COMPARATIVE ANALYSIS OF BIO- INSPIRED ALGORITHMS FOR BENCHMARK FUNCTIONS

Mr.G.Swami naidu, Assistant Professor, Department of Electronics and Communication engineering, Vignan's Institute of Engineering for Women, Visakhapatnam
P.Poorna siva sai, M.N.Rajyalakshmi, P.B.Likitha,M.Hanisha,K.Navya sree
Department of Electronics and Communication engineering, Vignan's Institute of Engineering for Women, Visakhapatnam

ABSTRACT:

This paper identifies an efficient technique for optimization process. Optimization plays an important role in solving different engineering problems. The goal of optimization process is to determine either a maximum or a minimum value of the problem being solved, generally known as the objective function. These problems include but not limited to systems design, electricity network operation, electricity generation, wireless communications routing and minimization of energy losses during electricity transmission. Proper validations of optimization algorithms require assessment of computational time and convergence rate in additionally to the accuracy to work out the minimum or maximum values. Some researchers have innovated optimization algorithms based on nature observations, these algorithms are known as nature-inspired algorithms.

The study of behaviour of bio-logical entities, their structure and organization principles paved a path to relate the needs in the modern problems. With this inspiration various mathematical and meta-heuristic algorithms have been developed. These bio-inspired algorithms are the most efficient search methods which will reduce time complexity and number of test cases. So, it is required to identify a powerful algorithm which provides efficient results among available bio inspired algorithms.

Comparative analysis for three bio inspired algorithms namely Genetic Algorithm (GA) , Cuckoo Search Algorithm (CSA) and Teaching –Learning based algorithm(TLBO) are to be computed for bench mark functions, among those bioinspired algorithms, Cuckoo Search Algorithm (CSA) will give best optimization results.

Keywords: Optimisation**,**Genetic algorithm,Teaching Learning based optimisation algorithm,Cuckoo search algorithm

1.INTRODUCTION :

The process of finding the maximum value or minimum value of something is called as optimization. The maximum or minimum values themselves are sometimes called as extrema. Who cares this optimization process are minimize the production of a company, minimize the expenditure

of a company, minimize energy expended by an organism in foraging, find time at which drug concentration in a patient peaks, determine the peak number of people sick during epidemic, determine chemical parameters producing the fastest reaction. Goals of optimization are keep improving the performance to reach optimal points and best is far better than others. The features of optimization are Flexibility, Robustness, Efficiency, Self repair, Self guidance, Reproduction.Optimization is the act of achieving the best possible result under given circumstances. In design, construction, maintenance, engineers have to take decisions. The goal of all such decisions is either to minimize effort or to maximize benefit.

The effort or the benefit can be usually expressed as a function of certain design variables. Hence, optimization is that the process of finding the conditions that give the maximum or the minimum value of a function. It is obvious that if a point x corresponds to the minimum value of a function f(x), the same point corresponds to the maximum value of the function −f(x). Thus, optimization are often taken to be minimization. There is no single method available for solving all optimization problems efficiently. Hence, a number of methods have been developed for solving different types of problems. Optimum seeking methods also are referred to as mathematical programming techniques, which are a branch of research. Optimization algorithms, which attempt to find the minimum values of mathematical functions, are everywhere in engineering. Among other things, they're used to evaluate design tradeoffs, to assess control systems, and to find patterns in data.

2.LITERATURE SURVEY

Optimization is the act of achieving the best possible result under given circumstances. Engineers need to take decisions while in design, construction, maintenance, etc. The goal of all such decisions is either to minimize effort or to maximize the benefit. Multi-objective optimization is that the process of simultaneously optimizing two or more conflicting objectives subject to certain constraints. Most multi-objective optimization studies are focused on nature-inspired algorithms. Many nature-inspired optimization algorithms have been proposed, such as the Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), Ant Colony Optimization (ACO), Harmony Search (HS), the Cuckoo search algorithm (CSA), teaching–learning-based optimization (TLBO) etc., these approaches are based on different natural phenomena.

Rajesh Kumar Singh [1] had cited a review on Genetic algorithm and it's applicability in various fields.Genetic algorithm basically is a soft computing technique which uses genetic operators to solve problems which can be represented as minimization or maximization problem.It is based upon it's operators which are initialization,selection,crossover,mutation.It finds the solution by

repeatedly applying it's operators till the solution is reached.Genetic algorithms are used to solve many problems such as Travelling Salesman problem,Adaptive signal processing,Image processing etc.

Ru Xue, Zongsheng[4] done a survey on various applications and classifications of Teaching – Learning based optimisation algorithm(TLBO). It works on the philosophy of teaching and learning which is employed to unravel multi-dimensional,linear and nonlinear problems with appreciable efficiency. TLBO optimization technique is popular for it's less computational cost and high consistency.Some of the applications of TLBO algorithm are Digital filter design,Image processing,Satellite image compress,Visual tracking etc.

