	0.296656	14.54911	3.82E-020	2.06E-021	0.44573	14.54911	7.35E-011	2.06E-021	0.54884	17.47995	0.002059	1.59E-007
Beale (11)	0	0.19054	0	1.22E-023	0	0.19054	0	1.22E-023	0	0.203776	0	1.22E-023
Engvall (12)	0	0	0	0	0	0	0	0	0	0	0	0
DeJong (13)	0	0	1.84E-034	1.55E-023	0	0	1.84E-034	1.55E-023	0	1.02E-47	1.84E-034	1.55E-023
Rastrigin (14)	0	0	0	0	0	0	0	0	0	0	0	0
Schwefel (15)	0	49.8427	2.16E-012	2.16E-012	0	50.58301	2.16E-012	2.16E-012	0	51.95111	2.16E-012	2.16E-012
Griewangk (16)	0.002232	0.000736	0	0.005988	0.002232	0.000736	0	0.005988	0.002232	0.001887	2.57E-006	0.005988
Ackley (17)	0	0	0	4.56E-012	0	0	0	4.56E-012	0	0	0	4.56E-012
Langerman (18)	0	0.286011	2.22E-016	0.155603	0	0.286011	2.22E-016	0.155603	0	0.285088	3.43E-016	0.155604
Michaelewicz (19)	0.157387	0.759209	0.238737	0.197975	0.157387	0.763187	0.300465	0.197975	0.157387	0.768329	0.374973	0.197975
Branin (20)	0	0	0	0	0	0	0	0	0	0	0	0
Six Hump Camel (21)	0	1.33E-15	1.33E-015	1.27E-015	0	1.33E-15	1.33E-015	1.27E-015	0	1.33E-15	1.33E-015	1.27E-015
Osborne 1 (22)	0.000205	0.482557	1.81E-006	1.77E-009	0.000364	0.482557	3.82E-006	1.79E-009	0.000937	0.496403	0.000216	9.34E-005
Osborne 2 (23)	0.000103	0.312003	3.71E-017	6.79E-017	0.001767	0.312005	5.00E-017	1.32E-015	0.006231	0.313051	0.008845	4.74E-005
Mod Rastrigin (24)	5.755315	11.92076	0.014792	0.617445	5.755315	11.92076	0.014792	0.617445	5.755315	11.89384	3.966187	0.617445
Mineshaft 1 (25)	0.392745	0.464042	0.466305	0.239943	0.392745	0.464042	0.391092	0.239943	0.392745	0.464042	0.158571	0.239943
Mineshaft 2 (26)	0	0.058289	1.33E-015	0.148668	0	0.058289	1.33E-015	0.148668	0	0.058289	1.33E-015	0.148668
Mineshaft 3 (27)	0.93892	0.9755	0.30168	0	0.93892	0.96	0.376568	0	0.93892	0.947418	0.405928	0
Spherical Contours (28)	0	0.002743	1.03E-031	6.64E-022	0	0.002743	1.03E-031	6.64E-022	0	0.002995	1.52E-007	3.73E-005
S1 (29)	0	0	0	7.54E-025	0	0	0	7.54E-025	0	0	0	7.54E-025
S2 (30)	0	0	0	0	0	0	0	0	0	0	0	0
S3 (31)	0	6.66E-16	6.66E-016	5.25E-015	0	6.66E-16	6.66E-016	5.25E-015	0	6.66E-16	6.66E-016	5.25E-015
Downhill Step (32)	0	0	0	0	0	0	0	0	0	0	0	0
Salomon (33)	0.009987	0	0	0.049445	0.009987	0	0	0.049445	0.009987	0	1.58E-015	0.049445
Whitley (34)	0.009418	0.012823	0	0	0.009418	0.01327	0	0	0.009418	0.01409	0	0
Odd Square (35)	0	6.34E-09	3.08E-009	0.126913	0	7.52E-09	1.15E-008	0.126911	0	1.79E-08	3.91E-007	0.126904
Storn Chebyshev (36)	173.6254	0	0.006155	0	173.6254	0	1.271737	0	173.6254	0	100.6916	0
Rana (37)	14.26028	12.50943	1.71E-012	10.60538	11.50347	12.50943	1.71E-012	10.60538	11.70672	12.50943	1.71E-012	10.60538
