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CS471 Project1

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Introduction

This Project used ten selected standard benchmark functions of different properties. The functions were as follows: Schwefel's, 1st De Jong's, Rosenbrock, Rastrigin, Griewangk, Sine Envelope Sine Wave, Stretched V Sine Wave, Ackley's One, Ackley's Two, and Egg Holder.

To compute these functions, a matrix R^{nxm} is used. n is a constant value of 30, which is the number of experiments. m is the given dimension, which can be 10, 20, or 30, but the results in this documentation will be with the dimension of 30. To fill this matrix with values, the Mersenne Twister pseudo-random number generator is used to create the vectors (i.e. the rows in the matrix). The program then runs each vector and stores the fitness of each row and the time (in milliseconds) to compute each vector to a CSV file for the statistical analysis.

Once each of the 10 functions has been executed and stored in the CSV file, a Python file is then used to do the statistical analysis of the average fitness value of each function, the standard deviation of each function's fitness, the range of the fitness values, the median, and lastly, the total time to run each function from start to finish.

Each function will be described with its ranges, the optimal value (i.e., the most optimal fitness that we want from the function), and some of the outputs from the functions.

1 Schwefel Function

$$f_1(x) = (418.9828 \cdot n) - \sum_{i=1}^{n} -x_i \cdot sin\left(\sqrt{|x_|}\right) \tag{1.1}$$

Schwefel function and its global optima is 0, its dimension is 30 with a range of $[-512, -512]^n$. Displayed in table 1.1 is the first 5 fitness findings with their runtime for each vector in milliseconds.

Table 1.1: Schwefel Function Results

Fitness	Runtime (MS)
12705.30	0.00
11740.80	0.00
13681.10	0.00
12171.60	0.00
12451.20	0.00

2 1st De Jong's Function

$$f_2(x) = \sum_{i=i}^{n} x_i^2 \tag{2.1}$$

1st De Jong's Function and its global optima is 0: its dimension is 30 with a range of $[-100, -100]^n$. Displayed in table 2.1 is the first 5 fitness findings with their runtime for each vector in milliseconds

Table 2.1: 1st De Jong's Function Results

Fitness	Runtime (MS)
114998.0	0.00
126197.0	0.00
101113.0	0.00
82707.7	0.00
75476.1.20	0.00

3 Rosenbrock

$$f_3(x) = \sum_{i=1}^{n-1} 100\left(x_i^2 - x_{i+1}\right)^2 + (1 - x_i)^2 \tag{3.1}$$

Rosenbrock Function and its global optima is 0: its dimension is 30 with a range of $[-100, 100^n$. Displayed in table 3.1 is the first 5 fitness findings with their runtime for each vector in milliseconds

Table 3.1: Rosenbrock Function Results

Fitness	Runtime (MS)
89356500000.0	0.00
63904800000.0	0.00
68153800000.0	0.00
74959400000.0	0.00
92593400000.0	0.00

4 RASTRIGIN

$$f_4(x) = 10 \cdot n \sum_{i=1}^{n} \left(x_i^2 - 10 \cdot \cos(2\pi \cdot x_i) \right) \tag{4.1}$$

Rastrigin Function and its global optima is 0: its dimension is 30 with a range of $[-30, 30]^n$. Displayed in table .1 is the first 5 fitness findings with their runtime for each vector in milliseconds

Table 4.1: Function Results

Fitness	Runtime (MS)
2801040.0	0.00
2861340.0	0.00
2561690.0	0.00
2928910.0	0.00
2654860.0	0.00

5 GRIEWANGK

$$f_5(x) = 1 + \sum_{i=1}^{n} \frac{x_i^2}{4000} - \prod_{i=1}^{n} \cos\left(\frac{x_i}{\sqrt{i}}\right) \tag{5.1}$$

The Griewangk function has a global optimum of 0. Its dimension is 30 with a range of $[-500, 500]^n$. The tables 5.1 show the first five fitness values and their corresponding run times in milliseconds.

Table 5.1: Griewangk Function Results

Fitness	Runtime (MS)
603.9	0.00
751.3	0.00
520.6	0.00
575.4	0.00
779.1	0.00

6 Sine Envelope Sine Wave

$$f_6(x) = -\sum_{i=1}^{n-1} 0.5 + \frac{\sin\left(x_i^2 + x_{i+1}^2 - 0.5\right)^2}{\left(1 + 0.001\left(x_i^2 + x_{i+1}^2\right)\right)^2} \tag{6.1}$$

The Sine Envelope Sine Wave function has a global optimum of $-1.4915(n-1)$. Its dimension is 30 with a range of $[-30, 30]^n$. The table 6.1 show the first five fitness values and their corresponding run times in milliseconds.

