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Implementation of Artificial Bee Colony Algorithm

Vimal Nayak*, Haresh Suthar, Jagrut Gadit*****
* Departement of Electronics & Commmunications Engineering, Parul institute of Engineering & Technology.
** Departement of Electronics & Commmunications Engineering, Parul Institute Technology.
*** Departement of Electrical Engineering, M.S.University of Baroda.

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ABSTRACT

Evolutionary algorithm is a stochastic search method that mimics the natural biological evolution and the social behavior of species. Artificial bee colony algorithm is also a kind of evolutionary algorithm which was proposed by Dervis karaboga in 2005.Such algorithms have been developed to arrive at near-optimum solutions of multimodal optimization problems, which may not be possible with traditional algorithms. This paper describes implementation of ABC algorithm on complex benchmark functions like rastrigin, rosenbrock; sphere and schwefel the analysis of the performance of ABC algorithm were compared for the optimization of above benchmark functions with Partical Swarm Optimization (PSO). The ABC algorithm was successfully implemented in software tool 'c'.

Corresponding Author:

Second Author,
Departement of Electronics & Commmunications Engineering,
Parul institute of Technology,
PO - Lomda, Ta-Waghodia, Vadodara, India.
Email: hareshsuthar@rediffmail.com

1. INTRODUCTION

There is a trend in the scientific community to model and solve complex optimization problems by employing natural metaphors. This is mainly due to inefficiency of classical optimization algorithms in solving larger scale combinatorial and/or highly non-linear problems. It is a well-known fact that classical optimization techniques impose several limitations on solving mathematical programming and operational research models.Classical optimization method needs good initial guess and if this initial guess is not good than it stuck up into the local optima and can't solve the multimodal optimization problems. Artificial Bee Colony algorithm which is powerful optimization tool that has been proposed in the past few years [3]. In this paper, ABC algorithm is successfully implemented and tested over the standard Benchmark functions.

The rest of the paper is organized as under, section two contains brief explanation of ABC algorithm; third section contains Pseudo code for ABC Algorithm with example; fourth section describes Descriptions of Benchmark functions; fifth section describes Optimization of Benchmark function using ABC Algorithm in Linux 'c', and at lat conclusion and reference.

2. ARTIFICIAL BEE COLONY ALGORITHM

A colony of honey bees can extend itself over long distances in order to exploit a large number of food sources at the same time[1]. The foraging bees are classified into three categories

1) Employed bees
2) Onlookers bees
3) Scout bees.

All bees that are currently exploiting a food source are known as employed bees.Employed bees exploit food sources and they carry the information about food sources back to the hive and share this information with onlooker bees [2].

Onlooker bees are waiting in the hive for the information to be shared by the employed bees. The employed bees shares the information about their discovered food sources and scout bees searches for the new food sources. Food patches with large amounts of nectar that can be collected with less effort tend to be visited by more bees, whereas patches with less nectar receive fewer bees. Employed bees share information about food sources by dancing in the designated dance area inside the hive. The nature of dance is proportional to the nectar content of food source just exploited by the dancing bee. An onlooker bee watches the dance and chooses a food source according to the probability proportional to the quality of that food source. Therefore, good food sources attract more onlooker bees compared to bad ones. Whenever food source is exploited fully, all the employed bees associated with it abandon the food source, and become scout.

Scout bees can be visualized as performing the job of exploration, whereas employed and onlooker bees can be visualized as performing the job of exploitation. The foraging process begins in a colony by scout bees being sent to search for promising food patches. When they return to the hive, the scout bees who have found a patch that is rated above a certain quality threshold go to the dance floor to perform a dance known as the waggle dance. This mysterious dance is essential for colony communication, and contains information regarding a food patch: like the direction in which it will be found, its distance from the hive and its quality rating (or fitness). This information helps the colony to send their bees to food patches precisely. Each individual's knowledge of the outside environment is solely derived from the waggle dance. This dance enables the colony to evaluate the relative merit of different patches like the quality of the food they provide and the amount of energy needed to fetch it. While searching from a patch, the bees monitor its food level. This is necessary to decide upon the next waggle dance when they return to the hive. If the patch is still good enough as a food source, then it will be advertised through waggle dance and more bees will be recruited to that source [4].

