Supervised By:

**Syed Qamar Askari**

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| LITERATURE REVIEW 1.0  Global Optimization Using Meta-Heuristics | |  |  | | --- | --- | | Faiza Shanawar | 15140070 | | Haider Ali | 15140101 | | Mohsin Qamar | 15140104 | | Usama Imran | 15140098 | |

Contents

[1. Introduction: 3](#_Toc6438069)

[1.1. Mathematical Optimization: 3](#_Toc6438070)

[1.1.1. Types: 3](#_Toc6438071)

[1.1.2. Applications: 4](#_Toc6438072)

[1.2. Meta-Heuristics: 4](#_Toc6438073)

[1.3. Properties of Meta-Heuristic Algorithms: 4](#_Toc6438074)

[1.3.1. Exploration: 4](#_Toc6438075)

[1.3.2. Exploitation: 4](#_Toc6438076)

[1.3.3. Convergence: 4](#_Toc6438077)

[1.4. Related Work: 4](#_Toc6438078)

[1.5. Benchmark Functions: 5](#_Toc6438079)

[1.5.1. Types: 5](#_Toc6438080)

[1.5.2. Overview: 6](#_Toc6438081)

[2. No Free Lunch Theorem: 9](#_Toc6438082)

[3. Literature Review: 9](#_Toc6438083)

[3.1. Genetic Algorithm: 9](#_Toc6438084)

[3.1.1. Inspiration: 9](#_Toc6438085)

[3.1.2. Working: 10](#_Toc6438086)

[3.1.3. Applications: 10](#_Toc6438087)

[3.2. Gravitational Search Algorithm: 11](#_Toc6438088)

[3.2.1. Inspiration: 11](#_Toc6438089)

[3.2.2. Working: 11](#_Toc6438090)

[3.2.3. Experimental Results: 12](#_Toc6438091)

[3.2.3.1. Unimodal Functions: 13](#_Toc6438092)

[3.2.3.2. Multimodal Functions: 14](#_Toc6438093)

[3.2.3.3. Multimodal with fixed Dimensions: 15](#_Toc6438094)

[3.2.4. Applications: 15](#_Toc6438095)

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# Introduction:

## Mathematical Optimization:

Mathematical Optimization can be defined as a technique of finding a maximum or minimum value of a function of several variables subject to set of constraints. More generally, optimization includes finding "best available" values of some objective function given a defined domain (or input), including a variety of different types of objective functions and different types of domains.



Graph of a paraboloid given by

z = f(x, y) = −(x² + y²) + 4. The global maximum at (x, y, z) = (0, 0, 4) is indicated by a blue dot.

### Types:

Optimization is classified into following types:

* Discrete optimization
* Continues optimization
* Single Objective Optimization
* Multi Objective Optimization
* Many Objective Optimization
* Combinatorial optimization
* Unconstrained optimization
* Constrained optimization

### Applications:

Optimization techniques are being used in real world problems some of their applications are as follows:

* Feature Selection
* Automatic Clustering
* Time Scheduling
* Wireless Sensor Network Optimization
* Vehicle Routing Problem
* Watermarking
* Bioinformatics
* Circuit Designing
* Game Strategy Planning
* Power Supply Management

## Meta-Heuristics:

Heuristic is a Greek word which means “to solve”. It pertains to trial-and-error method of problem solving used when an exact algorithmic approach is impractical. Main characteristic of meta-heuristics is that they are problem independent. Meta-heuristics give us a way to solve complex problems that are not solvable in polynomial time (NP-Hard Problems). Although they don’t give exact solution of a particular problem, meta-heuristics provide guidelines that can give best solution available

## Properties of Meta-Heuristic Algorithms:

In order to be successful a search algorithm needs to establish a good ratio between exploration and exploitation [1].

### Exploration:

Exploration is process of visiting entirely new regions of search space [1] . It is the ability to evaluate candidate solutions that are not neighbor to the current solution (or solutions). This operation serves to escape from a local optimum.

### Exploitation:

Exploitation is the process of visiting those regions of a search space within the neighborhood of previously visited points [1]. It is when a search is done in the neighborhood of the current solution (or solutions). It can be implemented as a local search.

