LADAR Signal Modeling Using Bacterial Foraging Optimization Algorithm (BFOA)

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***Abstract*—There is a strong need for an optimized management of the accuracy verification of LADAR, it is necessary to assess the data quality and to develop data processing algorithms. However, the accuracy verification of LADAR system is difficult, because we cannot know the accurate reflected positions of the returned signals at target's surface. Under the consideration of this difficulty, the verification based on LADAR simulation can be a more feasible alternative solution. In this paper, a new optimization algorithm called Bacterial Foraging Optimization Algorithm (BFOA) is proposed for simulation&Optimization of the received signal. A BFOA discloses a simulation method which delivers the performance of the power detection in more economical ways.**

Keywords-LADAR Systems, Bacterial Foraging Optimization Algorithm. Range Gate.

I. INTRODUCTION

LADAR: Laser Detection and Ranging, or Laser Radar. A device consisting of a photon source (frequently, but not necessarily a laser), a photon detection system, a timing circuit, and optics for both the source and receiver. Distance from the device to targets struck by the emitted photons is measured by the time-of-flight (TOF) divided by the speed of light. Strictly speaking the device could be a single shot "0-D" measurement system (range only), but these are more commonly referred to as laser rangefinders. LADAR, on the other hand, is generally assumed to generate a 3-D Range Image. Range Resolution: The smallest distance separation between two distinct objects illuminated by a LADAR source that can be detected in the signal return. In large part this term is controlled by the bandwidth of the receiver. Laser Detection and Ranging (LADAR) is currently poised to become the ubiquitous 3D spatial measurement tool in many disciplines. Initially used for remote sensing and aerial surveying, LADAR applications now include reverse engineering (3D models), ground surveys, automated process control, target recognition, and autonomous machinery guidance and collision(1). Optimization is associated with almost every problem of engineering. The underlying principle in optimization is to enforce constraints that must be satisfied while exploring as many options as possible within tradeoff space. There exists numerous optimization techniques. Bio-inspired or nature inspired optimization techniques are class of random search techniques suitable for linear and nonlinear process. Hence, nature based computing or nature computing is an attractive area of research. Like nature inspired computing, their applications areas are also numerous. To list a few, the nature computing applications include optimization, data analysis, data mining,computer graphics and vision, prediction and diagnosis, design, intelligent control, and traffic and transportation systems.Most of the real life problem occurring in the field of science and engineering may be modeled as nonlinear optimization problems, which may be unimodal or multimodal. Multimodal problems are generally considered more difficult to solve because of the presence of several local and global optima. Bacterial Foraging Optimization proposed in 2002 by K.M. Passino is based on the foraging behavior of Escherichia Coli (E. coli) (2) .

II. LADAR SYSTEMS

Fundamental physics of pure "pulsed" time-of-flight is shown in Fig.1. Key performance metrics are synchronization precision of pulse initiation between the source and detector, pulse width and power, and detector bandwidth. (Adapted from Lange, 2000) (1).When the transmitted power becomes a waveform of piecewise rectangular segments, the power in the waveform detected by the LADAR receiver is computed via:

$$P_{det}(k,t) = \frac{\tau_o \tau_a^2 D_R^2 \rho_t (dA) P_t(k,t)}{R^2 \theta_R (\theta_t R)^2} \qquad \dots(1)$$

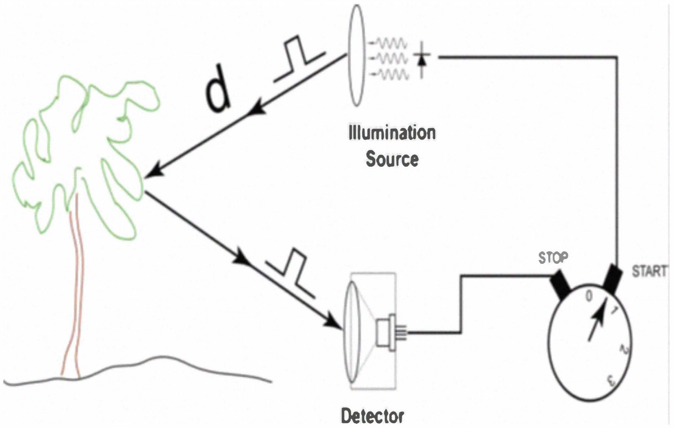

Figure.1: Fundamental physics of pure "pulsed" time-of-flight (1).