Rosenbrock 10D (38)	0.800642	79.12805	0.006282	7.16E-020	0.686242	79.12802	0.083821	2.72E-016	0.587817	81.46991	0.432216	0.023286
Rosenbrock 30D (39)	14.90065	8947.371	0.001629	5.96E-006	15.91657	8947.351	0.665747	0.139347	21.43761	8947.183	0.140335	8.650151
Mod Rosenbrock 1 10D (40)	9.687551	314.901	0.031629	1.127167	9.687551	314.901	0.042138	1.149815	9.687544	318.168	0.061401	1.163817
Mod Rosenbrock 1 30D (41)	45.69274	334.041	0.022442	6.185837	45.69274	334.0535	0.024738	6.211604	45.69502	350.0611	0.642863	42.90166
Mod Rosenbrock 2 10D (42)	0.376667	1.82757	0.052302	0.014619	0.376667	1.832608	0.07152	0.014619	0.376667	2.155357	0.225003	0.014758
Mod Rosenbrock 2 30D (43)	0.383134	1.719927	0.054468	0.010463	0.383134	1.71906	0.08702	0.010441	0.383134	2.022665	0.238489	0.334428
Spherical Contours 10D (44)	0	0	2.85E-032	3.15E-022	0	0	2.85E-032	3.15E-022	0	1.23E-45	3.11E-032	8.24E-018
Rastrigin 10D (45)	6.5826	6.549642	1.986652	0.613334	2.015283	6.564022	2.225028	0.613334	2.015176	6.88607	3.427226	0.613334
Rastrigin 30D (46)	26.154	26.02242	8.79619	1.331313	7.207864	26.0213	9.545773	1.331313	7.2129	26.02068	9.487318	1.307129
Schwefel 10D (47)	228.6542	326.6097	114.3907	142.7457	228.6542	326.6097	128.4158	142.7457	228.6542	329.2317	131.8472	142.7457
Schwefel 30D (48)	784.5893	744.3764	201.2209	298.7631	784.5893	744.3764	222.3171	298.7631	786.0776	744.3378	281.2943	300.3045
Griewangk 10D (49)	0.017456	0.073298	0.038384	0.001262	0.017456	0.074168	0.041646	0.001262	0.017456	0.075464	0.05994	0.001262
Griewangk 30D (50)	0.001866	0.097188	0	0	0.001866	0.097188	0	0	0.001866	0.109041	0.010733	0.015752
Salomon 10D (51)	0	0.063836	8.60E-012	0.176227	0	0.063836	3.65E-011	0.176227	0	0.064838	4.21E-009	0.176227
Salomon 30D (52)	0.041087	0.462752	0.030311	0.250637	0.041087	0.462752	0.040536	0.250637	0.041087	0.463789	0.031814	0.304924
Odd Square 10D (53)	0.032639	0.118679	0.000216	0.016301	0.032639	0.118674	0.000248	0.016301	0.032639	0.118664	0.000327	0.016301
Whitley 10D (54)	13.31067	11.21451	3.811289	0	13.22542	11.21736	3.979878	0	12.82504	11.22052	3.563271	2.74E-009
Whitley 30D (55)	94.78674	39082.2	14.97774	0	94.41092	39082.2	14.40303	0	93.16561	42553.06	16.65185	82.70786
Rana 10D (56)	567.8693	427.3699	7.393179	150.1853	657.3373	429.3507	8.506968	149.6746	540.2387	452.5264	118.8681	146.1382
Rana 30D (57)	2498.725	1061.921	1178.774	316.3914	2418.94	1067.271	1535.417	301.1813	1969.486	1085.752	1574.633	295.192

