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AN OPTIMIZATION PROCEDURE FOR MOBILE ROBOTS

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ABSTRACT

Autonomous navigation of mobile robots in an unknown cluttered environment is quite difficult task in the recent years. Many researchers have been developed several efficient methodologies in the navigation of mobile robot. The main objective of the mobile robot is to determine an optimal path for navigation, that means the robot should be navigate safely from the source to the pre-defined destination without colliding with the various types of obstacles present in an uncertain and complex environment. Path planning in mobile robots must ensure optimality of the path. The optimality achieved may be in path, time, energy consumed etc. A new algorithm named random particle optimization algorithm (RPOA) for local path planning problem of mobile robots in dynamic and unknown environments is proposed. The new algorithm inspired from bacterial foraging technique is based on particles which are randomly distributed around a robot This process is implemented without requirement to tuning algorithm or complex calculation, and furthermore, it is independent from gradient base methods such as heuristic (artificial potential field) methods. Therefore, in this paper, the problem of local mobile path planning is free from getting stuck in local minima and is easy computed.

1. INTRODUCTION

Application of mobile robots in industries, military activities, and indoor usages has been remarkably growing recently. In addition, in some missions such as hazardous or hardly accessible territorial, where humans could be in danger, mobile robots can carry out tasks such as nuclear plants, chemical handling, and rescue operations.One of the most challenging subjects in mobile robot's research is path planning. The path planning problem is usually defined as follows. Given a robot and a description of an environment, plan a path between two specific locations. The path must be collision-free (feasible) and satisfy certain optimization criteria minimum traveling distance [1]. Researchers have developed and used different concepts to solve the robot path planning problem. These concepts have been categorized into the following subclasses: the graphical approaches, the classical techniques and the heuristic approaches as well as the use of the potential field methods.Now-a-days mobile robot has lot of applications in industry, transportation, construction, aerospace and military operations. But the mobile robot should have learning capability to navigate safely in complex, unknown environment. In path planning, the aim of the mobile robot is to moves from source point to the target

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point without colliding with obstacles that present in environment. Firstly the path planning for navigation is divided into two categories: global path planning and local path planning. In global path planning the mobile robot have the prior knowledge about the environment and a collision free path is created to navigate the robot safely from the source point to target point. On the other side, local path planning (also called reactive strategy) means the environment is completely unknown for the mobile robot, in other sense the algorithm is capable of developing new path to reach at the destination point based on sensory information. Following path planning methodologies for autonomous mobile robots have been discussed in the review

UTONOMOUS navigation of mobile robots cover a wide spectrum of applications, including restaurants[1], libraries, and industrial and rescue robots [2]. The success of mobile robots in these applications depend on their intelligence capabilities, and of these capabilities, path planning is one of the most effective and important. This involves the creation of an optimised collision-free path from one place to another. Path planning can be divided into various categories depending on the nature of the environment: static path planning, where obstacles do not change their position with time, and dynamic path planning where the position and orientation of obstacles change with time. These can be further subdivided according to the knowledge level of the mobile robot into offline and online algorithms. In offline path planning, the mobile robot has a complete knowledge of the environment. Consequently, the path planning algorithm produces a complete path before mobile robot begins motion. In online path planning, however, information about the environment is obtained from a local sensor attached to the mobile robot, and the mobile robot requires the ability to construct a new path in response to the changes in the environment. This categorisation can be further subcategorised according to the target nature, into stationary target, where the mobile robot is searching for a static point in its workspace, and once it has located this point, never moves away from it; and dynamic target, wherein the mobile robot must search for a moving target while avoiding obstacles. In the latter case, the mobile robot and its target are both in motion [3]. Each scenario requires different path planning algorithms, and combinations of one or more of the aforementioned situations may require particularly complicated path planning algorithms. Path planning studies began in the late 1960s, and various techniques have been suggested involving cell decomposition [4], roadmap approaches [5], and potential fields [6]. The main drawbacks of these algorithms are inefficiency, because of high computational costs, and inaccuracy, because of the high risk of getting stuck in local minima. Adopting various heuristic methodologies can defeat the impediments of these algorithms, and these include the application of neural systems, genetics, and nature-inspired algorithms [7]. Rapid satisfactory solutions are one of the leading significant focal points of such heuristic methodologies, and these are particularly appropriate for finding solutions to NP-complete problems. Path planning on other hand can be divided into two groups according to the assumptions about the information available for planning. In path planning with complete information perfect knowledge about the robot and the environment are considered, shapes of obstacles are computed algebraically, and path planning is implemented offline. In path planning with incomplete information or sensor-based planning, the obstacles can be of arbitrary shape and the input information is, in general, local information from a range detector or a vision sensor [24]. Path planning could be either local or global. Local path planning means that path planning is done while the robot is moving; in other words, the algorithm is capable of producing a new path in response to environmental changes [25]. On the other, global path planning requires that environment to be completely known and all the features present within the terrain remain static and the algorithm generates a complete path from the start point to the destination point before the robot starts its motion.