Carlos Eduardo, M.Barbosa Germano[3] had investigated the efficiency of Cuckoo search algorithm and self adaptive cuckoo search algorithms through extensive experimentation in three problems,they are benchmark function optimization,Wind energy forecasting and data clustering.Cuckoo search algorithms are inspired by the brooding paratism of cuckoos which trick other animals into raising their young.These algorithms have better performance and convergence rate than other algorithms.

The Cuckoo search algorithm showed better performance with less computational effort for the large scale problems, i.e. problems with high dimensions. However, in general, to maintain the consistency in comparison of algorithms, the number of function evaluations is to be maintained same for all the optimization algorithms ,for all the benchmark functions considered.

In this paper the comparative analysis of Genetic ,TLBO and Cuckoo search algorithms are done using three benchmark functions and the best optimization technique which provides minimum mean square error with less computations is observed

3.Genetic Algorithm:

Genetic algorithms(GAs) are adaptive heuristic search algorithms that belong to the larger part of evolutionary algorithms.These are based on the ideas of natural selection and genetics.They are commonly used to generate high quality solutions for optimisation problems and search problems.The GAs maintains the population of n individuals having better fitness scores are given more chance to reproduce than others .Once the initial population is created the algorithm evolve the new generation using the following genetic operations:

Selection: It is the process of producing more number of good value of solution variables and removing the ones with less fitness value.

Crossover : It is the process of producing the new value of solution variable by randomly swapping already assigned value of solution variable

Mutation : The process of producing new value for the solution variable by randomly reversing one or more bits.Its purpose is to maintain diversity within the population and inhibit premature convergence.

Algorithm:

Step 1 : Randomly initialize population p

Step 2 : Determine fitness of population

Step 3 : Untill convergence repeat:

a)Select parent from population

b)Crossover and generate new population

c)Perform mutation on new population

d)Calculate fitness for new population

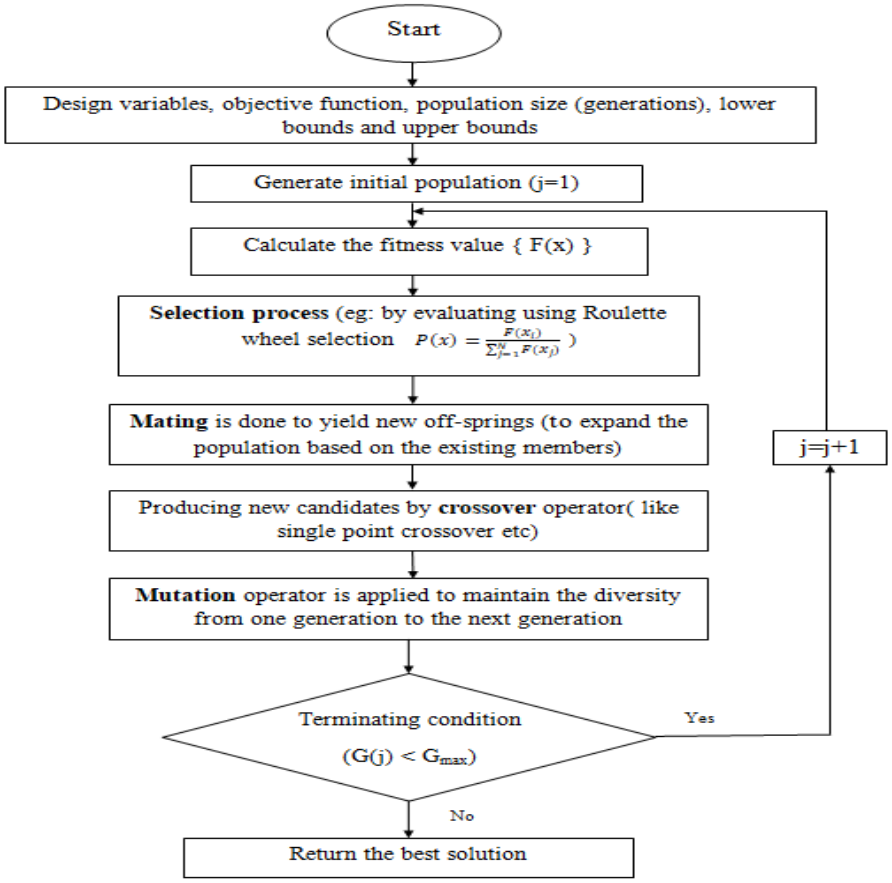

Figure 1.Flow chart of GA

4.Teaching-Learning based algorithm:

Teaching-learning-based optimization (TLBO) is a population-based algorithm which simulates the teaching-learning process of the class room. This algorithm requires only the common control parameters like the population size and therefore the number of generations and doesn't

require any algorithm-specific control parameters. It works on the philosophy of teaching and learning which is employed to unravel multi-dimensional, linear and nonlinear problems with appreciable efficiency.

