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Bacterial Foraging Optimization

Dr. Sunita Beniwal
Department of Computer Science and Engineering, Guru Jambheshwar University of Science and Technology, Hisar, Haryana, India

ABSTRACT

This paper reviews the optimization technique, Bacterial Foraging Optimization. The technique derives its working from Bacteria E.coli. The process of foraging is comprised of four mechanisms. The four mechanisms in the BFO algorithm are chemotaxis, swarming, reproduction and elimination-dispersal. This technique has been applied by many researchers for improving the performance of other techniques like genetic algorithms, particle swarm optimization etc. or has been used alone to solve optimization problems.

Keywords : Chemotaxis, swarming, reproduction and elimination-dispersal

I. INTRODUCTION

Passino [1] proposed bacterial foraging optimization algorithm i.e. BFOA which is an optimization technique which derives its idea from foraging behavior of Bacteria E. coli. The growth rate of E.coli bacteria is very high under suitable condition and sufficient food. The general behavior of E. coli bacteria is that in nutrient rich areas, its motion is very fast and if noxious substances are found in any area, it tries to move away from such areas. Taxes is the term used for the movement of the bacteria. The nutrients are to be searched and obtained in a manner so as to reduce the energy required. 8-10 flagella are placed randomly on the body of E.coli bacterium. Flagella are whip- like appendage on the cell body of bacteria, and helps in movement of bacteria i.e. swimming in aquatic environments. In bacteria the flagella are helical filaments that rotate independently like screws are made up of the protein flagellin. A few flagella may be used for signaling and sensation. The speed of flagella is around 100-200 rotations per second (rps).

II. BACTERIAL FORAGING OPTIMIZATION

The process of foraging is comprised of four mechanisms. The four mechanisms in the BFO algorithm are chemotaxis, swarming, reproduction and elimination-dispersal which are explained below and pictorial representation is shown in figure 3.2.

1. *Chemotaxis*

The E. coli bacteria have an inclination towards nutrient rich areas. They gather in such areas and this activity is called chemotaxis. An *E.coli* bacterium either tumbles or swims. Tumbling is the term used for a unit walk in a random direction. A run is a walk in the direction of the former step i.e. swimming. The bacteria continue to swim until fitness gets worse or when it reaches a predetermined threshold. Bacterium alternates between tumble and run in its search for food. The movement of bacteria is controlled by its flagella which can rotate clockwise or anticlockwise. When all the flagella rotate in counter clockwise direction, they propel the cell in a direction along a trajectory and this movement is a run. The bacterium moves in different directions with the flagella rotating in clockwise direction i.e. the bacterium tumbles. The location of bacterium is the solution of optimization problem. [2]

The location of any bacterium can be denoted as a D-dimensional vector θ. The formula for chemotaxis step is given below:

$$\theta^i(j+1,k,l) = \theta^i(\mathrm{j,k,l}) + \mathrm{C(i)}\frac{\Delta(\mathrm{i})}{\sqrt{\Delta^T(\mathrm{i})\Delta(\mathrm{i})}}$$

where c(i) is the run-length of the bacteria tumble movement, *J*(*i*, *j*, *k*, *l*) denote the cost and let θ^i(*j*, *k*, *l*) represents the location of *i-th* bacterium at *j-th* chemotaxis, *k-th* reproduction and *i-th* elimination-dispersal steps, and Δ is the randomly selected direction, whose elements lies in the range [-1, 1].

2. *Swarming*

Signals are sent by bacteria at time of stress in the form of attractants to other bacteria for swarming together. Repellant signals are also sent to others to maintain a minimum distance. Cell to cell attraction is signaled using attractant and repulsion by cell repellant. The values for the parameters need to be defined by the user. The cell-to-cell attraction and repelling effects are denoted as

$$J_{cc}(\theta, P(j,k,l)) = \sum_{i=1}^{S} J_{cc}^{i}\left(\theta, \theta^{i}(j,k,l)\right)$$

$$= \sum_{i=1}^{S}[-d_{attract}\exp(-w_{attract}\sum_{m=1}^{p}(\theta_{m-}\theta_m^i)^2)]$$

$$+ \sum_{i=1}^{S}[-h_{repellant}\exp(-w_{repellant}\sum_{m=1}^{p}(\theta_{m-}\theta_m^i)^2)] +$$

where J_{cc} (*θ*, P(*j*, *k*, *l*)) is the objective function value to be added to actual objective function to present a time varying objective function. S is the total bacteria, p is the number of variables, *θ* is a point in the optimisation domain and θ_m is the mth component of ith bacterium θ^i. $w_{attract}$, $d_{attract}$, $h_{repellant}$, $w_{repellant}$ are different coefficients used for signaling. The new fitness function will be calculated