2. RELATED WORKS

The primary requirement of autonomous mobile robots is to optimise the collision-free paths used. Numerous approaches have been used to solve single/multi-objective path planning problems for mobile robots, such as swarm/nature-inspired algorithms, neural networks, and fuzzy logic. The first group includes several previous studies that have exploited examples of natural swarm behaviours. The work utilised the standard Ant Colony optimization (ACO) to solve path planning problems for complex environments. The modified version of ACO exploiting the age of the ants has been applied to path planning using a grid-based method. Numerous works have also adopted heuristic methods and employed these to solve different aspects of path planning heuristic methods such as Particle Swarm Optimization , Cuckoo search (CS) algorithms, Self-adaptive bacterial foraging optimization (SABFO), Artificial Immune Systems, and the Whale Optimization Algorithm (WOA), which was implemented in a static environment to satisfy requirements for the shortest and smoothest path. GA and its modified versions are frequently implemented to find the shortest path for mobile robot path planning in different environments, while path planning using neural networks was developed. Integrating a path planning algorithm with the motion controllers of mobile robots was achieved, where several different motion control strategies were employed, including fuzzy logic controls , adaptive neuro-fuzzy inference systems, and model predictive controls. The Wind Driven Optimization (WDO) and Invasive Weed Optimization (IWO) algorithms were used to tune the parameters of the fuzzy logic controller and adaptive neuro-fuzzy inference systems, respectively, while ACO and PSO were used in the tuning of the fuzzy logic controller presented by [24]. The works incorporated two-level navigation algorithms, where the higher level was mainly concerned with path planning and guidance for the mobile robot, while the motion control directing the mobile robot in its configuration space was included in the lowest level. Path planning with energy constrained objective measures were demonstrated. The work in [7], and the

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references therein, are noted as a particularly excellent survey for path planning problems in mobile robots. One of the drawbacks in the studies mentioned is that throughout, the mobile robot was treated as a simple particle. While some of these algorithms were oriented toward finding the shortest path while avoiding static obstacles, others focused on the avoidance of dynamic obstacles while achieving the shortest distance without considering the smoothness of the path. Moreover, despite the ease of implementation of the gridbased methods used by some of the above researches, these have several disadvantages such as the imprecise representation of the obstacle, where if the obstacle occupies only a small area of the cell, the entire cell is nevertheless reserved for that obstacle. This leads to the waste of a space and less flexibility in a dynamic environment. Paper Contribution. The contribution of this paper is the development of a new path planning algorithm which consists of three main modules: the first module involves point generation, achieved using a novel heuristic nature-inspired algorithm, which is a hybridization between Particle Swarm Optimization and Modified Frequency Bat Algorithms, thus a PSO-MFB Algorithm. This fused algorithm generates and select the points that satisfy the multi-objective measure proposed in this work, which is a combination of shortest path and path smoothness. This algorithm was integrated with a second module, the Local Search technique, which converts infeasible solutions into feasible ones. In addition, to avoid obstacles, twelve sensors are deployed around the mobile robot to sense obstacles, and once such are detected, an avoidance algorithm is triggered. This is achieved in the third module, the Obstacle avoidance module. To the best of the authors' knowledge, no study found in the literature has previously combined a heuristic optimization algorithm, Local Search technique, and obstacle avoidance in a single integrated path planning algorithm

3. SYSTEM ARCHITECTURE

The wheeled mobile robot consists of IR range finders, position encoders; communication module etc.Three IR range finders will detect obstacles which are placed at RIGHT, FRONT and LEFT of the robot as shown in Fig.1. The position encoders will allow the robot to calculate how are the robot travelled from the location. The communication module, here Xbee, will allow the robot to communicate with the central station.

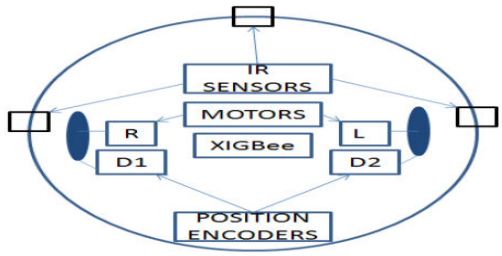

Fig -1: Wheeled Mobile Robot

Central Station consists of a desktop PC and a wireless module (Xbee). The central station will run the path planning algorithm, which will be communicated to the robot wirelessly. The environment is assumed to be a grid shaped known environment, where the location of robot is represented in 2D-cartesian coordinate system. Robot movement is assumed to be in vertical and horizontal direction, diagonal

movement is not considered. The assumptions and premises are as follows
i) Mobile robot is assumed to be point-size and occupies only one grid at a time
ii) Equipped with range sensors, position encoders, and communication sets
ii) Four moveable directions (North, East, South, West)

4. SWARM-BASED OPTIMIZATION

Swarm Intelligence (*SI*) is an artificial collection of simple agents based on nature-inspired behaviours that can be successfully applied to optimization problems in a variety of applications. The search process of such optimization algorithms continues to find new solutions until the stopping criteria are satisfied (either the optimal solution is found, or a maximum number of iterations is reached). These *SI* behaviours can be used to solve a variety of problems, and thus there are several *SI*-based algorithms. Two such algorithms are used in this paper.