APPENDIX H3: EA AVERAGE RUNTIMES

	1M Evals				500k Evals				100k Evals			
Average Times	SGA	PSO	DE	HJ	SGA	PSO	DE	HJ	SGA	PSO	DE	HJ
Rosenbrock (1)	0.319851	0.661206	2.588735	0.062946	0.095605	0.125411	3.231313	6.43E-002	0.036114	0.026586	0.871494	0.042723
McCormic (2)	0.745197	0.50781	12.6107	0.027362	0.199563	0.147628	6.263521	0.028157	0.040995	0.030484	1.04807	0.027303
Box and Betts (3)	3.417751	3.792626	38.5275	0.212804	1.165555	1.18415	19.88069	2.12E-001	0.250277	0.241329	3.74805	0.212381
Goldstein (4)	0.357452	0.483631	10.93035	0.031758	0.099577	0.134415	5.317853	0.030672	0.029613	0.027637	0.940538	0.02994
Easom (5)	0.846109	0.581973	12.91661	0.022352	0.230731	0.168576	7.002376	0.022195	0.047667	0.036106	1.302125	0.021588
Mod Rosenbrock 1 (6)	0.066604	0.632082	24.88099	0.028132	0.035291	0.178316	7.162911	2.85E-002	0.032968	0.036227	1.155675	0.027689
Mod Rosenbrock 2 (7)	0.201365	0.646098	29.02836	0.028404	0.066597	0.185372	6.594825	2.88E-002	0.033558	0.037227	1.310414	0.028127
Bohachevsky (8)	0.931895	0.699621	30.2498	0.034847	0.271139	0.21523	9.226137	0.035208	0.055919	0.043551	1.356162	0.0346
Powell (9)	1.595837	1.557739	32.20129	0.67614	0.460975	0.452185	13.44322	3.70E-001	0.093717	0.088793	1.515195	0.10222
Wood (10)	1.506234	1.50981	53.88003	0.181333	0.403008	0.366736	27.03689	1.74E-001	0.082144	0.075729	2.563349	0.087644
Beale (11)	0.981901	0.828306	15.70233	0.149948	0.271304	0.212124	13.92302	9.34E-002	0.054606	0.043189	1.488648	0.048513
Engvall (12)	1.391059	1.139825	55.14794	0.037922	0.401442	0.341174	22.62874	0.037388	0.081437	0.069696	1.47962	0.037032
DeJong (13)	1.072421	0.703544	0.99901	0.041686	0.288438	0.17797	0.582221	4.09E-002	0.04815	0.035758	0.366594	0.040744
Rastrigin (14)	0.783004	0.552719	24.06083	0.031052	0.219757	0.168886	10.82106	0.030287	0.0446	0.034742	1.187726	0.030207
Schwefel (15)	0.828975	0.605558	20.97309	0.026968	0.235905	0.183842	15.49648	0.026197	0.048179	0.037783	1.016114	0.026184
Griewangk (16)	0.830961	0.620122	21.15184	0.02945	0.227742	0.181648	15.06419	0.028429	0.046971	0.03715	1.094922	0.028458
Ackley (17)	1.005627	0.735233	0.604656	0.03788	0.285181	0.232682	0.500604	3.56E-002	0.059304	0.049712	0.319354	0.035812
Langerman (18)	0.984165	1.902969	35.59931	0.523948	0.321464	0.555729	34.03204	0.323447	0.118103	0.144774	3.196857	0.125942
Michaelewicz (19)	2.994342	4.627286	75.48753	0.370136	1.133409	1.490355	59.55888	0.367781	0.318978	0.307714	5.815372	0.334932
Branin (20)	0.87318	0.610074	20.03385	0.028152	0.230854	0.174703	15.00193	0.029704	0.047313	0.035655	1.033181	0.027631
Six Hump Camel (21)	0.928168	0.705126	19.08592	0.030607	0.260015	0.200043	14.9501	0.031696	0.053494	0.040896	1.111058	0.029973
Osborne 1 (22)	6.388661	6.55822	120.1365	3.898343	2.091386	2.196128	72.25564	1.945381	0.426985	0.444273	7.501744	0.418745
Osborne 2 (23)	22.42565	22.80346	540.575	8.677647	7.465944	7.293182	173.1934	6.44458	1.513514	1.475335	20.95916	1.26879
Mod Rastrigin (24)	0.967737	0.966675	69.0733	0.03454	0.287285	0.278983	14.22649	0.034429	0.064645	0.06332	1.029338	0.034472
Mineshaft 1 (25)	0.896475	1.014679	71.62272	0.020531	0.272609	0.307867	6.820621	0.020427	0.062009	0.066137	1.177044	0.020445
Mineshaft 2 (26)	0.717138	0.446293	61.16598	0.015329	0.187913	0.134424	8.629298	0.015379	0.03771	0.027602	0.950771	0.015289
Mineshaft 3 (27)	0.70138	0.549356	79.48093	0.028111	0.184268	0.150969	8.845495	0.028184	0.038852	0.032444	1.325617	0.027969
Spherical Contours (28)	4.503199	6.841566	98.23889	0.635646	1.106677	1.176611	61.11754	6.35E-001	0.222908	0.259135	5.5132	0.322209
