Modified Bee Colony Optimization for the Selection of Different Combination of Food Sources

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Abstract: *There is a trend in the scientific community to model and solve complex optimization process by employing natural metaphors. In this area, Artificial Bee Colony optimization (ABC) tries to model natural behaviour of real honeybees in food foraging. ABC algorithm is an optimization algorithm based on the intelligent behaviour of honey bee swarm. In this work, ABC is used for solving multivariable functions with different combinations of them. That is, all the routes are identified to the bees and using all the possible combinations, the outputs are measured. Based on the output the optimum value is selected.*

Keywords: *ABC algorithm, optimization, benchmark functions.*

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1. Introduction

In the last two decades, the computational researches have been increasingly interested to the natural sciences especially biology as source of modelling paradigms. Many researches are massively influenced by the behavior of various biological entities and phenomena. It gave birth to most of the population based meta heuristics such as evolutionary algorithms, Particle Swarm Optimization (PSO) and bee colony optimization. Bee colony optimization is one of the best methods in the real world problems which are used to get the best optimal solution to the situation given. In the natural evolution, each species searches for beneficial adaptations in an ever changing environment. As species evolve, the attributes are encoded in the chromosomes of individual members. The term swarm is used in a general manner to refer to any restrained collection of interacting agents or individuals. The classic example of a swarm is the bees swarming around their hive but the metaphor can easily be extended to other systems with a similar architecture.

Several approaches have been proposed to model the specific intelligent behavior of honeybee swarms and applied for solving combinatorial type problems. Tereshko and Lee [13] considered a bee colony as dynamical system gathering information from an environment and adjusting its behavior in accordance to it. They established a robotic idea on the foraging behaviour of bees. Usually, all these robots are physically and functionally identical, so that, any robot can be randomly replaced by the others.

The swarm possesses a significant tolerance; the failure of a single agent does not stop the performance of the whole system. The swarm develops a collective intelligence. The experiment showed that the insect like robots are successful in real robotic tasks and this work has been established in [15]. They also, developed a minimal model of forage selection that leads to the emergence of collective intelligence which consists of three essential components: Food sources, employed foragers and unemployed foragers. This model defines two leading modes of the behavior recruitment to a nectar source and abandonment of a source [13, 14]. Teodorovic and Dell'orco [11, 12] suggested to use the bee swarm intelligence in the development of artificial systems aimed at solving complex problems in traffic and transportation and also proposed the bee colony optimization meta heuristics which is capable of solving deterministic combinatorial problems as well as combinatorial problems characterized by uncertainty [12]. Drias *et al*. [4] introduced a new intelligent or meta heuristics called Bees Swarm Optimization (BSO), which is inspired by the behavior of the real bees and they adapted it to the features of the maximum weighted satisfiability (max-sat) problems. The organization and arrangement of sources has been neatly explained and executed [18].

Similarly Benatchba *et al*. [1] introduced a meta heuristic to solve a S-sat problem based on the process of bees' reproduction. Weedle *et al*. [16] presented a novel routing algorithm called Bee Hive, which has been inspired by the communicative and evaluative methods and procedures of honey bees. In Bee hive algorithm, bee agents' travel through network regions called foraging zones. On their way their information on the network state is delivered for updating the local routing tables which has been discussed by Weedle *et al*. [16].

Fahimeh and Mohammed [5] used an algorithm which is the combinations of bees colony optimization with learning automata. This algorithm gives a control over the bees in the hives. Stanarevic *et al.* [10] proposed a different bee colony optimization for constrained problems. Karaboga and Akay [6] proposed a powerful algorithm and it was compared with other optimization techniques, like Genetic Algorithm (GA), PSO and Particle Swarm Inspired Evolutionary Algorithm (PS-EA) have been compared. They found that ABC gives a better solution as compared to the other techniques. Based on the suggestions discussed in this article, we proceed to take Artificial Bee Colony optimization (ABC) for producing better results in our area. Deb [2] developed a constraint handling method based on the penalty function approach which does not require any penalty parameter. Yang [17] discussed a model and applications of algorithm for the natural things. These have been discussed neatly in this work.