Table 6.1: Sine Envelope Sine Wave Results

Fitness	Runtime (MS)
-20.9	0.00
-21.8	0.00
-21.3	0.00
-20.0	0.00
-20.0	0.00

7 Stretched V Sine Wave

$$f_7(x) = \sum_{i=1}^{n-1} \left(\sqrt[4]{x_i^2 + x_{i+1}^2} \cdot \sin\left(50\sqrt[10]{x_i^2 + x_{i+1}^2}\right)^2 + 1\right) \tag{7.1}$$

The Stretched V Sine Wave function has a global optimum of 0. Its dimension is 30 with a range of $[-30, 30]^n$. The tables 7.1 show the first five fitness values and their corresponding run times in milliseconds.

Table 7.1: Stretched V Sine Wave Results

Fitness	Runtime (MS)
357.3	0.00
424.5	0.00
332.7	0.00
362.6	0.00
289.5	0.00

8 Ackley's One

$$f_8(x) = \sum_{i=1}^{n-1} \frac{1}{e^{0.2}} \sqrt{x_i^2 + x_{i+1}^2} + 3\left(\cos(2x_i) + \sin(2x_{i+1})\right) \tag{8.1}$$

The Ackley's One function has a global optimum of $-7.54276-2.91867(n-3)$. Its dimension is 30 with a range of $[-32,32]^n$. Displayed in Table 8.1 are the first five fitness values and their corresponding run times in milliseconds.

Table 8.1: Ackley's One Results

Fitness	Runtime (MS)
539.0	0.00
573.9	0.00
570.4	0.00
519.5	0.00
659.4	0.00

9 Ackley's Two

$$f_9(x)=\sum_{i=1}^{n-1} 20+e-\frac{20}{e^{0.2\sqrt{\frac{x_i^2+x_{i+1}^2}{2}}}}-e^{0.5(\cos(2\pi x_i)+\cos(2\pi x_{i+1}))} \tag{9.1}$$

The Ackley's Two function has a global optimum of 0. Its dimension is 30 with a range of $[-32,32]^n$. Displayed in Table 9.1 are the first five fitness values and their corresponding run times in milliseconds.

Table 9.1: Ackley's Two Results

Fitness	Runtime (MS)
582.5	0.00
604.3	0.00
598.0	0.00
589.9	0.00
603.8	0.00

10 Egg Holder

$$f_{10}(x)=\sum_{i=1}^{n-1} -x_i\cdot\sin\left(\sqrt{|x_i-x_{i+1}-47|}\right)-(x_{i+1}+47)\cdot\sin\left(\sqrt{\left|x_{i+1}+47+\frac{x_i}{2}\right|}\right) \tag{10.1}$$

The Egg Holder function does not have a closed-form global optimum. Its dimension is 30 with a range of $[-500,500]^n$. Displayed in Table 10.1 are the first five fitness values and their corresponding run times in milliseconds.

Table 10.1: Egg Holder Function Results

Fitness	Runtime (MS)
-3160.0	0.00
2241.6	0.00
-348.4	0.00
894.4	0.00
1720.4	0.00

11 Statistical Analysis Table With Compared Data

Table 11.1: Statistical Analysis of Blind Search Fitness Values

Function	**Average**	**Median**	**SD**	**Range**	**Total Runtin**
Schwefel	12644.1	12645.5	1176.1	7818.3	90.4
1st De Jong	99987.0	100583.5	16629.7	113334.9	59.7
Rosenbrock	56969136000.0	56154300000.0	14638236960.2	100180500000.0	30.5
Rastrigin	2704891.7	2715660.0	467932.5	2937380.0	297.3
Griewank	625.7	622.8	100.7	603.6	219.7
Sine Envelope Sine Wave	-21.2	-21.1	1.3	7.1	15.7
Stretched V Sine Wave	360.8	361.0	56.2	315.0	132.6
Ackley's One	578.5	581.7	57.3	347.8	84.8
Ackley's Two	583.2	585.5	16.7	108.6	261.0
Egg Holder	-102.9	-119.6	1551.4	9770.8	261.9

[1] Surface Laptop Studio

[2] Processor 11th Gen Intel(R) Core(TM) i7-11370H @ 3.30GHz, 3302 Mhz, 4 Core(s), 8 Logical Processor(s)

[3] Total Ram: 2147483648 per channel 8 total

Key findings: Because a blind search was used, the values of the vectors were very random and very wide, resulting in averages for the fitness that do not get near the global optima. In my experiments, I also timed the time it would take to run a single vector through the function and not start the program to finish so the time is solely how long it took to run the matrix x number of times. Further versions of this code will use better search methods and optimize the previous functions to improve the data and its statistics.