In the ABC algorithm, each food source is a possible solution for the problem under consideration and the nectar amount of a food source represents the quality of the solution represented by the fitness value. The number of food sources is same as the number of employed bees and there is exactly one employed bee for every food source. This algorithm starts by associating all employed bees with randomly generated food sources (solution). In each iteration, every employed bee determines a food source in the neighborhood of its current food source and evaluates its nectar amount (fitness).

The i^{th}food source position is represented as $Xi = (xi1, xi2 \ldots xid)$. F (Xi) refers to the nectar amount of the food source located at Xi. If an employed bee's new fitness value becomes better than the best fitness value achieved so far, then the employed bee moves to this new food source abandoning the old one, otherwise it remains in its old food source. When all employed bees have finished this process, they share the fitness information with the onlookers inside the hive, each of which selects a food source according to the probability. The probability depends on the quality of the food source. With this scheme, good food sources will get more onlookers than the bad ones. Each bee will search for better food source around neighborhood patch for a certain number of cycles (limit), and if the fitness value will not improve within limitnumber of cycles, then that bee becomes scout. The procedure is continued until the termination criterion is attained [5, 6].

3. PSEUDO CODE FOR ABC ALGORITHM WITH EXAMPLE

Main steps of the algorithm are given below:

1. Initialize the food source positions.
2. Each employed bee produces a new food source in their food source site and exploits the better source.
3. Each onlooker bee selects a source depending on the quality of her solution, produces a new food source in selected food source site and exploits the bettersource.
4. Determine the source to be abandoned and allocate its employed bee as scout for searching new food sources.
5. Memorize the best food source found so far.
6. Repeat steps 2-5 until the stopping criterion is met.

3.1 Step by step procedure of ABC Algorithm

Consider following function for optimization.

$$F(x) = x_1^2 + x_2^2 \qquad -5 <= x_1, x2 <= 5 \qquad (1)$$

Control Parameters of ABC Algorithm are set as: Colony size, CS = 6, dimension of the problem, D = 2, Limit for scout, L = (CS*D)/2 = 6.

3.1.1 Step 1: Employed Bees Phase

Employed bees are half of colony size.

EB=CS/2;

Initialization Phase

First of all, initialization of the positions of 3 food sources (CS/2) of employed bees is randomly done Using uniform distribution in the range (-5, 5).

x =	x1	x2
1.4112	-2.5644	
0.4756	1.4338	(2)
-0.1824	-1.0323	

Hence f(x) values are substituting in equation (10 values of x1, x2.

8.5678
2.2820
1.0990

From these values we can calculate the value of the fitness function using following equation.

$$\text{Fitness function: } fit_i = \begin{cases} \frac{1}{1+f_i} & if\ f_i \geq 0 \\ 1 + abs(f_i) & if\ f_i < 0 \end{cases} \quad (3)$$

After substituting values of f(x) in equation (3) initial fitness of Employed Bees vector is:

0.1045
0.3047
0.4764

Here maximum fitness of the employed bee is 0.4764. To improve the fitness of the employed bee iteration cycle starts.in iteration cycle employed bee tries to improve its location by finding better neighborhood location.

3.1.2 Step 2: produces a new food source.

The following formula produces a new solution.

$$V_{i,j} = x_{i,j} + \Phi_{ij}(x_{i,j} - x_{k,j})$$

Where,

k=1; k is a random selected index.
j=0*; j* is a random selected index.

For, first employed bee location

$\Phi = 0.8050$; Φ is randomly produced number in the range [-1, 1].

V_0=2.1644 -2.5644

Calculate function and fitness of the new location.