The algorithm describes two basic modes of the learning: (i) through teacher (known as teacher phase) and (ii) through interaction with the opposite learners (known as learner phase). In this optimization algorithm, a gaggle of learners is taken into account as population and different subjects offered to the learners are considered as different design variables of the optimization problem and a learner's result's analogous to the'fitness'value of the optimization problem. The best solution within the entire population is taken as the teacher. The design variables are actually the parameters involved in the objective function of the given optimization problem and the best solution is the best value of the objective function.

Algorithm:

Step 1 : Initialization Stage: Initialize the population (learners), design variables (numbers of subjects offered to the learners) with random generation, threshold values, and termination criterion.

Step 2 : Teaching Phase: Select the best learners of each subject as a teacher for that subject and calculate mean result of learners in each subject.

(a) Keep the elite solution

(b) Calculate the mean of every design variable

(c) Select the best solution

(d) Calculate the diverged mean and modify the solutions based on best solution

Step 3 : Teaching Phase: Evaluate the difference between current mean result and best mean result by utilizing the teaching factor TF.

(a) If the new solution is best than the prevailing solution, then accept alternatively the previous solution

(b) Select the solutions randomly and modify them by comparing with each other

(c) Modify duplicate solution via mutation on randomly selected dimensions of duplicate solutions before executing the next generation

Step 4: Learners Phase:Update the learner's knowledge with the help of teacher's knowledge

(a) If the new solution is better than the existing solution, then accept or else keep the previous solution

(b) Replace worst solution with elite solution

Step 5 : Stoppage Criterion: Repeat the procedure from Step 2 to Step 4 till the termination criterion is met. (a) If termination criterion is fulfilled, then we get the final value of the solution or else repeat from Step 2 to Step 4.

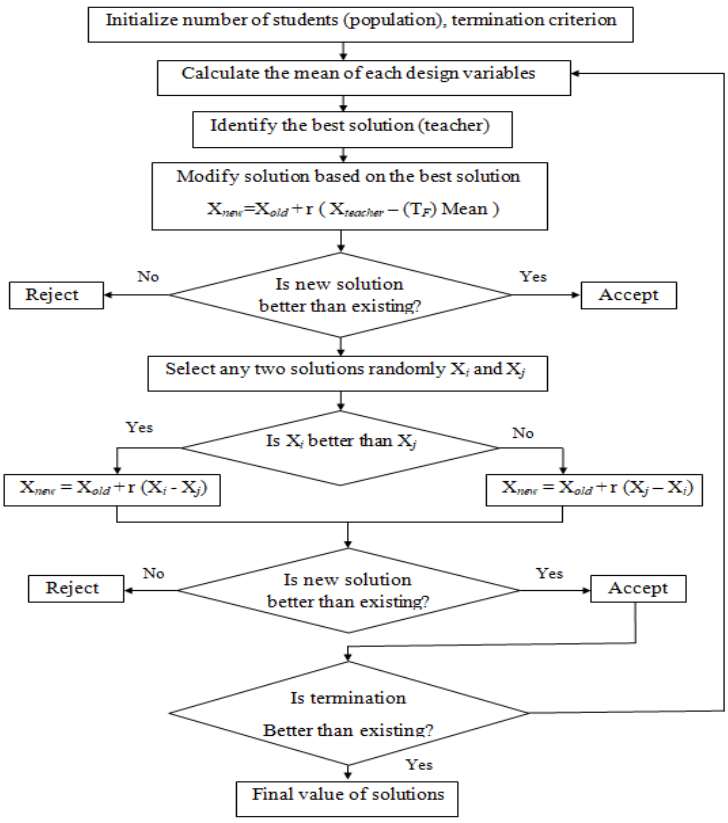

Figure 2 Flow chart of TLBO

5.Cuckoo Search algorithm:

The cuckoo search is a recently developed metaheuristic optimisation algorithm,which is used for solving various types of optimisation problems.This is a nature inspired meta-heuristic optimisation algorithm,which is based on brood parasitism of cuckoo species,along with Levy flights random walks.In this algorithm we have two bird species Cuckoo bird and Host bird .The cuckoo bird lay their eggs in the host bird and imitate their colour and pattern to increase it's survivability and productivity

Three idealized rules for cuckoo search:

- Each cuckoo lays one egg at a time, and dumps it in a randomly chosen nest.
- The best nest with high quality of eggs (solutions) will carry over to the next generations.
- The number of available host nests is fixed, and a host can discover an alien egg with a probability p(0,1).

Levy Flights: A Levy flight is a random walk in which the step-lengths are calculated according to a heavy-tailed probability distribution. The distance from the origin of the stochastic process tends to a stable distribution after an outsized number of steps.

Algorithm:

Step 1 : Generate initial population of n host nests

Step 2 : Lay the egg(solution) in the K nest ,where k is randomly selected nest

Step 3 : Compare the fitness of cuckoo's egg with the host egg

Step 4 : If the fitness of cuckoo's egg is better than host egg,replace the egg in nest K with cuckoo's egg

Step 5 : If the host bird notice it the nest is abandoned and the new one is built

Iterate steps 2 and 5 until termination criterion satisfied.

