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Autonomous robot path planning in dynamic environment using a new optimization technique inspired by bacterial foraging technique

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HIGHLIGHTS

- Increasing number of obstacles will need more time to reach goal.
- Nonlinear fitness function makes it useful in complex environment in a feasible time.
- Provides much smoother and less jagging path than the other method.

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ABSTRACT

Path planning is one of the basic and interesting functions for a mobile robot. This paper explores the application of Bacterial Foraging Optimization to the problem of mobile robot navigation to determine the shortest feasible path to move from any current position to the target position in an unknown environment with moving obstacles. It develops a new algorithm based on Bacterial Foraging Optimization (BFO) technique. This algorithm finds a path towards the target and avoiding the obstacles using particles which are randomly distributed on a circle around a robot. The criterion on which it selects the best particle is the distance to the target and the Gaussian cost function of the particle. Then, a high level decision strategy is used for the selection and thus proceeds for the result. It works on local environment by using a simple robot sensor. So, it is free from having generated additional map which adds cost. Furthermore, it can be implemented without requirement to tuning algorithm and complex calculation. To simulate the algorithm, the program is written in C language and the environment is created by OpenGL. To test the efficiency of the proposed technique, results are compared with Basic Bacterial Foraging Optimization (BFO) and another well-known algorithm called Particle Swarm Optimization (PSO) to give the guarantee that the proposed method gives better and optimal path.

1. Introduction

An autonomous mobile robot is a programmable and multi-tasks mechanical device capable of moving freely in the environment including obstacles; executing various functions and acquiring the environment information through the sensors. Usually, they are used in higher, deeper and riskier environment where human cannot imagine treading. For this, the last few decades have witnessed ambitious research efforts in this area of mobile robotics.

In order to achieve tasks, they are intelligent in deciding their own actions. Especially, the topic of navigation is one of the focused points in the correlation of mobile robots. As their use is increasing day by day and navigation is an essential and obvious task for initial interaction, the studies in this area deal now with autonomous indoor and outdoor navigations.

Navigation consists of two essential components known as

Localization which refers to the ability of determining accurate position at any moment relative to the search space according to the environment perceptions gathered by sensors.

Path planning is considered as the computation of an optimal path according to some criteria such as distance, time, cost, and energy. Distance and time being the most commonly adopted criteria. So, for designing a fast and efficient procedure for navigation, path planning is an essential aspect. It can be divided into classes according to the atomicity and availability of knowledge of the information about the environment which is shown below:

In the static environment, all the obstacles would be static, while in dynamic environment, obstacles can be both static and dynamic and may move at arbitrary directions with varying speeds.

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0921-8890/

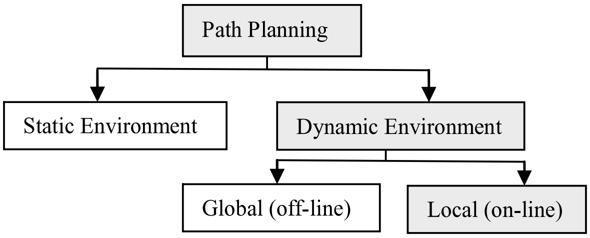

Fig. 1. Classification of path planning. (Scope is shown in dark.)

Again, in global planning, the map of the environment is totally known, where, in local planning, the information of the environment is not known in advance. So, the robot needs the capability to build a map of the environment (see Fig. 1).

As the real application contains arbitrary obstacles (moving and fixed) and most of the cases the environment remains unknown, so establishing an efficient path planning algorithm on local dynamic environment would be meaningful and significant; which is the main concern of this paper. A great number of different techniques in this regard have been and are being developed which can be classified as

(1) Analytical method.
(2) Enumerative method.
(3) Evolutionary Algorithm.

Each of these above methods has its own strengths and weaknesses. But the main weakness arise from the fact that the analytical methods are too complex to be used in tangible and enumerative search methods are overwhelmed by the size of the search space. On the other hand, many evolutionary algorithms have been shown to be ineffective in path planning when the search space is large.