$F_0(x)$ =11.2610 fit_0=0.0816

Now, by using the greedy selection method between X0 and V_0 gives us best Solution for our problem.0.0816 < 0.1045 (comparing with initial fitness vector), the solution 0 couldn't be improved so increase its trial counter.

For second employed bee

$V_{i,j} = x_{i,j} + \Phi_{ij}(x_{i,j} - x_{k,j})$

$\Phi = 0.0762$; Φ is randomly produced number in the range [-1, 1].

V_1=0.4756 1.6217

Calculate function and fitness of the new location.

$F_1(x)$ = 2.8560 fit_1 = 0.2593

Now, by using the greedy selection method between X_1 and V_1 gives us best Solutionfor our problem.0.2593 < 0.3047, the solution 1 couldn't be improved so increase its trial counter.

For third employed bee

$V_{i,j} = x_{i,j} + \Phi_{ij}(x_{i,j} - x_{k,j})$

Φ = -0.0671 ; Φ is randomly produced number in the range [-1, 1].

V_2=-0.0754 -1.0323

$F_2(x)$ = 1.0714 fit_2 =0.4828

Now, by using the greedy selection method between X_2 and V_2 gives us best Solution for our problem.0.4828 > 0.4764, the solution was improved so its trial counter is set to 0 and replace the solution X_2 and V_2.

3.1.3 Step 3: substituting improved solution and again calculating fitness.

Substituting improved solutions in matrix X equation (2).

X = x1 x2
1.4112 -2.5644
0.4756 1.4338
-0.0754 -1.0323

F(X) values are;
8.5678
2.2820
1.0714

Fitness vector is:
0.1045
0.3047
0.4828

3.1.4 Step 4: calculating probability using formula.

Calculate the probability values *p* for the solutions *x* by means of their fitness for onlooker bees.

$$P_i = \frac{fit_i}{\sum_{i=1}^{\frac{cs}{2}} fit_i} \quad (4)$$

p =
0.1172
0.3416
0.5412

3.1.5 Step 5: Onlooker Bee phase.

Produce new solutions V_i for the onlookers from the solutions *xi* selected and depending on *pi* and evaluate them. Onlooker bee chooses random employed bee as per the probability formula.

Improved solutions for onlooker bee

x =
1.4112 -2.5644
0.1722 1.4338
0.0348 -1.0323

f(x) values are;
8.5678
2.0855
1.0669

Fitness vector is:
0.1045
0.3241
0.4838

Memorize the best one

Best = 0.0348 -1.0323

3.1.6 Step 6: Scout Bee phase.

In this phase solutions which were not improved those solutions are replaced by the scout bee.
Trial Counter =

1
0
0

There is no abandoned solution since L = 6
If there is an abandoned solution (the solution of which the trial counter value is higher than L = 6); generate a new solution randomly to replace with theabandoned one.

3.1.7 Step 7: Check trial counter.

Cycle=cycle+1.

The procedure is continued until the termination criterion is attained.The following figure.1 shows the screen shot of optimized function F(x) $=x_1^2 + x_2^2$; -5<=x_1, x2<=5.