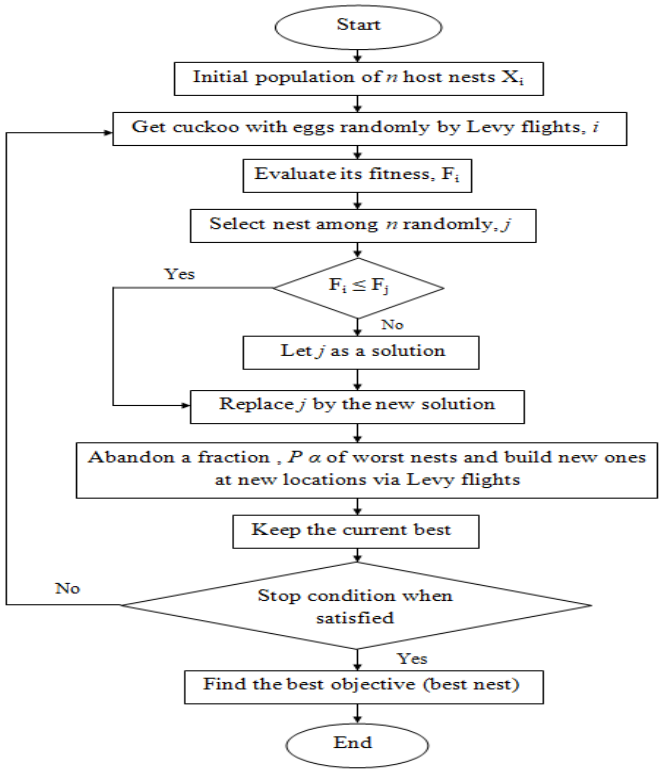

Figure 3 Flow chart of CSA

6.Bench mark functions

Quality of optimization procedures are frequently evaluated by using common standard benchmarks functions. . There are several classes of such test functions, all of them are continuous:

(a) unimodal, convex, multidimensional,

(b) multimodal, two-dimensional with a small number of local extremes,

(c) multimodal, two-dimensional with huge number of local extremes

(d) multimodal, multidimensional, with huge number of local extremes

In this paper three benchmark functions namely De Jong's function,Rastrigin's function and Ackley function are applied to the three algorithms and the results (Best cost/least mean square error) are observed for each of them to find the best optimisation algorithm.

i)De Jong's function (Sphere function)

So called first function of De Jong's is one among the only test benchmark. Function is continuous, convex and unimodal. It has the following general definition

$$f(x) = \sum_{i=1}^{n} x_i^2$$

Test area is typically restricted to hyphercube $-5.12 \leq x_i \leq 5.12$, i = 1....n. Global minimum $f(x) = 0$ is obtainable for $x_i = 0$, i = 1, . . . n.

ii)Rastrigin's function

Rastrigin's function is predicated on the function of De Jong with the addition of cosine modulation so as to supply frequent local minima. Thus, the test function is highly multimodal. However, the situation of the minima are regularly distributed. Function has the following definition

$$f(x) = 10n + \sum_{i=1}^{n} [x^2 - 10\cos(2\pi x_i)]$$

iii)Ackley's function

Ackley's is a widely used multimodal test function. It has the following definition

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

It is recommended to line $a = 20$, $b = 0.2$, $c = 2\pi$. Test area is usually restricted to hyphercube $-32.768 \leq x_i \leq 32.768$, $i = 1..... n$. Its global minimum $f(x) = 0$ is obtainable for $x_i = 0$, $i = 1.....n$.

7.Simulation Results

GA:

