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Efficient collision-free path-planning of multiple mobile robots system using efficient artificial bee colony algorithm

Jun-Hao Liang, Ching-Hung Lee *

Department of Mechanical Engineering, National Chung Hsing University, Taichung 402, Taiwan, ROC

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ABSTRACT

This paper aims to propose a novel design approach for on-line path planning of the multiple mobile robots system with free collision. Based on the artificial bee colony (ABC) algorithm, we propose an efficient artificial bee colony (EABC) algorithm for solving the on-line path planning of multiple mobile robots by choosing the proper objective function for target, obstacles, and robots collision avoidance. The proposed EABC algorithm enhances the performance by using elite individuals for preserving good evolution, the solution sharing provides a proper direction for searching, the instant update strategy provides the newest information of solution. By the proposed approach, the next positions of each robot are designed. Thus, the mobiles robots can travel to the designed targets without collision. Finally, simulation results of illustration examples are introduced to show the effectiveness and performance of the proposed approach.

1. Introduction

Many researches are conducted for multiple mobile robots system since multiple robots can improve the working capability and performance. The task of the path planning is to guide the mobile robots toward the goal without collision with obstacles and other robots. Design of a fast and efficient method is one of the important problems for multiple mobile robots. Recently, there have been many interesting research work in the literature for path planning of mobile robots [1,3,4–16,26–32,35]. Many literatures indicated swarm intelligence techniques are among the methods that have recently received considerable interest in the area of mobile robot path planning [6,7,9,14,27]. As above, path planning is an important issue for multiple mobile robots system navigation, especially on-line path planning approach. In this paper, we consider the on-line path planning problem for multiple mobile robots system, which is the task of determining an optimal path from the initial position to the target while avoiding collision between robots and obstacles. Based on the artificial bee colony (ABC) algorithm, we propose an efficient method for solving the on-line path planning by choosing the proper objective function for target, obstacles, and robots collision avoidance.

The ABC algorithm is a new population-based algorithm which has the advantages of finding global optimization solution, being simple and flexible, and using very few control parameters [2,17–21]. The ABC algorithm has been applied to many real-world applications, e.g., function optimization, real-parameter optimization, digital filter design, clustering, neural network training [2,17–21,34]. Although the ABC algorithm benefits to the aforementioned advantages, it has something disadvantages of accuracy of the optimal value and low convergence speed. Herein, we propose the efficient artificial bee colony (EABC) algorithm to improve the performance of optimization. The proposed EABC algorithm enhances the performance by using elite individuals for preserving good evolution, the solution sharing provides a proper direction for searching, the instant update strategy provides the newest information of solution.

In this paper, the on-line path planning method for multiple mobile robots system without collision with obstacles and other robots is developed using the proposed EABC algorithm. This task can be transferred as an optimization problem with hybrid objective function, i.e., the proposed EABC with hybridization of objective functions for distances between goal, other robots, and obstacles are adopted to on-line plan the path of each mobile robot. This method results optimal paths of mobiles robots toward to the goal and without collision in travel period. Simulation results of illustration examples are shown to demonstrate the effectiveness and performance of the proposed approach.

The rest of the paper is as follows: Section 2 introduces problem formulation for path planning of multiple mobile robots. The on-line path planning design using EABC is introduced in Section 3.

* Corresponding author.
E-mail address: chleenchu@dragon.nchu.edu.tw (C.-H. Lee).

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Simulation results of illustration examples and discussion are presented in Section 4. Finally, conclusion is given.

2. On-line path planning strategy design of multiple mobile robots

Multiple mobile robots usually operate in the same environment for many situations. Thus, path planning problem becomes an important issue for multiple mobile robots system [3,7,11,14,27,29,30]. The off-line method is adopted usually for the case in which the environment is exactly known, and the on-line path planning is used for unknown environment. In this paper, the on-line collision-free path planning strategy for multiple mobile robots system is developed by using the proposed EABC algorithm with hybrid objective functions.

2.1. Problem description

At first, we introduce the environment of on-line path planning strategy for multiple mobile robots system shown in Fig. 1. The design goal is to determine the corresponding optimal path for each mobile robot such that the mobile robots move from the corresponding initial positions to the target "Goal" without any collisions with obstacles and other robots. Fig. 2 shows the illustration of EABC-based approach for multiple mobile robots system. Detailed description will be introduced as follows.