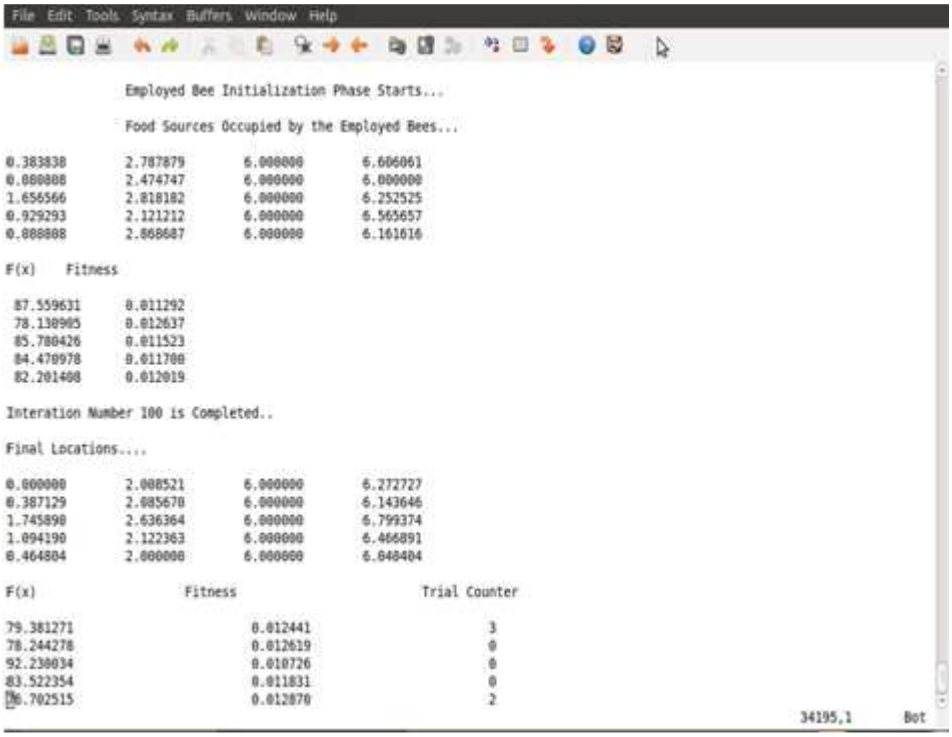

Figure.1.Screen shot of the above optimized function.

4. DESCRIPTIONS OF BENCHMARK FUNCTIONS.

In the simulation studies, Artificial Bee Colony (ABC) Algorithm was applied for finding the global minimum of the well-known four test functions. A function is multimodal if it has two or more local optima. A function of variables is separable if it can be rewritten as a sum of functions of just one variable. The problem is more difficult if the function is multimodal. The search process must be able to avoid the regions around local minima in order to approximate, as far as possible, to the global optimum. The most complex case appears when the local optima are randomly distributed in the search space. The dimensionality of the search space is another important factor in the complexity of the problem. Four classical benchmark functions are implemented using Artificial Bee Colony Algorithm.

The first function is Rastrigin [3] function whose value is 0 at its global minimum (0,0,…,0). Initialization range for the function is [−15, 15].This function is based on Sphere function with the addition of cosine modulation to produce many local minima. Thus, the function is multimodal.

$f_1(\vec{x}) = \sum_{i=1}^{D}(x_i^2 - 10\cos(2\pi x_i) + 10)$

The second function is Rosenbrock function whose value is 0 at its global minimum (1, 1… 1). Initialization range for the function is [−15, 15].

$f_2(\vec{x}) = \sum_{i=1}^{D} 100(x_i^2 - x_{i+1})^2 + (1 - x_i)^2$

The third function is Sphere function whose value is 0 at its global minimum (0, 0… 0). Initialization range for the function is [−100, 100].

$f_3(\vec{x}) = \sum_{i=1}^{D} x_i^2$

The fourth function is Schwefel function whose value is 0 at its global minimum (420.9867, 420.9867… 420.9867) . Initialization range for the function is [−500,500].

$f_4(\vec{x})$ = D*418.9829 $+\sum_{i=1}^{D} -x_i \sin(\sqrt{|x_i|})$

5. SIMULATION & RESULT OF ABC ALGORITHM.

The above discussed four benchmark functions were optimized using ABC algorithm in a language C. The screen shot is placed in the following figures and results of the parameters were compared with available results of PSO algorithm [7] in subsequent table 1&2.