To overcome these drawbacks, meta-heuristic approaches have been attracting considerable research interest in recent years like Ant colony algorithm, Particle Swarm Optimization, Bacterial Foraging Optimization. Among these, Bacterial Foraging Optimization is relatively new and has much scope. It meets all the major concerns, e.g. it can find the destination in a relatively short time which provides *efficiency*. By using this, a feasible path can avoid all known obstacles in the area which ensures *safety* of planning. Finally, it *accurately* and always finds and follows the determined path. It also reduces the difficulties related to path planning problem like it is easily computed avoiding most of the computational complexity, free from getting stuck in the local minima and no need to tuning algorithm which offers availability.

Therefore, this paper presents a new and modified algorithm on the basis of Bacterial Foraging Optimization. Using the facial appearance of BFO and the new method proposed, it makes the good solution better in terms of time and path's feasibility.

The remainder of the paper is organized as follows. In Section 2, recent works on BFO is discussed; Section 3 explains the problem formally; full description and implementation is presented in Section 4; Section 5 shows the experimental setup and result, and the paper is concluded in Section 6.

2. Related work

Researchers could apply the BFO algorithm successfully in various fields. For example, in the context of biologically inspired optimization methods, several models of bacterial chemotaxis algorithm based on the pioneered work of *Bremermann* [1] have been proposed in the literature for many applications including robotics [2]. In this paper, the foraging theory is applied to bacteria, adopting the bacterial colonies nomenclature. The fact that bacteria are one of the simplest living beings existing on Earth and they use the forage theory to benefit the group motivated this study. Bacteria own a control system that allows the foraging control and avoidance of noxious substances. In this context, the cooperation activity in a bacterial colony may be used in an optimization procedure, based on the forage strategy, as proposed by *Passino* [3].

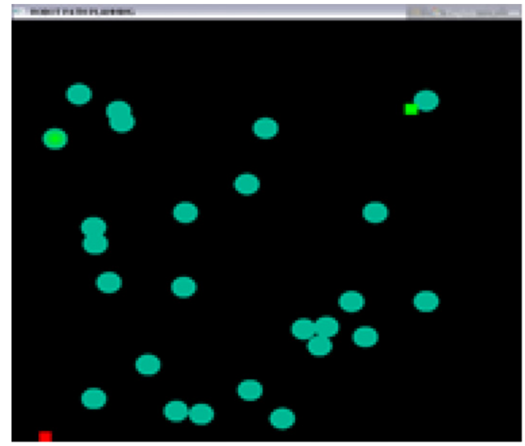

Fig. 2. Model of environment. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

An important feature of chemotaxis is exact adaptation: a change in the concentration of a chemical stimulant induces a rapid change in the bacteria's tumbling frequency, which gradually adapts back precisely to its pre-stimulus value [4]. Because of highly nonlinear and computationally expensive properties of path planning problem of mobile robots, developing efficient planning methods has been on focus of interest. Variety of techniques have been used to find smallest trajectory both in static and dynamic environments. One of the most popular planning methods is the artificial potential fields [5]. However, this method gives only one trajectory solution that may not be the smaller trajectory in a static environment. Recently, the interest in using evolutionary algorithms and swarm intelligence for robot path planning is increasing. Up to now, the genetic algorithm and bacterial foraging optimization are used in mobile robots trajectory planning, generally when the environment description is given [6,7].

So, we focus on the problem of path planning in a practical surrounding which can be categorized as an optimization problem to apply the BFO technique and modify it as necessary to solve the problem.

3. Problem representation

To search for an optimal robot path successfully, the model of an environment should be first constructed.

3.1. Environment

Fig. 2 shows the environment. It is a two-dimensional rectangular workspace where all the objects including robot, obstacles, source and destination point are located.

Mobile robot is defined as a white square object which is represented by $C(Cx, Cy)$ in the 2D space.

Obstacles are unpredictable objects that the robot may encounter during the execution of the task. In general, obstacles can be of any shape and size with a representation of each point by $O(Ox, Oy)$. To avoid a safe region around obstacles, the obstacle is wrapped by a circle. The radius, R of the circle is chosen in accordance with the size of the obstacle.

Goal is defined as a green square object which is represented by $G(Gx, Gy)$ in the 2D space.