S1 (29)	0.016061	0.427705	22.12088	0.021057	0.007984	0.09263	6.783996	2.11E-002	0.007852	0.019192	0.758173	0.020886
S2 (30)	0.69194	0.453968	33.86719	0.023418	0.172566	0.120624	10.89271	0.023391	0.035066	0.024947	1.301756	0.023201
S3 (31)	0.762456	0.660322	31.36389	0.027836	0.207933	0.146194	9.22878	0.027618	0.042575	0.030631	1.395048	0.027416
Downhill Step (32)	0.829926	0.575196	32.78951	0.020072	0.214956	0.15907	8.527874	0.020194	0.043451	0.03283	1.525539	0.020059
Salomon (33)	0.768348	0.543484	6.757439	0.026379	0.202266	0.152134	1.737277	2.65E-002	0.041165	0.031721	1.427841	0.026263
Whitley (34)	0.992173	0.772739	34.24384	0.034312	0.306158	0.256077	7.9437	0.034418	0.061529	0.051871	1.835276	0.034222
Odd Square (35)	0.320384	0.662657	19.57072	0.04324	0.096478	0.18611	6.667039	0.040639	0.038235	0.03826	1.886024	0.034353
Storn Chebyshev (36)	332.3932	447.8262	3418.643	18.15485	83.81739	109.2536	2159.078	18.22605	18.77702	21.85248	266.7349	17.21152
Rana (37)	0.397842	1.109471	35.88439	0.046067	0.303557	0.305357	19.34766	0.045846	0.069096	0.062229	2.986996	0.045206
Rosenbrock 10D (38)	1.804917	2.387264	99.85368	0.363429	0.453604	0.458378	31.08256	2.69E-001	0.091039	0.103426	5.465263	0.116367
Rosenbrock 30D (39)	4.480845	6.696809	206.451	1.051606	1.140024	1.189505	78.48417	6.40E-001	0.22915	0.262991	14.53299	0.303754
Mod Rosenbrock 1 10D (40)	3.421346	3.749666	144.1915	0.370021	0.947916	0.891108	58.76778	3.40E-001	0.19146	0.180538	10.29831	0.218356
Mod Rosenbrock 1 30D (41)	9.824867	12.31192	294.7595	3.086308	2.708026	2.728127	161.3912	2.219271	0.549485	0.562656	23.40123	0.614013
Mod Rosenbrock 2 10D (42)	1.566294	3.297579	128.0833	0.227363	0.484336	0.93519	64.73948	2.25E-001	0.157132	0.188378	8.45997	0.214569
Mod Rosenbrock 2 30D (43)	4.102206	9.837654	283.7122	1.541268	1.251796	2.824061	153.4387	1.530152	0.423715	0.565772	25.93551	0.624236
Spherical Contours 10D (44)	1.847627	1.774351	1.755212	0.164077	0.427529	0.393593	3.805814	1.62E-001	0.086734	0.079601	3.473874	0.142616
Rastrigin 10D (45)	1.102545	1.150778	72.12576	0.177529	0.560032	0.572084	27.46748	0.175451	0.123034	0.117401	4.166322	0.164698
Rastrigin 30D (46)	2.945447	3.950472	168.6543	0.883639	1.509391	1.622623	62.05809	0.882093	0.322448	0.355343	9.973408	0.416805
Schwefel 10D (47)	1.895303	2.090809	88.72526	0.172173	0.601663	0.648836	20.90016	0.170543	0.139993	0.132839	5.543193	0.15252
Schwefel 30D (48)	5.26723	6.465816	105.2512	1.068933	1.732886	1.88068	53.74162	1.031255	0.369303	0.403416	15.08789	0.390164
Griewangk 10D (49)	2.197651	2.129162	58.63975	0.209207	0.654876	0.652793	14.90469	0.20961	0.139861	0.134044	5.105058	0.177032
Griewangk 30D (50)	5.833809	7.87719	125.0116	1.184918	1.806757	1.894439	45.20151	1.181512	0.375267	0.409996	14.85333	0.452206
Salomon 10D (51)	0.156388	1.500534	53.23237	0.111122	0.06689	0.396915	13.25448	0.112801	0.056275	0.081477	3.87226	0.10989
Salomon 30D (52)	0.372813	3.870647	112.6671	0.43911	0.187513	1.019964	35.08719	0.445352	0.183892	0.208638	11.16681	0.266609
Odd Square 10D (53)	1.82336	2.203812	58.0489	0.193965	0.495113	0.488829	15.04528	0.18227	0.103	0.104858	4.528191	0.122352
Whitley 10D (54)	5.938569	9.741788	169.4725	1.44485	2.506619	3.276137	69.41116	1.438095	0.668711	0.661689	26.26784	0.695218
Whitley 30D (55)	51.64383	81.33867	325.7421	42.40803	25.16108	26.92615	524.9065	26.16995	5.437968	5.422787	217.797	5.610855
Rana 10D (56)	2.044444	4.417761	64.23444	1.200554	0.743544	1.299391	39.23571	0.927819	0.180133	0.264237	8.42341	0.26675
Rana 30D (57)	4.824764	12.93345	133.7552	5.707075	1.752178	3.794124	97.71415	2.915894	0.455017	0.771524	32.23139	0.696137