Lucic and Teodorovic [8] published the first study on bee system based on the PhD thesis of Lucic for Travelling Sales men Problem (TSP) and they aimed at exploring the possible applications of collective bee intelligence in solving complex traffic and transportation engineering problems. In this context, TSP and vehicle routing problem were studied. In this paper a different possible combinations of collective food sources are identified. Using a different ABC algorithm, we tried to optimize the output. SengPoh [9] proposed a paper to compare the performance of GA with different operation techniques by using the benchmark functions. This can prove that different techniques applied in the operations can let GA produces different result. Based on the experiment result, GA is proved to perform well in the optimization problems but it highly depends on the techniques implemented.

2. Proposed Modified Bee Colony Algorithm for the Combinations of Food Sources

The Bee system consists of two essential components. They are food sources and foragers.

1. Food Sources: The value of food source depends on different parameters such as its proximity to the nest, richness of energy ease of extracting this energy.
2. Foragers:
   a. Employed Foragers: Based on the nature, recruitment is done. These recruited Bees finds the food sources and also the nature of food contained in the food source are also identified.
   b. Unemployed Foragers: (Scout Bee) If a Bee starts spontaneously without any knowledge. This nature is known as Scout Bee.
   c. Experienced Foragers: These types of foragers use their historical memories for identification of the location of the food sources and also, the quality of the food source.

Using the above hypothesis, one can conclude that the employed foragers are the experienced too. The food sources are classified on the basis of the nature and the amount of food contained in the food source.

Let x denotes the nature of food contained in the food sources and let $X(ij)$ be the amount of food contained in the respective food source i. A model structure of a hive with food sources is neatly illustrated in Figure 1.

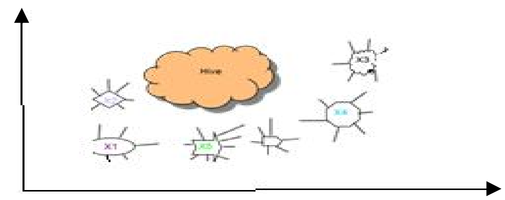

Figure 1. The representation of hive with the corresponding food sources.

Let $X=\{X_1, X_2, X_3, ..., X_m\}$ be the m number of food sources and let $X_{ij}=\{X_{1j}, X_{2j}, X_{3j}, ..., X_{mj}\}$ where j= 1, 2, 3, ..., n, n being the number of food sources having the same nature. The food sources have different tastes (for example, the bees always collecting the honey from different flowers with different flavours. Each flower is the food source for the bees and the flavors are the nature) with different nature to each.

This system has a set of unemployed foragers and a set of employed foragers. There are no restrictions about the number of employed foragers. If there are m number of food sources, the number of employed foragers, obviously, may be less than or the strength may be more than the number of food sources. So, if the numbers of bees are more than the number of food sources, there is a chance of collecting the information from a food source that is done by more than bee. When a bee is considered for knowing the optimal collection policy, its value is counted from all the food sources. Then, finally, the optimum value is calculated by adding the value of the food collected at each of the food source where the bee met. The collection process is monitored and administered by a set of experienced foragers. These types of foragers find the number of employed bees and the capacity and the ability of them in collecting the information from the food sources. This ability is defined as the fitness function of the bees. Let fi denote the ability function or a value of the honey which is collected by the i^{th} bee from all the food sources or from a few. The fitness f unction of the bees is calculated using the formula $F=f_i/ \Sigma f_i$ where i is the food source. If the food sources equal to m, the number of bees can be sent in multiples of m.

According to the multiplier, the percentage of bees can be selected and sent for collecting the food. This percentage is calculated using fitness function.

For example, a manufacturing company produces a different type of products. If it is interested to know the popularity of rates from the people who are using the products, then the company should use any of the following criteria viz., the advertising, marketing strategy etc., by considering the above case in to account, there may be different types of criteria are applied in each case. Let us assume, without loss of generality, that the criteria like advertising, marketing are noted to be stages. The different possibilities in each stage are known as states. If a product passes through all stages with different combinations of states, the output is discussed to the entire product which is passing through all of the products. The following diagram illustrates the food collection places and also it illustrates the way of combining the canters on the stages specified.