Operationally, to calculate the received waveform power as a function of time involves the construction of a loop over time indices. To calculate the received waveform power as a function of time involves the construction of a loop over time indices. This structure allows different discrete times to be visited in the simulation between the minimum and maximum times for which the receiver is programmed to measure the signal returning from the target. This set of times corresponds to the range gate of the LADAR system, R_{gate}:

$$R_{gate} = \frac{(T_{max} - T_{min})c}{2} \qquad \dots(2)$$

Where $T_{min}$the LADAR system corresponds to the first time begins to measure the return signal from the target, and T_{max}corresponds to the last time the return signal is measured. The target range profile takes the place of the target area variable times the surface reflectivity. In situations where the area of the target is determined by the IFOV of the sensor, the areas of the different surfaces in the IFOV will sum together to be equal to the total area *dA*. If the *dA*parameter times the reflectivity$\rho_t$is removed from the range equation, the returned signal power from a target can be computed that has an area of $1m^2$with a unity reflectance (4) :

$$P_{det}(k,t) = \frac{\tau_o \tau_a^2 D_R^2 P_t(k,t)}{R^2 \theta_R (\theta_t R)^2} \qquad \dots(3)$$

III. BACTERIAL FORAGING OPTIMIZATION ALGORITHM (BFOA)

The Bacterial Foraging Optimization Algorithm belongs to the field of Bacteria Optimization Algorithms and Swarm Optimization, and more broadly to the fields of Computational Intelligence and Metaheuristics. The Bacterial Foraging Optimization Algorithm is inspired by the group foraging behavior of bacteria such as E.coli and M.xanthus. Specifically, the BFOA is inspired by the chemotaxis behavior of bacteria that will perceive chemical gradients in the environment (such as nutrients) and move toward or away from specific signals. Bacteria perceive the direction to food based on the gradients of chemicals in their environment. Similarly, bacteria secrete attracting and repelling chemicals into the environment and can perceive each other in a similar way. Using locomotion mechanisms (such as flagella) bacteria can move around in their environment, sometimes moving chaotically (tumbling and spinning), and other times moving in a directed manner that may be referred to as swimming. Bacterial cells are treated like agents in an environment, using their perception of food and other cells as motivation to move, and stochastic tumbling and swimming like movement to re-locate. Depending on the cell-cell interactions, cells may swarm a food source, and/or may aggressively repel or ignore each other (3). The brief descriptions of these steps involved in Bacterial Foraging are presented below:

A. Chemotaxis

During chemotaxis, the bacteria climb the nutrient concentration, avoid noxious substances, and search for a way out the of neutral media. This process is achieved through swimming and tumbling. The bacteria usually take a tumble followed by a tumble, tumble followed by a run, or swim. This movement of bacteria in each chemotaxis step can be expressed by Eq. (4)

$$\theta^i(j+1,K,l) = \theta^i(j,K,l) + C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\,\Delta(i)}} \qquad \dots(4)$$

Where $\theta^i(j,K,l)$ represents position vector of i-th bacterium, in *j-th*chemotaxis step, in *k-th* reproduction step and in l-th elimination and dispersal step. $C(i)$shows the step size taken in the random direction specified by the tumble. *Δ(i)* depict the direction vector of the j-thchemotaxis step. When the bacterial movement is run or swim, *Δ(i)* is taken as same that was available in the last chemotaxis step; otherwise, *Δ(i)* is a random vector whose elements lie in [-1, 1].

B. Reproduction

Using Eq.(5), the health/fitness of the bacteria is calculated.

$$J_{health}^i = \sum_{j=1}^{Nc+1} J(i,j,k,l) \qquad \dots(5)$$

Where, Nc is the maximum step in a chemotaxis step. During reproduction, all bacteria are sorted in reverse order according to fitness values. The least healthy bacteria die and the rest healthiest bacteria each splits into two bacteria, which are placed in the same location in the search space. This makes the population of bacteria remains constant .The reproduction process of bacterial foraging aims to speed up the convergence suitable in static problems, but not in dynamic environment.