### Convergence:

It is often called termination condition of algorithm. More precisely, it stops the algorithm because each individual of population becomes identical as far as their fitness is concerned.

## Related Work:

Following are the lists of optimization Algorithms:

|  |  |
| --- | --- |
| **Algorithm** | **Inspiration** |
| Genetic Algorithm | This algorithm is inspired by biological processes: crossover and mutation. |
| Gray Wolf Optimization | This algorithm is inspired by pack of wolves that are search for hunt. |
| Particle Swarm Optimization | This algorithm is inspired by flock of birds. |
| Gravitational Search Algorithm | This algorithm is inspired by Newton’s Law of Gravitation. |
| Whale Optimization | This algorithm is inspired by Whale hunting. |
| Dragonfly Optimization | This algorithm is inspired by dragonflies and their hunting behavior. |
| Centipede Optimization | This algorithm is inspired by centipede’s hunting behavior |
| Bat Optimization | This algorithm is inspired by bat’s echolocation |
| Ant Colony Optimization | This algorithm is inspired by ant’s colony |
| Artificial Bee Colony Optimization | This algorithm is inspired by Bees |
|  |  |

## Benchmark Functions:

After the algorithms are proposed, they are tested on some evaluation functions which are known as benchmark functions. Algorithms are subjected to benchmark functions their performance is checked through comparison with already existed algorithms.

### Types:

Following are the types of benchmark functions:

1. Unimodal
2. Multimodal
3. Differentiable
4. Non-differentiable
5. 1- Dimensional
6. 2-Dimentional
7. 3-Dimensoinal
8. N-Dimensional
9. Convex
10. Non-convex
11. Parametric
12. Separable

### Overview:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Function name*** | ***Graph*** | ***Equation*** | ***Nature*** | ***Range*** |
| Ackley N. 2 Function |  | f(x,y)=−200e−0.2√x2+y2 | N-dimensional, unimodal, convex, differentiable | [-6,6] |
| Booth Function |  | f(x,y)=(x+2y−7)2+(2x+y−5)2 | 2-dimensional, continuous, convex, differentiable, non-separable, unimodal convex | [−10,10] |
| Brent Function |  | f(x,y)=(x+10)2+(y+10)2+e−x2−y2 | 2-dimensional continuous convex differentiable non-separable unimodal convex | [−10,10] |
| Drop-Wave Function |  | f(x,y)=−1+cos(12√x2+y2) (0.5(x2+y2)+2) | 2-dimensional continuous unimodal non-convex | [−5.2,5.2] |
| Exponential Function |  | f(x)=f(x1,...,xn)= −exp(−0.5n∑i=1x2i) | n-dimensional continuous differentiable non-separable unimodal convex | [−1,1] |
| Leon Function |  | f(x,y)=100(y−x3)2+(1−x)2 | 2-dimensional continuous differentiable non-separable unimodal non-convex | [0,10] |
| Deckkers-Aarts Function |  | (x,y)=105x2+y2−  (x2+y2)2+10−5(x2+y2)4 | 2-dimensional continuous differentiable non-separable multimodal non-convex | [−20,20] |
| Styblinski-Tank Function |  | f(x)=f(x1,...,xn)=  12n∑i=1(x4i−16x2i+5xi) | n-dimensional continuous multimodal non-convex | [−5,5] |
| Bartels Conn Function |  | f(x,y)=  |x2+y2+xy|+|sin(x)|+|cos(y)| | 2-dimensional non-separable multimodal non-convex non-differentiable | [−500,500] |
| Schwefel 2.20 Function |  | f(x)=f(x1,...,xn)=n∑i=1|xi| | 2-dimensional continuous differentiable non-separable unimodal non-convex | [−100,100] |
| Egg Crate Function |  | f(x,y)=x2+y2+25(sin2(x)+sin2(y)) | 2-dimensional continuous differentiable separable multimodal non-convex | [−5,5] |
| Shubert Function |  | f(x)=f(x1,...,xn)=  n∏i=1(5∑j=1cos((j+1)xi+j)) | n-dimensional, continuous, differentiable non-separable, multimodal, non-convex | [-10,10] |
|  |  |  |  |  |

# No Free Lunch Theorem:

# Literature Review:

## Genetic Algorithm:

### Inspiration:

Genetic Algorithm is one of the most famous optimization algorithms. It is inspired by the Darwin’s Theory of Evolution (natural selection). This algorithm exhibits the process of natural selection until the fittest population is obtained.