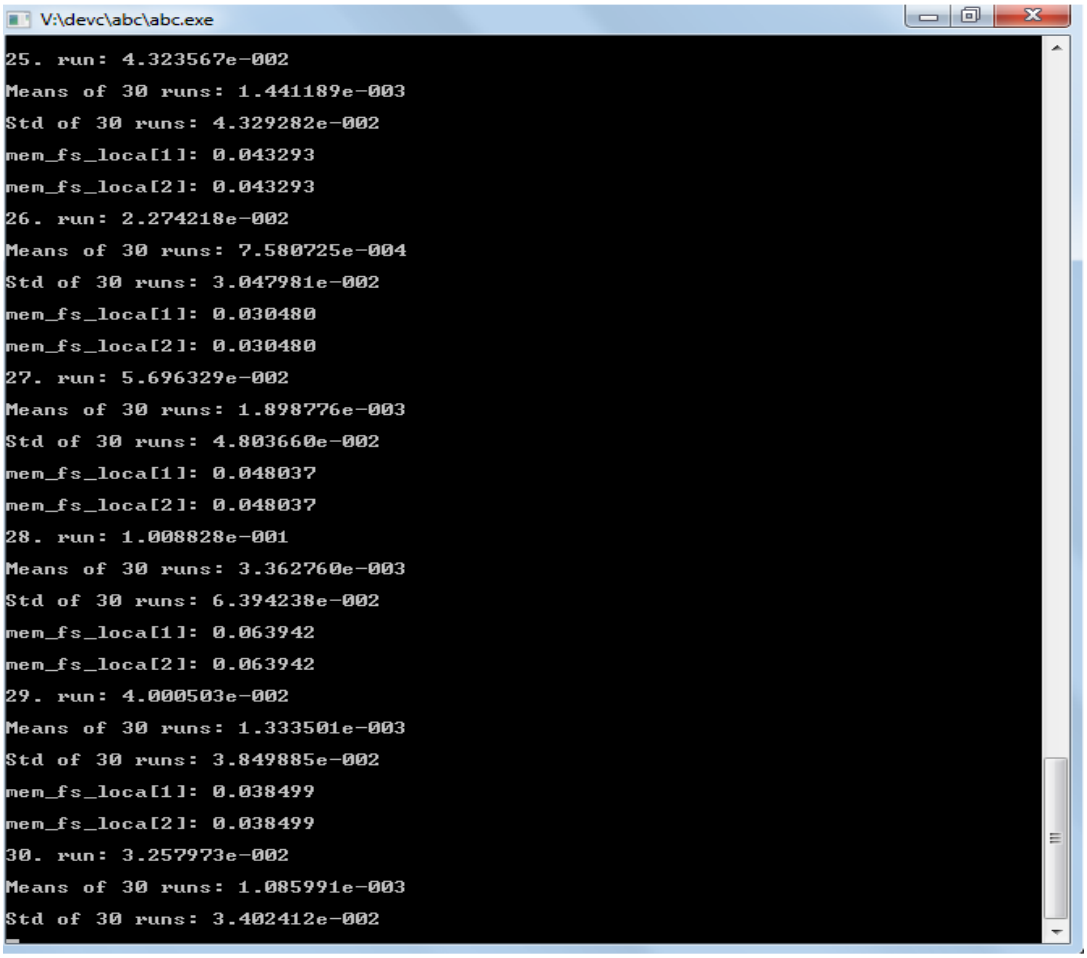

Figure 2 Optimization of rastrigin function

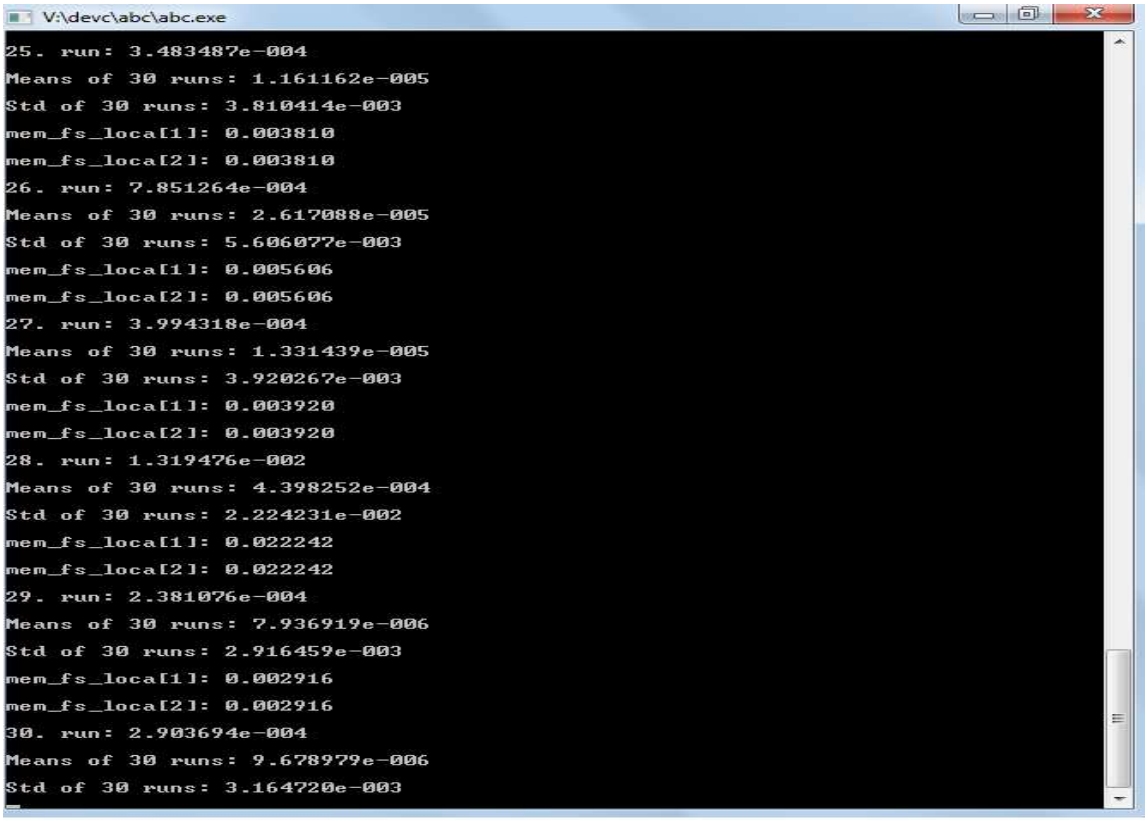

Figure 3Optimization of rosenbrock function

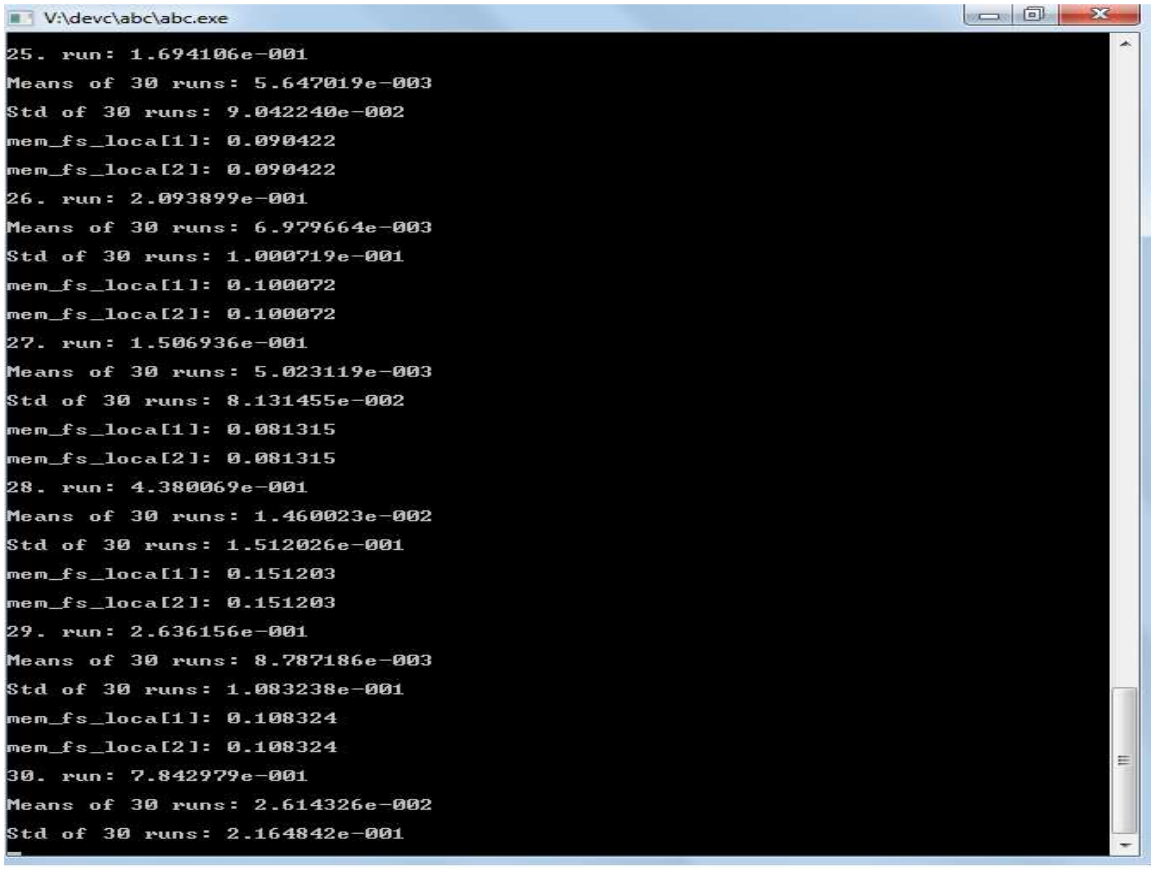

Figure 4 Optimization of sphere function

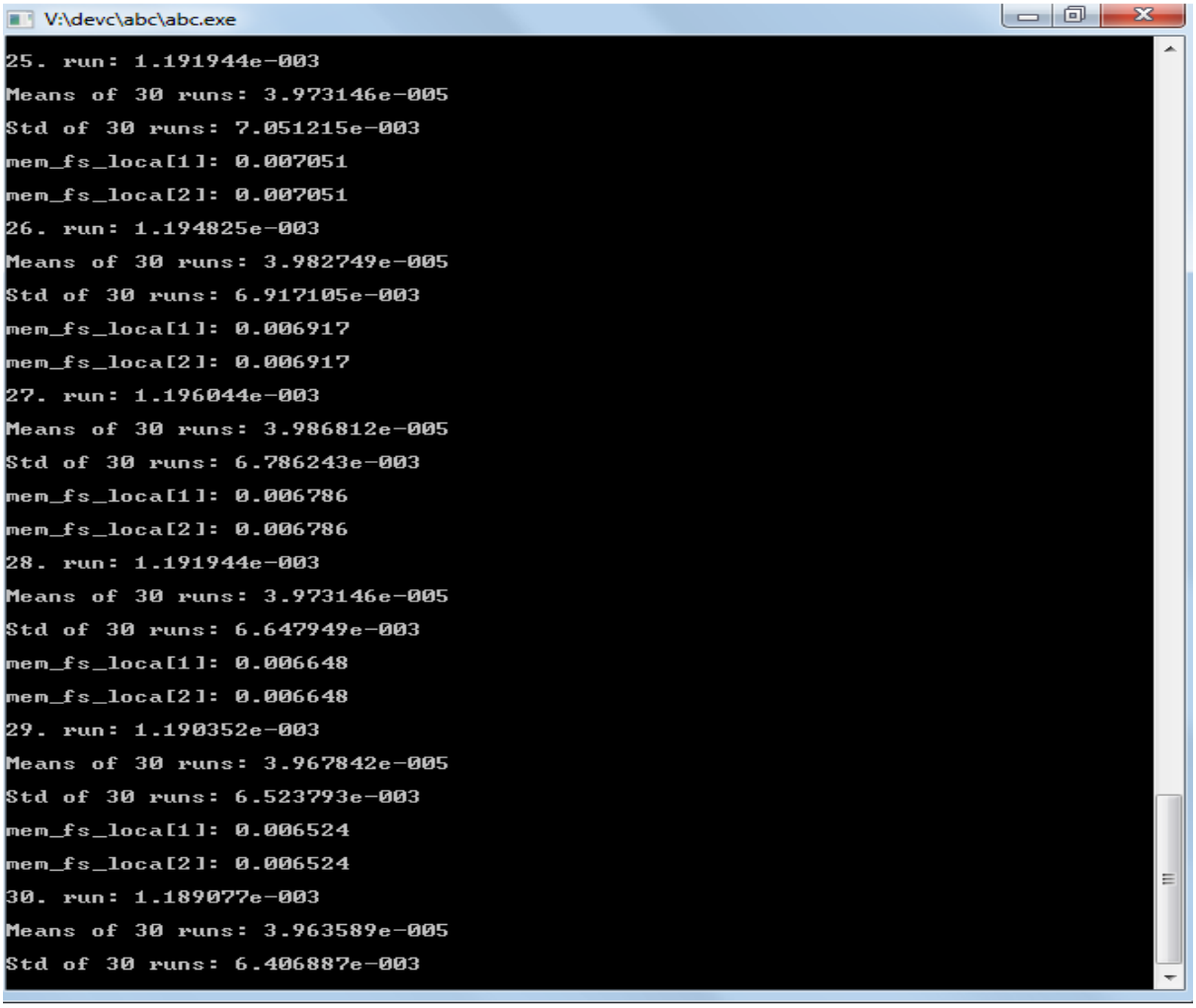

Figure 5 Optimization of Schwefel function

Table 1 Parameters of ABC Algorithm

Control Parameters of ABC Algorithm		
Parameter	Number	Constraint
Colony Size(CS)	9	No
Number of onlooker Bees	50% of CS	No
Number of employed Bees	50% of CS	No
Number of scout Bees	1	No
Number of Iteration	2000	No
Number of Runs	30	No

Table 2 Results obtained by ABC Algorithms & comparing with standered PSO algorithm.