APPENDIX I: PARAMETER VALUE LIST FOR SMOA AND VARIANTS

Parameter Values from Section 3.2: Vegetative State		
Parameter	Value	Description
c	0.5	Scaling factor for random movement.
MIN_SEARCH_TIME	30	Minimum number of time steps an amoeba must spend in the Vegetative State.
NUM_PSEUDOPODS	4	The number of pseudopods (searches) an amoeba uses during a time step in the Vegetative State.

Parameter Values from Section 3.3: Aggregative State		
Parameter	Value	Description
c_1	0.2	Scaling factor for previous timestep velocity.
c_2	0.4	Scaling factor for the direction of the neighboring vertex with the most cAMP.
c_3	0.4	Scaling factor for the direction of the pacemaker.
c_4	0.4	Scaling factor for the random movement in the velocity update equation.
k	256	Maximum amount of cAMP allowed at a vertex.
c	8	Maximum cAMP deposit allowed by an amoeba.
ε	0.05	Allowed error in ε-ANN
minAggregateCount	50, (0.5* aggregateCountThreshold if originally greater than or equal to 50)	Minimum number of amoeba in an aggregate (slug)
aggregateCountThreshold	NUM_AMOEBAE / NUM_NEIGHBORS	Minimum preferred number of amoeba in an aggregate. Not effective if NUM_NEIGHBORS is large
MAX_AG_TIME	30	Maximum amount of time an amoeba may spend aggregating before reverting to the vegetative state.