The proposed EABC algorithm is used to choose the optimal local position for next position in the neighborhood of each mobile robot. Herein, each mobile robot's state in the current time instant is defined by $(x_{ci}, y_{ci}, \theta_{ci})$, $i = 1,2,\ldots,p$, where p denotes number of robots. In this paper, the optimization problem for next position is evaluated by three values: objective value for Goal, objective value for obstacles avoidance, and objective value for robots avoidance. That is, the next planned positions (x_{ri}, y_{ri}) for ith robot is designed, where the subscript r denotes the planned position by EABC, and it also play the role of reference trajectory for tracking control of robots in the current time instant. In addition, the deriving angles are calculated by $\theta_{ri} = \tan^{-1}\left(\frac{y_{ri}-y_{ci}}{x_{ri}-x_{ci}}\right)$. Subsequently, the tracking control of each mobile robot can be solved by the results of [22–25], i.e., tracking controller generates suitable control action/signals (δd_i and $\delta\theta_i$) such that all mobile robots move to the next planned states $(x_{ri}, y_{ri}, \theta_{ri})$, $i = 1,2,\ldots,p$.

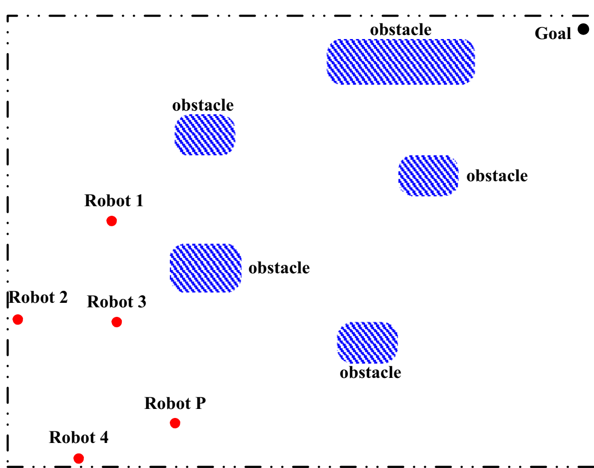

Fig. 1. Environment illustration of on-line path planning strategy for multiple mobile robots system.

2.2. Collision-free path planning by local navigation

Herein, the on-line path planning of multiple mobile robots is regarded as an optimization problem for searching local optimal position step by step. The optimization considers the distances between goal, obstacles, and other mobiles for designing the next position and collisions. The swarm intelligence techniques have recently received considerable interest in the area of mobile robot path planning. Herein, we use the proposed EABC algorithm to find the optimal path for next position. The next target position is searched in the neighborhood with a pre-selected radius r of the current position shown virtual mobile robots in Fig. 3. From Fig. 3, each robot uses its own EABC algorithm to find the optimal solution for next position. The current position of mobile robot is denoted by (x_c, y_c) and the virtual mobile robot position (x_i, y_i), $i = 1,2,\ldots,P_S$, where P_S is the chosen number of virtual robots, i.e., population number. It presents the individuals for minimizing the objective function, where d denotes the changing distance, d_x denotes the changing distance in horizontal, d_y denotes the

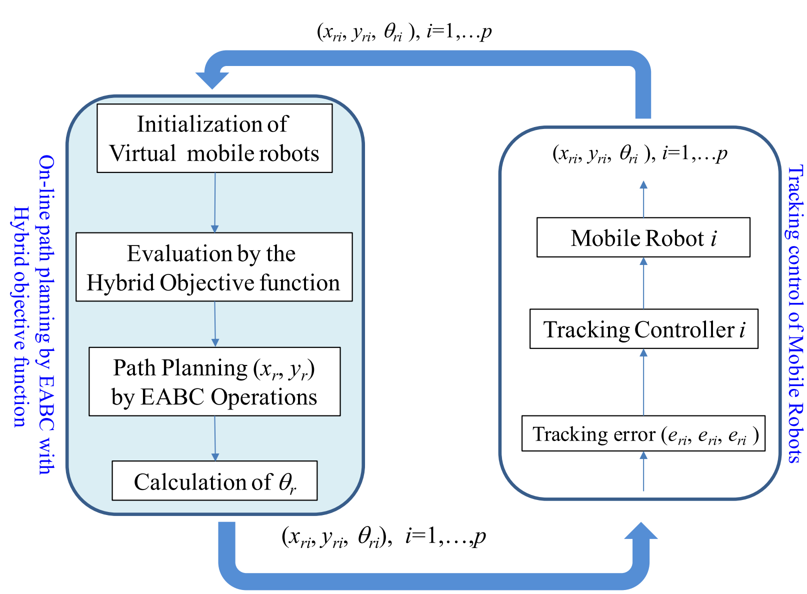

Fig. 2. The illustration of EABC-based approach for multiple mobile robots system.