C. Elimination and Dispersal

The elimination and dispersal events assist chemotaxis progress by placing the bacteria to the nearest required values. In BFO, the dispersion event happens after a certain number of reproduction processes. Each bacterium according to a fixed probability dispersed from their original position and move to best position within the search space. These events may prevent the local optima trapping but lead to disturb the optimization process. Elimination and dispersal helps to avoid premature convergence or, being trapped in local optima (2).

D. Social Communication

In nature there is the social communication between Bacterium such that they are neither close together nor far away from each other. This is done by releasing the chemical by the Bacteria. The chemical signal can be either attractant or Repellent. If the chemical signal released by the particular Bacteria is attractant in nature, then nit attracts other Bacteria to come to its position. On the contrary if the chemical signal released by the particular Bacteria is Repellent in nature, it doesn't allow other Bacteria to come to its position. The social communication between Bacterium can be simulated using the modified objective function to be computed for the i_{th}position corresponding to the i_{th}position Bacteria as given below.

$$J_{mod}(X^i) = J(X^i) + J_{social}(X^i) \qquad \dots(6)$$

Where $J_{mod}$is the modified Objective function computed for the i_{th}position X^i corresponding to the i_{th}Bacteria.$J(X^i)$is the actual objective function value computed for the i_{th}position X^i corresponding to the i_{th} Bacteria. $J_{social}(X^i)$ is the attractant cum repellent signal computed for the i_{th}position X^i corresponding to the i_{th} Bacteria as displayed below.

$$Let\ d_{ij} = |\ |X^i - X^j|\ |^2$$

$$J_{social}(X^i) = M(\sum_{j=1}^{N} e^{-Rd_{ij}} - \sum_{j=1}^{N} e^{-Ad_{ij}}) \qquad \ldots.(7)$$

Note that if the first term is reduced if distance between the i_{th}position and others are made large and hence it acts as the repellent signal. Similarly the second term $\sum_{j=1}^{N} e^{-Rd_{ij}}$ is reduced if the distance between the i_{th}position and others are made small and hence it acts as the attractant signal. 'R' is the Repellent factor and 'A' is the attractant factor (5).

IV. COMPUTER SIMULATION AND RESULTS

A LADAR system is used to illuminate a target 1000 m away. if the receiver is set up with a range gate between 990 and 1010 m. The laser transmitter is assumed to be transmitting a Gaussian shaped pulse. The simulation has been used to obtained receiver pulse from one surface which is shown in Fig. 2, and to simulate and optimize the received power from two surfaces separated by 5 m is shown in Fig. 3. Using Bacterial Foraging Optimization Algorithm that allows simulating different cases of the received power with different space between two targets. We use the algorithm to try to find the minimum of the range gate in Fig. 4. We assume that this surface can be sampled, but that the gradient is not known. The bacteria are initially spread randomly over the optimization domain. The results of the simulation are illustrated by motion trajectories of the bacteria on the contour plot of function in Fig. 4 as shown in Fig. 5 and Fig. 6 in the first generation, starting from their random initial positions, searching is occurring in many parts of the optimization domain, and we can see the chemotactic motions of the bacteria as the black trajectories where the peaks are avoided and the valleys are pursued. Reproduction picks the 25 healthiest bacteria and copies them, and then, as shown in Fig. 5 and Fig. 6 in generation 2, all the chemotactic steps are in five local minima. This again happens in going to generations 3 and 4, but bacteria die in some of the local minima, so that in generation 3, there are four groups of bacteria in four local minima, whereas in generation 4, there are two groups in two local minima. Next, with the above choice of parameters, there is an elimination-dispersal event, and we get the next four generations shown in Fig. 7 and Fig. 8. Notice that elimination and dispersal shifts the locations of several of the bacteria and thereby the algorithm explores other regions of the optimization domain. However, qualitatively we find a similar pattern to the previous four generations where chemotaxis and reproduction work together to find the global minimum; this time, however, due to the large number of bacteria that were placed near the global minimum, after one reproduction step, all the bacteria are close to it (and remain this way). In this way, the bacterial population has foundthe global minimum. The final bacterial movement to explore the global minima is described in Fig. 9 because of the small pulse duration the detection power remains small. This process lasts until the time at which the rate of the detection power into the cooler zones is equal to the rate of the power of the received signal.