Parameter Values from Section 3.6: Slug State		
Parameter	Value	Description
c_1	0.2	Scaling factor for previous timestep velocity in slug.
c_2	0.2	Scaling factor for the direction of the neighboring amoeba with the best objective function value.
c_3	0.4	Scaling factor for the direction of the head.
c_4	0.4	Scaling factor for the random movement in the slug velocity update equation.
MIN_SLUG_UPDATES	30	Minimum number of timesteps an amoeba must spend in the slug state. Unnamed in Section 3.6.

Parameter Values from Section 3.7: Slime Mold Optimization Algorithm		
Parameter	Value	Description
NUM_AMOEBAE	50, 100, 250, or 500	Number of amoebae in the population
NUM_EVALS	100,000, 500,000, or 1,000,000	Number of objective function evaluations to be used in the algorithm.
NUM_NEIGHBORS	Based on neighbor strategy	Number of neighbors used in the ε-ANN data structures.

Parameter Values from Section 4.1.1: Simplex Vegetative State		
Parameter	Value	Description
ALLOWED_ERROR	0.05	The probability of making a random point in the simplex the reflected point.
λ	2	Scaling factor for the size of the reflected Simplex. A value of 2 produces a symmetric reflection.

Parameter Values from Section 4.1.2: Razor Search Vegetative State		
Parameter	Value	Description
ε_{min}	10^{-10}	Overall smallest allowable step size during Razor Search.
ε_{razor}	Average distance between amoebae	Initial smallest allowable step size
MAX_PATTERN_EVALS	100	The maximum number of pattern iterations.
κ	7	The maximum number of Razor Search iterations.

Parameter Values from Section 4.2: DE+Followers (HTDE) Slug State		
Parameter	Value(s)	Description
F	0.5	DE constant for mutation factor
CR	0.9	DE constant for crossover probability
MINIMUM_SIZE_FOR_DE	4	Fewest number of amoebae that may be in the slug for DE to work.
PERCENT_HEAD	0.20	The appropriate percentage of amoebae to put in the head of the slug.

VITA

David R. Monismith Jr.

Candidate for the Degree of

Doctor of Philosophy

Dissertation: THE USES OF THE SLIME MOLD LIFECYCLE AS A MODEL FOR NUMERICAL OPTIMIZATION

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Scope and Method of Study:

This work provides a discussion of the lifecycle of the cellular slime mold, *Dictyostelium discoideum* (Dd), as it may be used for numerical optimization with emphasis on its use as an Evolutionary Algorithm. The study begins with a review of a number of existing numerical optimization algorithms that make use of direct search methodology (i.e. they do not require the computation of a derivative to perform optimization) such as Pattern Search, Downhill Simplex, and Razor Search. These algorithms are of interest because they were precursors to Evolutionary Optimization, and their search strategies, in some cases, are similar to amoeboid movement. Next, a review of some existing Evolutionary Algorithms is provided. This includes a review of Differential Evolution, Particle Swarm Optimization, and a Real-Coded Genetic Algorithm. The second part of the review is of Dd lifecycle, biological computation, and simulations thereof. With simulations in hand, several data structures are introduced to handle the transition from simulation to optimization. Then, the Slime Mold Optimization Algorithm is introduced. It follows the lifecycle of Dd, using vegetative, aggregative, mound, slug, and dispersive states to perform optimization. Thereafter, several variants of the Slime Mold Optimization Algorithm are created.

Findings and Conclusions:

The Slime Mold Optimization Algorithm and its variants were tested on a comprehensive function suite consisting of objective functions of varying difficulty, dimensionality, and modality. Results were compared by varying parameters of the algorithm including number of amoebae and maximum numbers of objective function values. Results were also compared to those of existing Evolutionary Algorithms. These results show promise and in some cases are better than existing Evolutionary Algorithms, though work is needed to make the algorithm better suited to extremely large search spaces and problems with high dimensionality. Variants of the algorithm were also tested showing improvement over the original version of the Slime Mold Optimization Algorithm.

ADVISER'S APPROVAL: Dr. Blayne E. Mayfield