### Working:

This algorithm has five phases in which two are major phases: “Crossover” and “Mutation”. Algorithm starts from instantiating a random population and their fitness is calculated by **Objective Function**[[1]](#footnote-1)**.** Each member of population is named “**gene**”.This is 1st phase which can be called as “population initialization”. In the 2nd phase, fittest genes are selected which are to be subjected to crossover and mutation. This 2nd phase is called “**selection**”**.** After the selection of fittest genes, they undergo “**crossover”** phase which is 3rd phase of this algorithm. After crossover, genes go through “**mutation**” phase which is 4th phase of this algorithm. After mutation, fitness is calculated again and fittest genes after crossover and mutation are replaced by least fit genes in initialized population. This process is repeated until fittest population is obtained and then it is terminated in the last phase of this algorithm which is called “**termination**”.



### Applications:

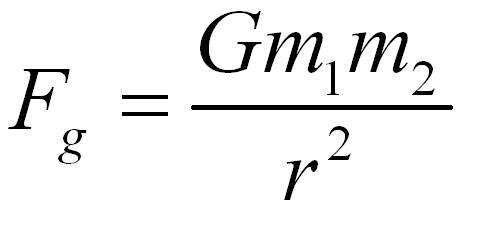
Several problems have been solved by this algorithm, some of them are as follows:

|  |  |
| --- | --- |
| ***Application*** | ***Description*** |
| Product Designing | Product design is increasingly recognized as critical activity that has a significant impact on the performance of firm, when firms undertake a new or existing product or redesign, it is important to employ techniques that will generate optimal solution [2]. |
| Molecular Geometry Optimization | The geometry of a molecule determines many of its physical and chemical properties. This is why it is very important that we understand the geometry of a molecule when running computations[3]. |
| Automotive Design | Automotive design is the process of developing the appearance, and to some extent the ergonomics, of motor vehicles, including automobiles, motorcycles, trucks, buses, coaches, and vans [4]. |
| Optimization of architectural shapes | Architectural design optimization (ADO) is a subfield of engineering that uses optimization methods to study, aid, and solve architectural design problems, such as optimal floorplan layout design, optimal circulation paths between rooms, and the like [5]. |
| Capacitated Vehicle Routing Problem | The vehicle routing problem with simultaneous pickup and delivery considering customer satisfaction is based on a time window at each customer location. In such a problem, the transportation requests have to be performed by vehicles, each request having to be met as early as possible [6]. |

## Gravitational Search Algorithm:

### Inspiration:

Gravitational Search Algorithm is inspired by Newton’s Law of Gravitation which states that every object of mass m1 in a universe attracts other object of mass m2 with a force with is directly proportional to product of masses of objects and inversely proportional to square of distance between them.



### ***Working***:

**Gravitational Search Algorithm** is Physics based algorithm which is, as the name suggests, inspired from Newton’s law of Gravitation. In this algorithm, every solution is treated as an object. And the object’s fitness is determined by the mass of that object, greater the mass, greater would be the fitness. The object of higher fitness attracts the object of lower fitness by following the rules of physics. The attraction of lighter mass towards heavier mass promotes exploration of algorithm.