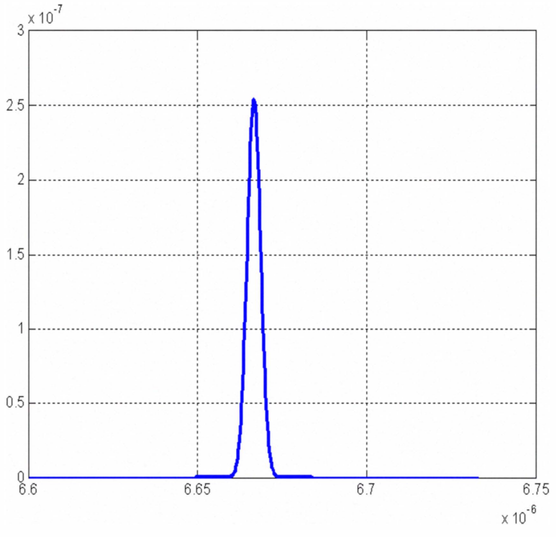

Figure 2. Received signal power as a function of time

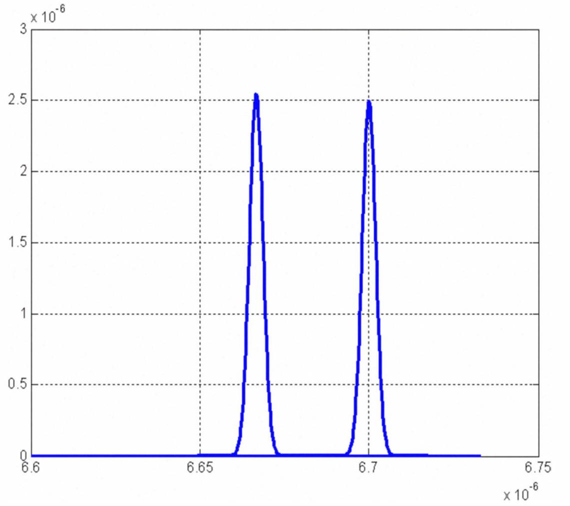

Figure 3. Plot of the received power from two surfaces separated by 5 m.

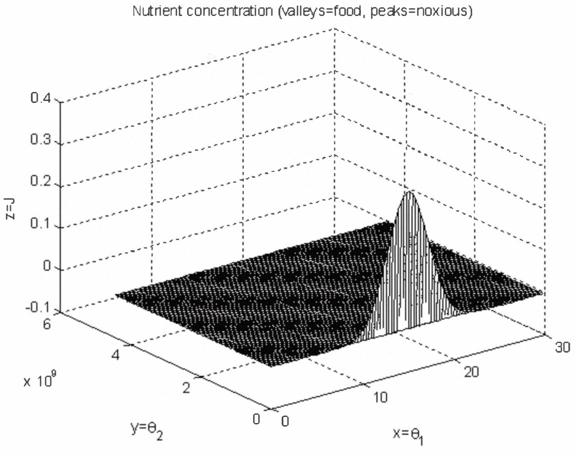

Figure 4.The intensity of power detection.

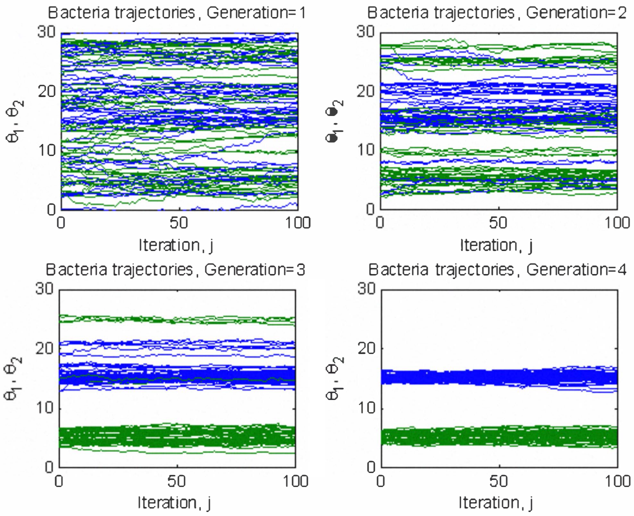

Figure 5.Bacteria trajectories through problem domain.