Benchmark Function	PSO		ABC	
	Mean	Standard Deviation	Mean	Standard Deviation
Rastrigin	2.6559	1.3896	1.085691E-003	3.402412E-002
Rosenbrock	4.3713	2.3811	9.678979E-006	3.164720E-003
Sphere	1.10E-05	1.79E-05	2.614326E-001	2.164842E-001
Schwefel	161.87	144.16	3.963589E-005	6.406887-003

6. CONCLUSION.

The main objective of this paper is to describe step by step procedure with example for implementing ABC algorithm and after that apply it to some of the standerd functions. The ABC algorithm is successfully implemented and checked its performance with similar natur inspired algorithm i.e. PSO.

The benchmark functions which were taken are having different characteristics like multimodality, local minimias and difficult to converge. The parameter of ABC algorithm were set as shown in table 1 and result of standerd mean and deviation were compared with PSO algorithm for the same number of run and iteration. The result in the table 2 shows that ABC algorithm outperforms the PSO algorithm for the above four functions. Hence, we can conclude that ABC can be proposed as optimization algorithm of the function with similar characteristic. We cannot say that ABC is the better than PSO algorithm because, we have tested ABC and PSO only for limited benchmark functions, for different functions results may vary.

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BIOGRAPHIES OF AUTHORS

Vimal Nayak
He is purshing his Master in Electronics & Communication Enggineering at Parul Institute of Engineering & Technolohy,Vadodara.

Haresh A.Suthar
He is Reader and Head of the E&C Engineering Department at Parul Institute of Technolgy,Vadodara.He got his BE-Electronics and Master in Autmatic Control & Robotics from M.S.U of Baroda. His area of interest is embedded, control systems and Artificial Intelligence.

Dr. Jagrut J. Gadit
He is Reader in Electrical Engineering Department at Faculty of Technology & Engineering, M.S.U of Baroda.He received his BE-Electrical and Master in Automatic Control and Robotics.He is Phd in the area of control system.