A. Particle Swarm Optimization (PSO) Algorithm

This is a population-based heuristic strategy for optimization problems developed by J. Kennedy and R. C. Eberhard in 1995 [31], stimulated by the social conduct of schooling fish and flocking birds. It consists of a swarm of particles, and each particle in PSO has a position xi and velocity vi. The position represents a solution suggested by the particle, while the
velocity is the rate of change to the next position with respect to the current position. These two values (position and velocity) are randomly initialized, and the solution construction of a PSO algorithm includes two phases, as shown below:

 Velocity Update of the Particle

$$v_i(t+1) = v_i(t) + c_1 r_1 (pbest_i - x_i) + c_2 r_2 (gbest - x_i)$$

 Position Update of the Particle

$$x_i(t+1) = x_i(t) + v_i(t+1)$$

A. Proposed Hybrid PSO-MFB Algorithm

Hybridisation refers to mixing two or more optimization algorithms to obtain the advantages of all of these algorithms, and thus, as a result, increasing the overall performance of the optimization process. In this paper, a hybridisation between PSO and MFB algorithms is proposed. The variations of loudness, Ai, and pulse emission rates, ri, also provide an auto zooming capability for the optimization algorithm. Finding the optimum values of the MFB algorithm parameters (α, γ) is handled by the PSO algorithm. However, such parameter settings may be problem-dependent and thus tricky to define. In addition, the use of time-varying parameters during such iterations may be advantageous. The proper control of such parameters can thus be important, and consequently, variations of the parameter α (hence the loudness Ai) and the parameter γ (hence the pulse rate ri) within a suitable range have been adapted by the PSO algorithm to find a balance between *exploration* and *exploitation* in the MFB algorithm. The pseudo code for the proposed Hybrid PSO-MFB algorithm is shown in **Algorithm 1** and the overall procedure of the proposed Hybrid PSO-MFB algorithm is shown in Fig.2.

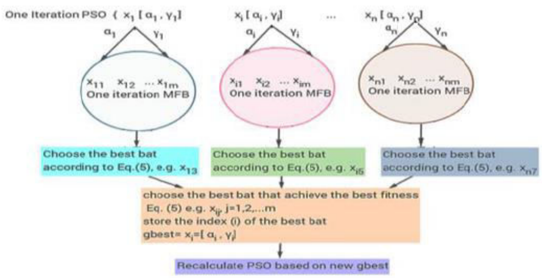

Fig.2. Proposed Hybrid PSO-MFB optimization algorithm.

Algorithm 1: Pseudo code for Proposed Hybrid PSO-MFB

1: Initialize PSO and MFB parameters: population size of n particles, r_1, r_2, c_1, c_2, population size of m bats, frequencies f_i, pulse rates r_i and the loudness A_i;
2: Randomly generate an initial solutions, $x_1 = [\alpha_1, \gamma_1]$, $x_2 = [\alpha_2, \gamma_2]$, …, $x_n = [\alpha_n, \gamma_n]$;
3: **for** $i = 1: n$
4: Call PSO algorithm, (10)-(11);
5: **end for**
6: **for** $i = 1: m$
7: Call MFB algorithm, (12)-(17);
8: **end for**
9: Choose the best bat that achieves the best fitness defined in (5), e.g. x_{kj}, $j = 1: m$;
10: Store index (k);
11: $Gbest = x_k = [\alpha_k, \gamma_k]$;
12: **If** stopping criteria not satisfied **then**
13: Update velocity and position of particles according to (10)-(11);
14: Go to 3;
15: **else**
16: obtain results;
end if

The solution of the PSO in the proposed algorithm is a vector of dimension 2, where (1,1) represents the value of α while $x(1,2)$ is the value of γ.

B. Proposed Local Search (LS) Technique

The solution is considered infeasible if the next point generated by the hybrid PSO-MFB algorithm lies within an area occupied by an obstacle. Another infeasible solution is where the next point, $wp(t+1)$, forms a line segment with the previous point, $wpj(t)$, and this line passes through the obstacle.

The LS technique converts these infeasible solutions into feasible ones. These two situations are explained in the following section with the aid of graphical and mathematical illustrations of the proposed solutions.

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CONCLUSIONS

This paper proposed a path planning algorithm for mobile robots using a Hybrid PSO-MFB swarm optimization algorithm integrated with Local Search (LS) and obstacle detection and avoidance (ODA) strategies. Path planning in known environment is designed and implemented. The robot could navigate to the target through shortest path. It was found that there are deviations from robots actual path from the desired path. This may be due to the wheel slippage, position encoder errors, battery charge fluctuation and difference in friction between wheel and path. This can be avoided using Simultaneous Localization And Mapping techniques like Extended Kalman Filter, Particle Filter etc. The deviation from the path can be predicted using probabilistic techniques and it can be corrected accordingly.

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