Algorithim 1 MBC algorithm for combining and to select the optimum solution is discussed as below:

Algorithm 1: MBC algorithm for combining and to select the optimum solution.

Step 1: *Initialize the stages and state variables.*
Step 2: *Find the fitness values of all products and select the number of bees to be sent for employing the decided work.*
Step 3: *Decide the number stages and let it be m.*
Step 4: *Send the number of bees which is equal to or multiples of m.*
Step 5: *Decide the number of combinations to each state among the stages*
Step 6: *Memorize the solution at each step and the subsequent values which are collected by the bees at each stage is added.*
Step 7: *Find the total value obtained by all the bees.*
Step 8: *Go to step 2 and repeat the process till all the recruited bees collected the information from the algorithm.*
Step 9: *Find the maximum of all of the above bees. This will give the optimal solution.*

3. Explanations of the Algorithm

In the first step, initialization of the stages and states are fixed. Based on the fitness function, the number of states in each stage is fixed. This may be considered and fixed in an interval. The lower limit gives the minimum amount of food source admitted and the upper limit of the interval represents the maximum amount of food source possible at the respective food source. There are two types of foragers. The first one is the experienced and the second type of Bee is called as the employed foragers. The first types of bees have the idea of food collection centers and the nature of the honey which is collected from the sources.

This first type is used to give the idea of the food collection centers and the nature of food with them. Initially, the experienced foragers identify the level of food sources. This gives the direction to the employed foragers to collect the honey. After the collection of honey by the second type of bees, the best combination is analyzed by the experienced foragers. The better result is explained and analyzed by this algorithm. A model representation of states and stages is depicted in Figure 2 and Table 1 show some modified functions to explain and to verify algorithm.

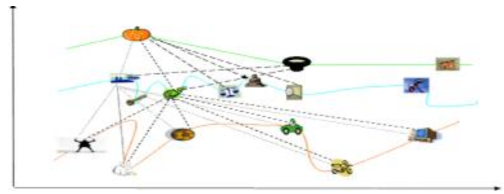

Figure 2. Different functions are denoted by the curves and the places where the honey is selected by the bees are indicated by the curves.

Table 1. Some modified functions.

No	Name of the Function	Equation of the Function	RRange	Nature F- minimum
1	Modified Sphere Function	$\sum_{i=1}^{N}\left[(X_i+(-1)^i\,i\,k)^2-(-1)^i\frac{N}{i}\right]$ Where k=3.125	(-100 , 100)	20.30
2	Modified Rosen Brock Function	$\sum_{i=1}^{N-1}\left[400\left[\left(X_{i+1}-\frac{i+1}{2}(-1)^{i+1}\right)-\left(X_i-\frac{i}{2}(-1)^i\right)^2\right]^2+\left(X_i-\frac{i}{2}(-1)^i\right)^2+i\right]$	(-30, 30)	435
3	Modified Quadratic Function	$\sum_{i=1}^{N}\left[i\left(X_i-(-1)^i\;k\;i\right)^4\right]+\frac{1}{2i}\;random\,[0,1)$ Where k=0.02	(-30, 30)	1.997

4. Numerical Example

Karaboga and Bastruk [7] introduced the ABC algorithm superior to DE, PSO and EA. In all of the algorithms discussed by others give the optimum solutions of single functions.

But in this MBC, more than one function has been chosen. In this algorithm, a comparison is made with a point on a function to all the points of other functions. Table 2 gives the idea on the functions which are in simplified forms rather the functions applied directly like modified functions.

Table 2. Some simplified functions.