$$J(i,j,k,l) = J(i,j,k,l) + J_{cc}((\theta_i(j,k,l)$$

3. *Reproduction*

Reproduction is done after chemotaxis is over. Fitness value of each bacterium is calculated and stored in decreasing order. The worst half is eliminated. Reproduction is done by making a duplicate copy of best half thus maintain a fixed size of swarm. The population size remains constant after the reproduction step. The health of bacteria is given by the following formula:

$$J_{health}^{i} = \sum_{j=1}^{Nc+1} J(i,j,k,l)$$

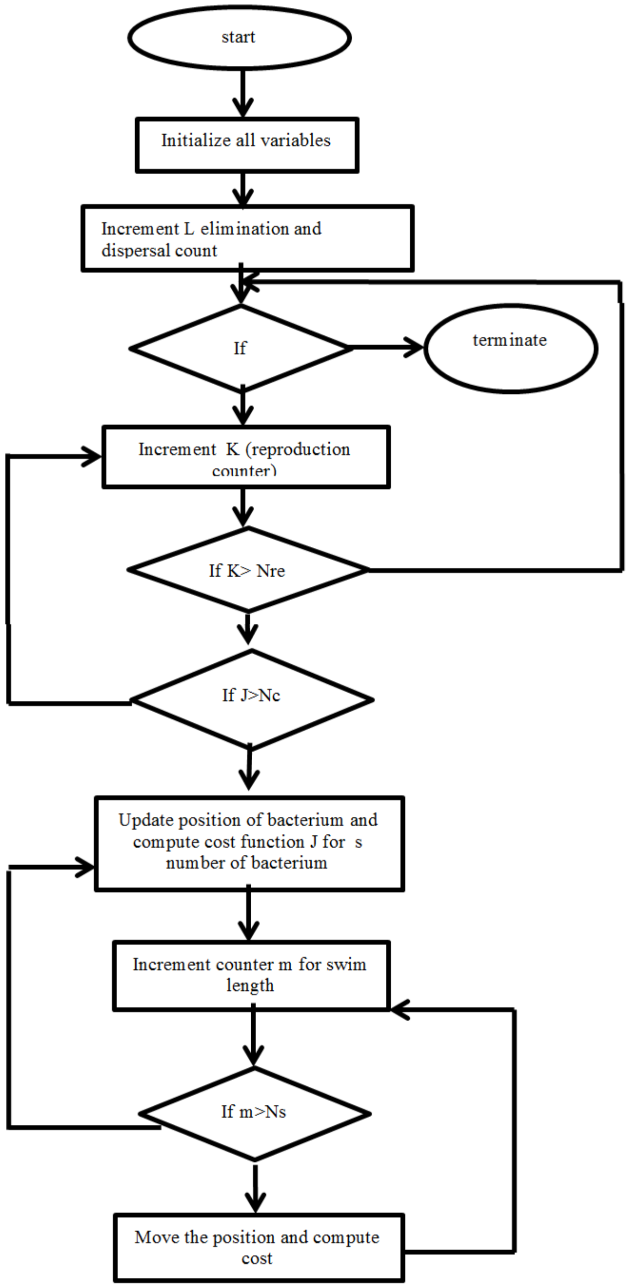

Figure 1: Flowchart of Bacterial foraging optimization algorithm

4. *Elimination and Dispersal*

To avoid bacteria being stuck around local optima positions, bacteria are diversified gradually or suddenly to obtain a global optima. This process of dispersion is done following a specified reproduction steps. Any bacteria are chosen for dispersal with a probability equal to elimination and dispersion probability and moved to another position within the environment.

III. APPLICATION OF BFO ALGORITHM

BFO has been used by many researchers for optimization. BFO algorithm and Particle Swarm Optimization algorithm have been used together for tuning a Fractional order speed controller and it was reported that the performance was good. [3] Kim et al. [4] proposed an efficient approach which used genetic algorithms and bacterial foraging algorithms to tune a PID controller of an automatic voltage regulator. Bacterial foraging optimization were also reported to train neural networks showing better speed and accuracy than Genetic algorithms and neural networks[5]. Lee and Lin proposed a strategy-adaptation-based bacterial foraging optimization algorithm for the optimization of complex problems by using strategy adaptation method in the chemotaxis step for improving the exploratory capability of each bacterium in the search space and showed improved performance[2]. Li and Zhu[6] used BFO algorithm for selecting an optimal set of parameters for ACO algorithm and reported that the proposed technique gave better results than other techniques using Genetic algorithm and PSO.

IV. CONCLUSION

Bacterial foraging optimization technique can be used for finding the best possible solutions to a given problem. It can be combined with other techniques to improve their performance.

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