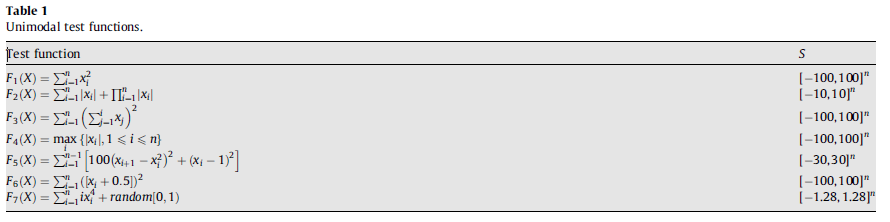


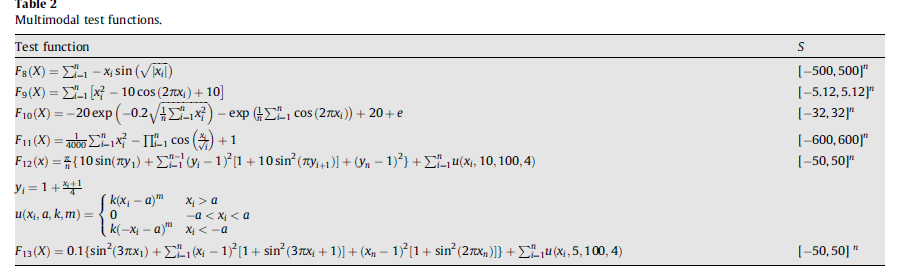
### Experimental Results:

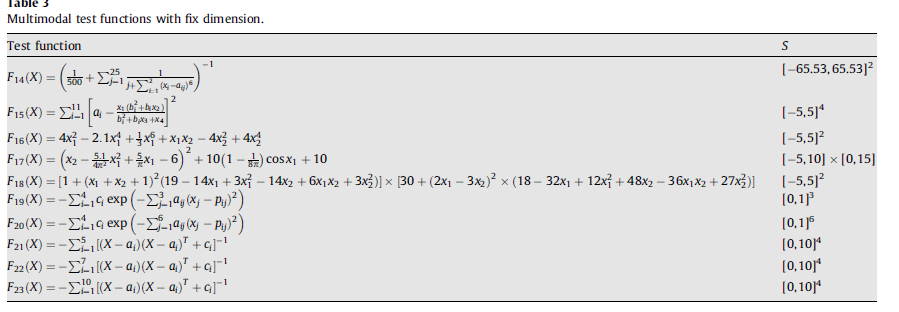
This algorithm was compared with:

* 1. PSO (Particle Swarm Optimization)
  2. CFA ()
  3. RGA (Regularized Global Approximation)

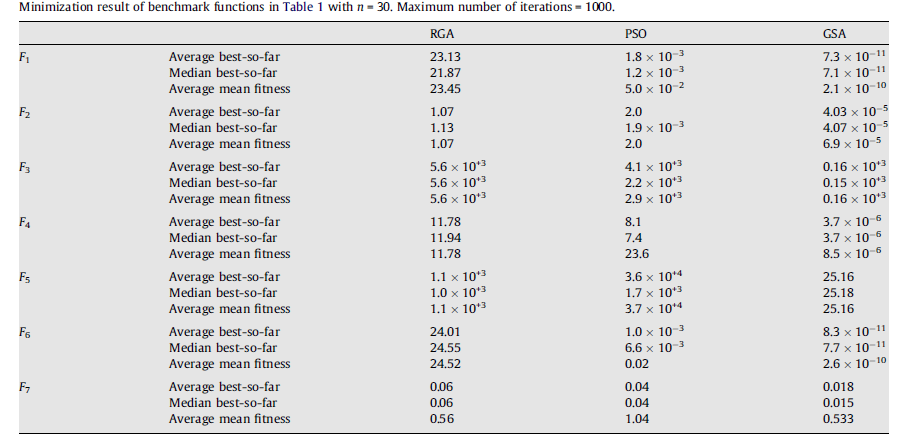
This Algorithm is tested on following benchmark functions:



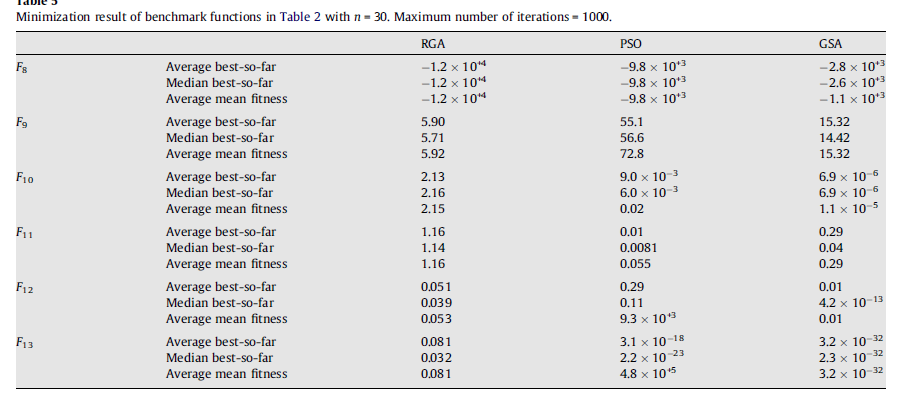




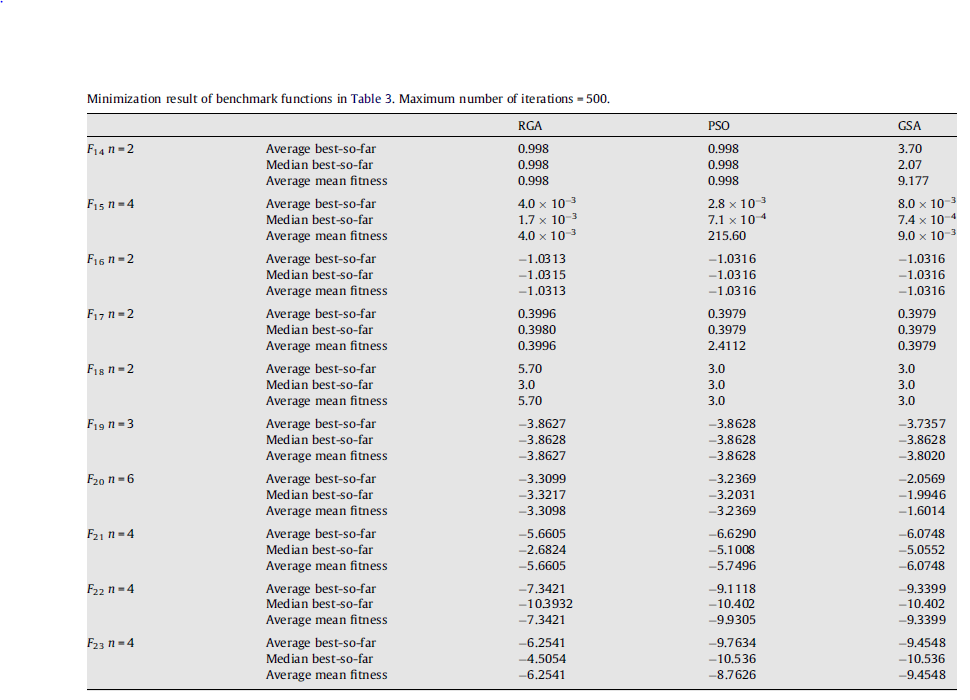
### Unimodal Functions:



### Multimodal Functions:



### Multimodal with fixed Dimensions:



### Applications:

|  |  |
| --- | --- |
| ***Application*** | ***Description*** |
| Economic Load Dispatch Problem (ELD) | Economic Load Dispatch (ELD) is a method of determining the most efficient, low-cost and reliable operation of a power system by dispatching available electricity generation resources to supply load on the system most economically. The ELD problem is multimodal, non-differentiable and highly nonlinear [7]. |
| Energy Management System | EMS problem in an MG including different types of DG units with particular attention to the technical constraints. The EMS consists of a stand-alone wind turbine (WT), photovoltaic (PV), microturbine (MT) and energy storage (ES) system. The objective function for the optimization of the EMS is the total general cost. The application includes the implementation of some variation in load consumption model considering accessibility to the ES and demand response. The GSA provides a good compromise between computation time and precision of the solution [7] |
| Feature Subset Selection | Pattern recognition, data mining and knowledge discovery problems require feature subset selection (FSS) to represent the patterns to be classified (Zalama et al. 2014; Amezquita-Sanchez, Adeli 2015). The FSS problem refers to the task of identifying and discovering a useful subset of features to represent a pattern from a larger set of features which may be redundant and even irrelevant causing unnecessary computational complexity and cost (Jackowski et al. 2014). The research problem is then how to select the minimum subset of features to represent the original knowledge effectively. Thus, FSS can be viewed as a search problem. The FSS problem can be treated as an optimization problem in a search space of 2N. Han et al. (2013) introduced a binary GSA to solve the FSS problem [7]. |
| Unit Commitment | Unit commitment (UC) problem in power systems aims to schedule the most cost-effective combination of generating units to meet the forecasted load and reserve requirements while adhering to generator and transmission constraints. The commitment schedule takes into account the inter-temporal parameters of each generator (minimum run time, minimum down time, notification time, etc.) but does not specify production levels which are determined five minutes before delivery. The determination of these levels is known as economic dispatch and is the least-cost usage of the committed assets during a single period to meet the demand. The objective is to minimize the total system cost of generating power from N units over a specific time Roy (2013) applied GSA to the UC problem [7]. |
| Training the Neural Networks | In general, feed-forward neural network (NN) consists of one input layer, one or more hidden layers with a nonlinear activation function and one output layer with a linear activation function (Adeli, Park 1998). Biases can be set to non-zero or zero. The problem is to find the connection weights of the network for the given architecture to produce the correct output for the function for each corresponding input [7]. |

## Gray Wolf Optimization:

### Inspiration:

This algorithm is inspired by pack of wolves which are going out for hunting.

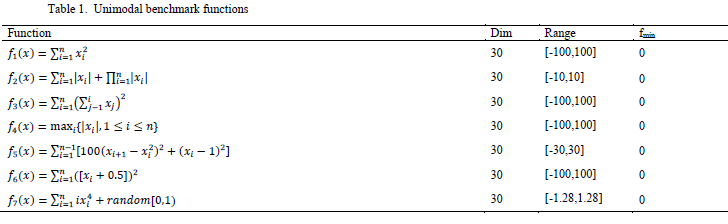
### Working:

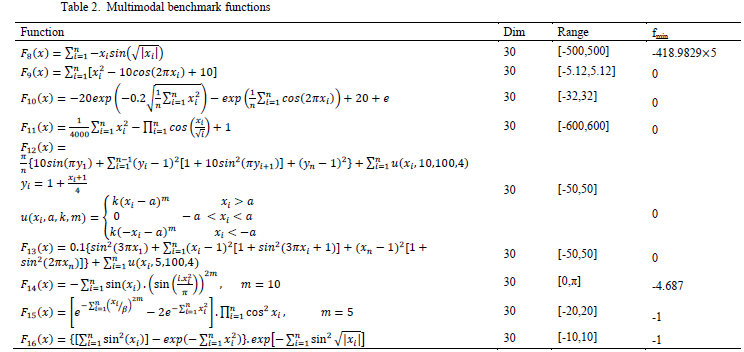
In this algorithm, each solution is treated as wolf and the highest fitness wolf is considered as “alpha”, second highest fit wolf is known as “beta”, third one is called “delta” and all the others are known as “omega”. All wolves follow the alpha wolf and they get the global best solution which is called “prey” [8]



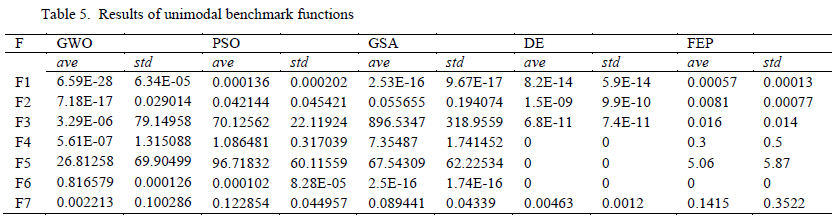
### Experimental Results:

This algorithm is tested on following benchmark functions:





### Unimodal functions:



### Multimodal Functions:

1. Objective Function is basically a function that describes the fitness of each sample of population which needs to be either maximized or minimized. Every problem on which metaheuristic algorithms are applied, requires objective function which is minimized of maximized according to the need. [↑](#footnote-ref-1)