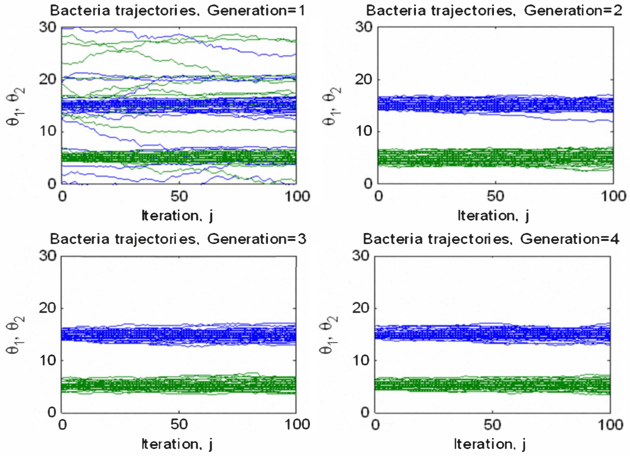

Figure 6.Bacteria trajectories through problem domain.

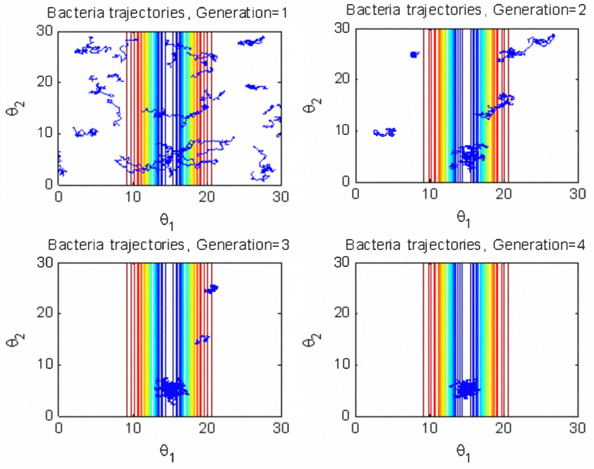

Figure 7.Bacteria trajectories through problem domain.

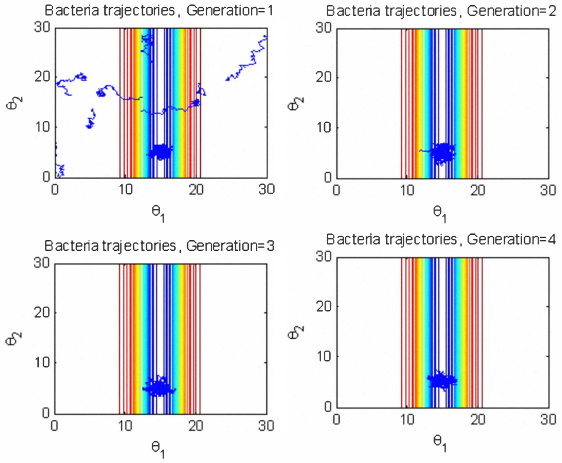

Figure 8.Bacteria trajectories through problem domain.

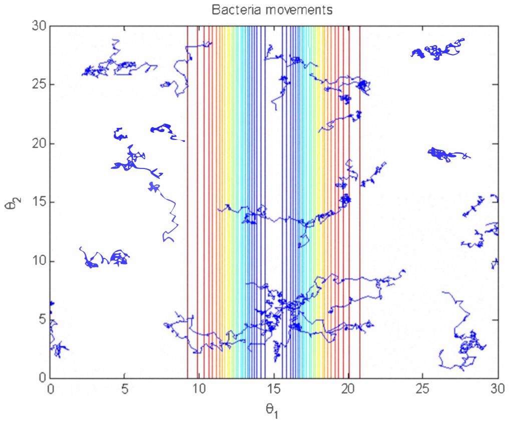

Figure 9.Bacteria movements.

V. Conclusions

As discussed earlier, our approach has been to enable LADAR systems to simulate the received signal from the surface of targets. So that they can interact with power detection more effectively. Two particular focus schemes, one for communication and one for cooperation in a task, illustrate Bacterial Foraging Optimization Algorithm which used in this approach.

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