S. No	Name of the Function	Nature of the Function (N- the Range of the Interval)
1	Simplified Sphere Function	$\left(X+(-1)^N\;N\;k\right)^2-(-1)^N$ Where k=3.125 in (-100, 100)
2	Simplified Rosen Brock Function	$400[(X-\frac{N+1}{2}(-1)^{N+1})-(X-\frac{N}{2}(-1)^N)^2]^2+[X-\frac{N}{2}(-1)^N]^2+N$ in (-30, 30)
3	Simplified Quadratic Function	$N\;[X-(-1)^N\;k\;N]^4+\frac{1}{2N}$ in (-30, 30)

For verification of the algorithm, some bench mark functions have been selected. Based on the above bench mark functions, some authors have discussed the optimum solutions to the individual functions. Dilay *et al*. [3] discussed with few bench mark functions for verifying the ABC algorithms. These have been named as modified benchmark functions. In this work, the above said algorithms have been simplified and they are used for the verification of modified bee colony optimization which is developed in this work.

The benchmark functions and the range of the variable have been discussed as below. The above author discussed the individual optimization to the functions separately by considering different levels and dimensions. Because of random initialization for both of the algorithms, the programs run for 30 times and the best, the worst and the average of these 30 runs have been presented in the paper which has been published by the above author. But in this work, simplified forms of the benchmark functions have been used and also the functions are grouped to find the optimal values.

The grouping is made at each point of a function with the points on the other function. The resultant value is then calculated for each combination. The best and the worst results have been identified, and then they are named as the maximum and the minimum values of the combination. This gives the combined effect of the functions. The above said functions are simplified and they are discussed as below. The simplified functions are not considered for repeated calculations because the motive of the algorithm is to find the combined effect of functions not on the optimum level of the functions individually.

The above functions are represented with some points on them in Figures 3, 4 and 5 and each point is known as the value of the respective function at a particular point. The points on each function are marked with smaller circles. These circles are to be grouped with the circles of the other functions.

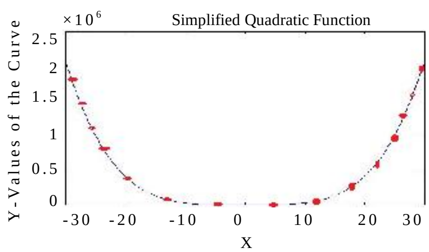

Figure 3. Some points on quadratic function.

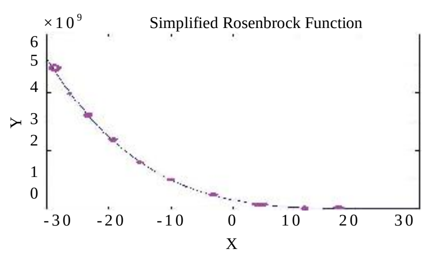

Figure 4. Points on rosenbrock function.

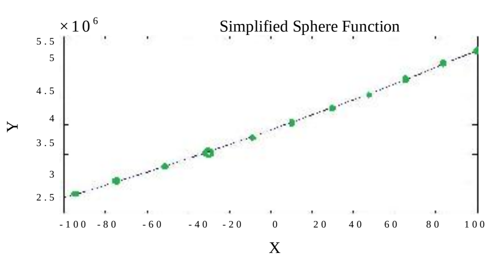

Figure 5. Some points on sphere.

There are many points assumed in a particular interval and correspondingly the values of the function at all the points are identified on the curve. The value of the function on every curve at each point is different. If the curve is considered individually, the optimum value may be selected easily. But, the MBC algorithm discusses the comparison of the points on a curve with the points on the other curves by making a linear combination of all the functions. The optimum value is then identified. Using *C* Program, the optimum combination of the above which are assumed as the bench mark functions is calculated. The value is equal to 13086.36987.

5. Conclusions

In a marketing scenario of all factories which are concerned with the results of the output of all regions, the better combination of the output gives the factory a good margin and the profit too. This method yields the idea of giving the best solution in terms of combination of the different types of outputs.

6. Future Works

This MBC algorithm gives the optimum value of the combination of a group of some related functions. There is no weight age assigned to the states in every stage. The weight ages can be allotted with respect to the probabilities of existence of the individual state of nature.

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