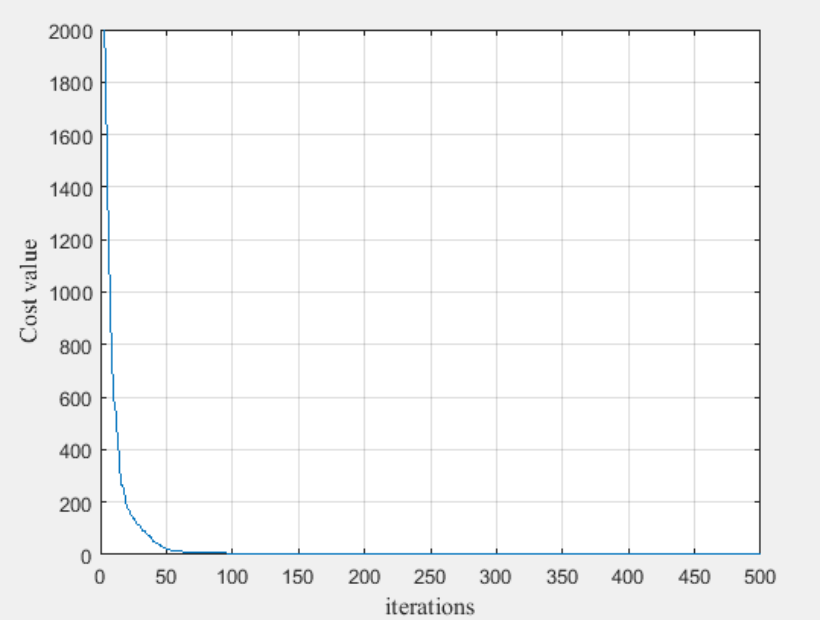

Figure 4 :GA Sphere Waveform

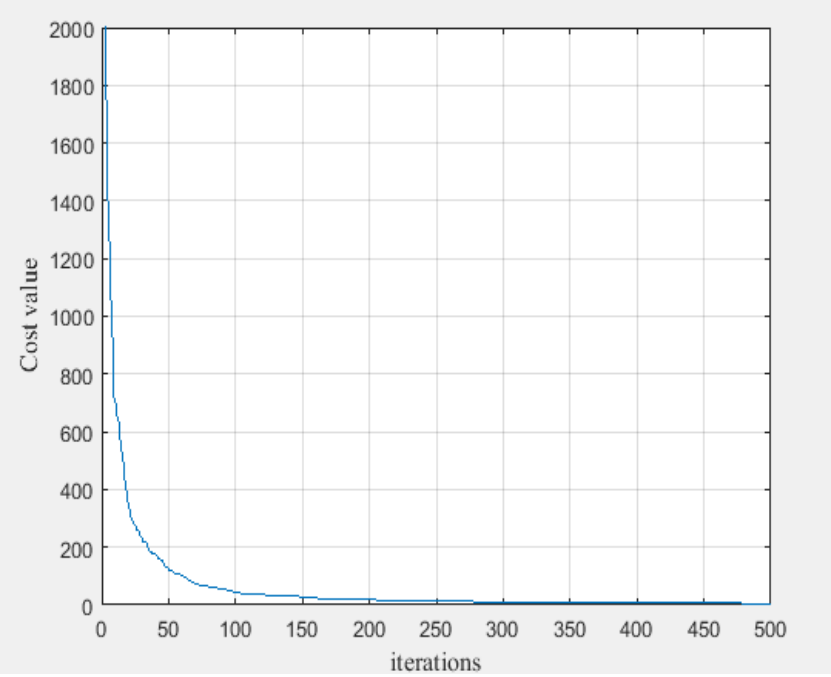

Figure 5 : GA Rastrigin Waveform

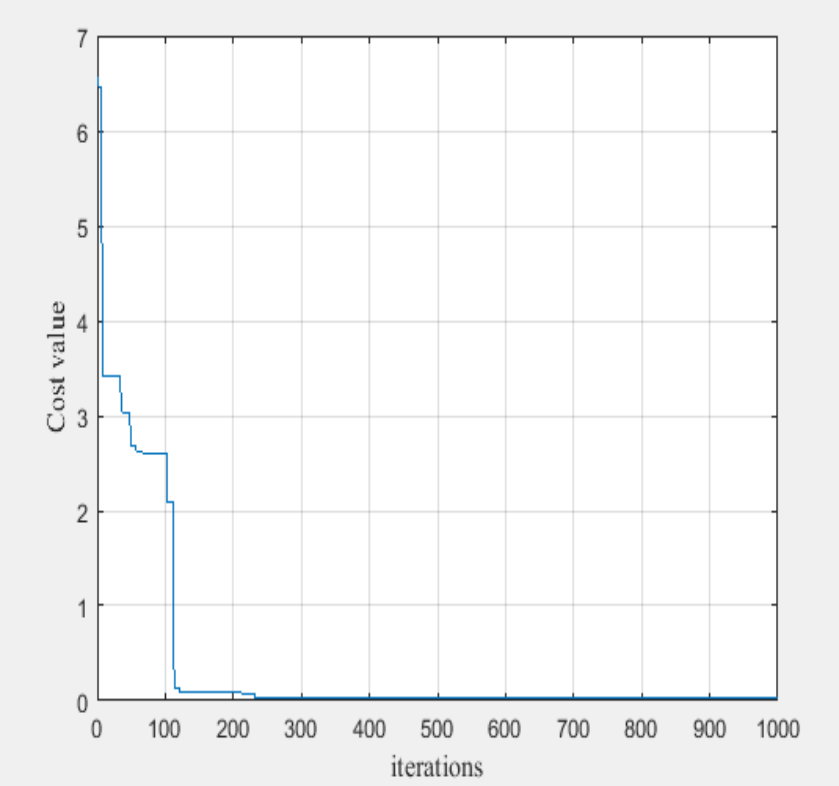

Figure 6 : GA Ackley Waveform

TLBO:

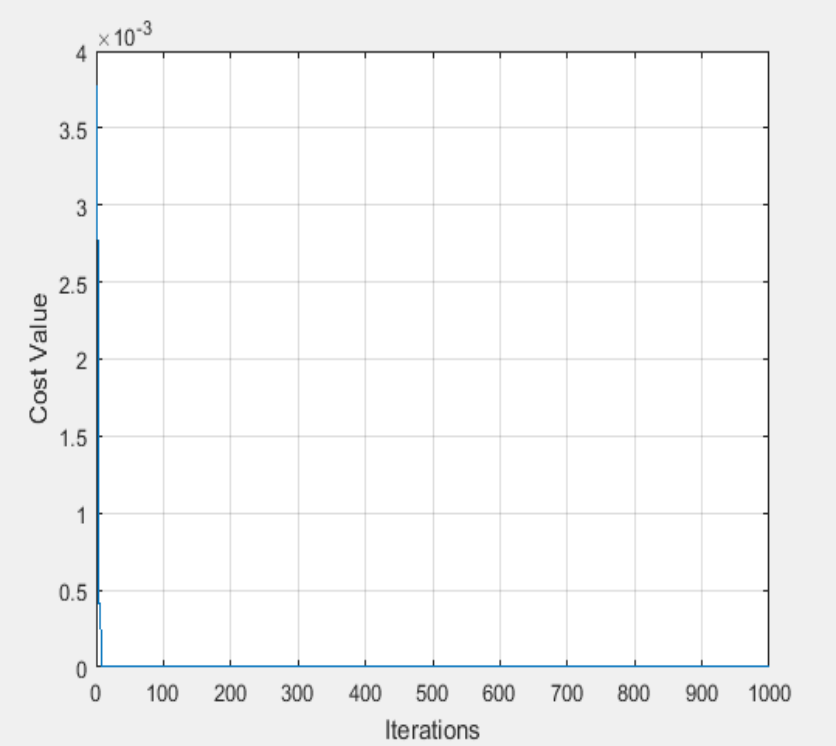

Figure 7 : TLBO Sphere Waveform

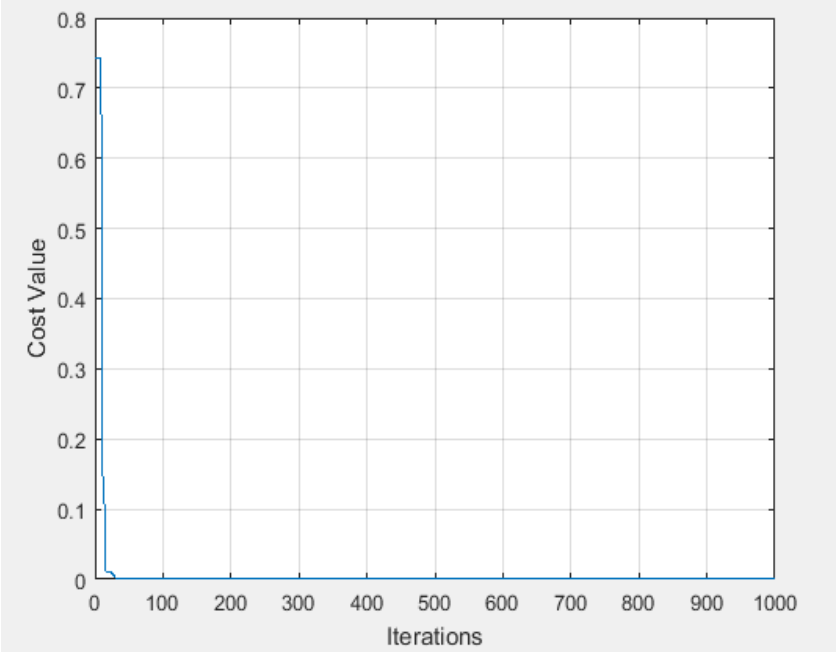

Figure 8 : TLBO Rastrigin Waveform

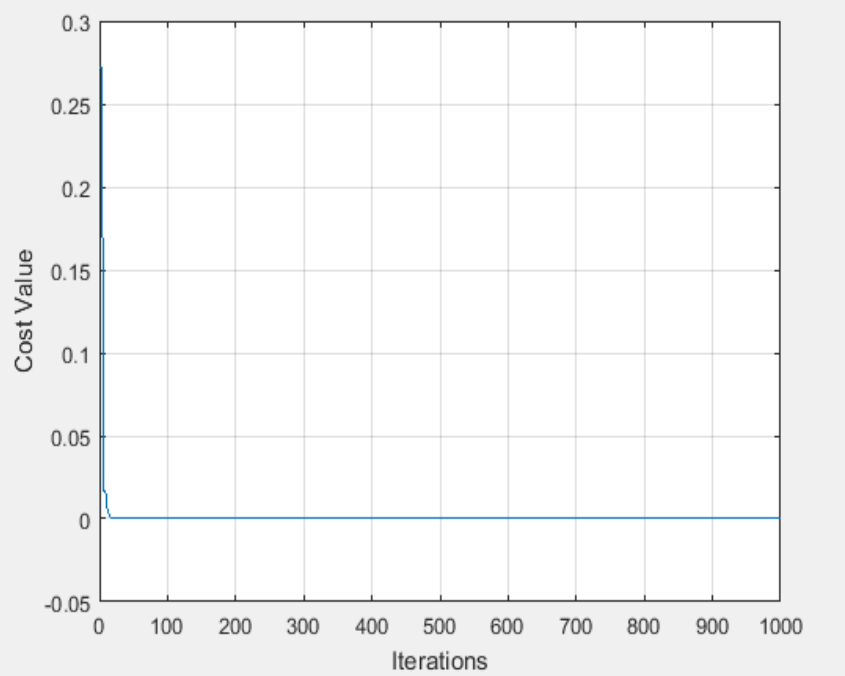

Figure 9 : TLBO Ackley Waveform

CSA:

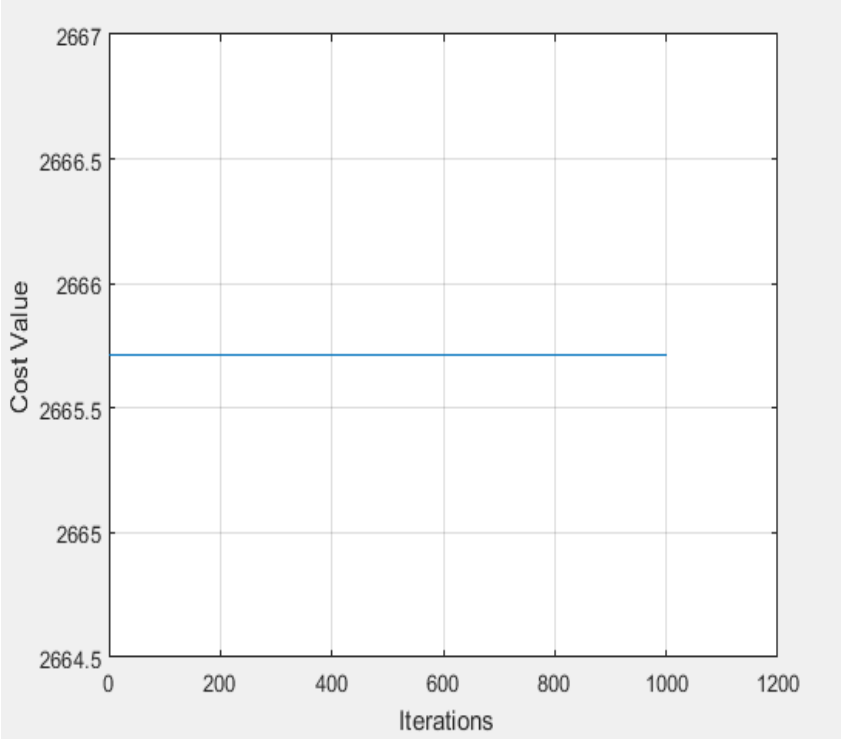

Figure 10 : CSA Sphere Waveform

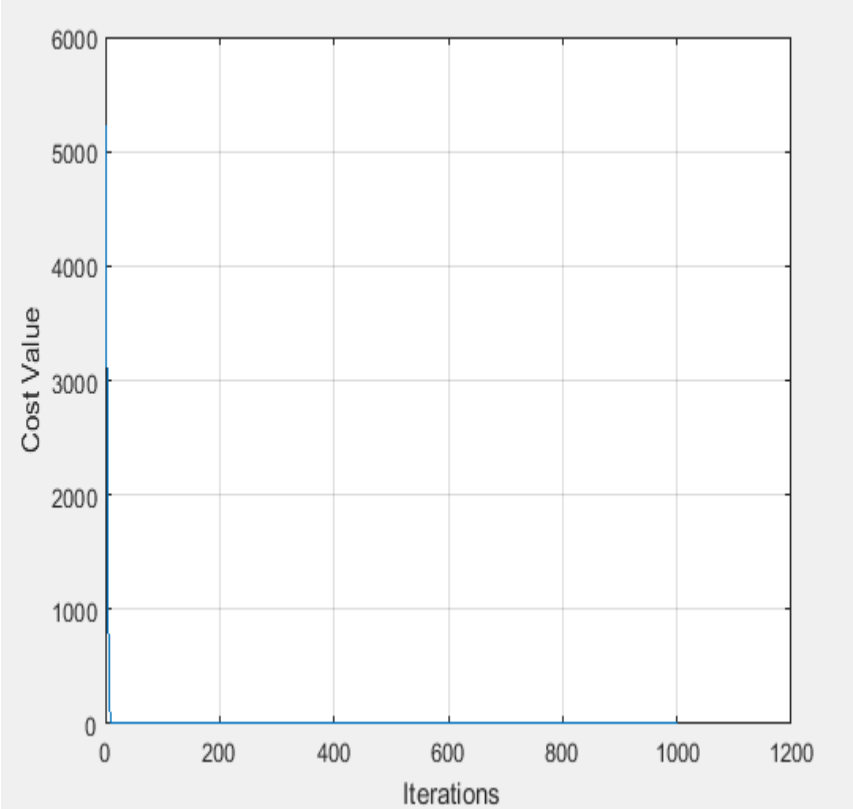

Figure 11 : CSA Rastrigin Waveform

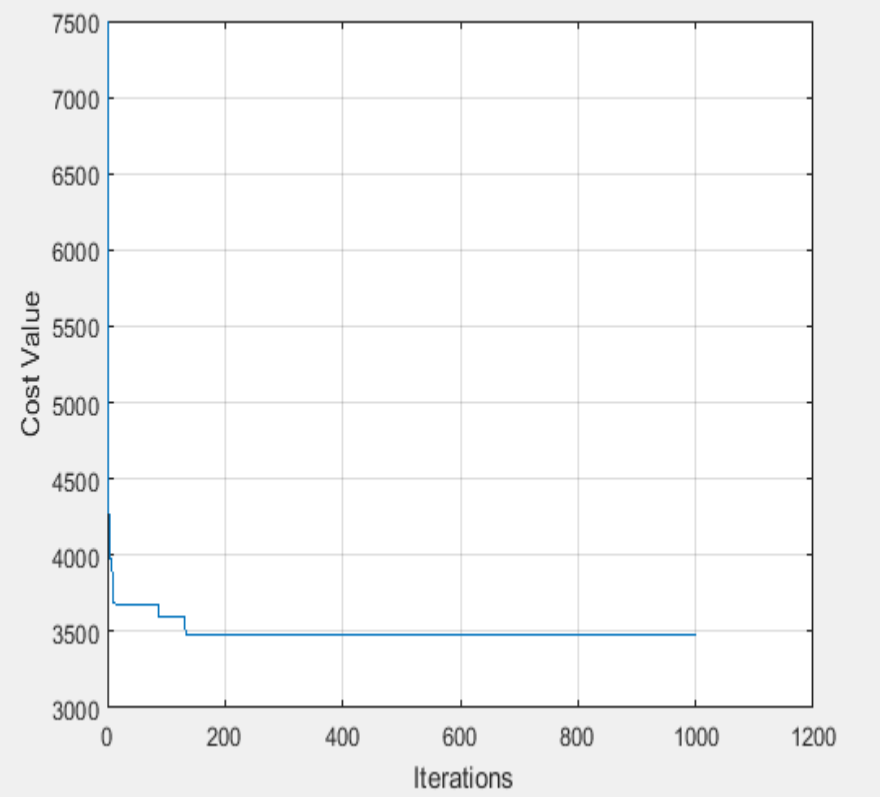

Figure 12 : CSA Ackley Waveform

Comparison table among GA, TLBO and CSA for different benchmark functions:

OPTIMIZATION ALGORITHM	BENCHMARK FUNCTION	BEST COST	ELAPSED TIME
GA	Rastrigin	1.9897	17.6413
	Ackley	0.0630	16.9073
	Sphere	0.0124	16.3382
TLBO	Rastrigin	1.3016e-09	4.4612
	Sphere	-1.4643e-163	3.8777
	Ackley	-2.2252e-16	3.7274
CSA	Sphere	2.2900e+03	20.8729
	Ackley	1.1930e+03	20.4581
	Rastrigin	0	20.1827

8. CONCLUSION

Comparative analysis for bio inspired algorithms namely Genetic Algorithm (GA), Teaching Learning Based Optimisation(TLBO) and Cuckoo Search Algorithm (CSA) are computed for bench mark functions.Initially the three benchmark functions are implemented for Genetic algorithm and the best cost or Mean square error for each benchmark function is observed in MATLAB software.The same Benchmark functions are then applied to TLBO and Cuckoo search algorithms and the best cost is observed. Among those bio inspired algorithms, Cuckoo Search Algorithm(CSA) gave best optimisation results by reaching to zero. However, the main drawback of the CSA is slow rate of Convergence

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Mr. G. Swami Naidu Assistant Professor in Electronics and Communication in Vignan's Institute of Engineering for Women.

P. Poorna Siva Sai pursuing B.Tech in Vignan's Institute of Engineering for Women in electronics and communication.

M. N. Rajyalakshmi pursuing B.Tech in Vignan's Institute of Engineering for Women in electronics and communication.

P. B. Likitha pursuing B.Tech in Vignan's Institute of Engineering for Women in electronics and communication.

M. Hanisha pursuing B.Tech in Vignan's Institute of Engineering for Women in electronics and communication.

K. Navya Sree pursuing B.Tech in Vignan's Institute of Engineering for Women in electronics and communication.