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Integrated Motion Planning and Control for Multi Objectives Optimization and Multi Robots Navigation

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Abstract: This study proposes model of the optimal motion planner and controller for multi mobile robots. The proposed controller is responsible for avoiding the collision among multi robots after generating the optimal trajectory in term of multi objective for each robot. This work includes two stages: the first is to generate multi objective optimal path and trajectory for each robot independently from the start to the goal position using the modified genetic algorithm (**MGA**) with **A*** search algorithm (**A***). The second one is to establish a movement strategy to let the robots navigate with avoiding collision risk with each other by introducing Sugeno first order fuzzy controller. Five objective functions have been proposed in this study for minimizing travelling length, time, smoothness, security and trajectory and reducing the energy consumption for each mobile robot by using Cubic Spline interpolation curve fitting for optimal planned path. The simulation results show that the multi mobile robots navigate successfully with avoiding static obstacles as well as avoiding the collision between each other.

Keywords: Multi objective, multi robot, motion planner, motion controller, fuzzy control, optimization.

1. INTRODUCTION

A motion planning and controller for multi mobile robot are very important issues for the successful usage in different industrial applications. To allow the robot to travel between two specific positions and avoiding the collision risk in the surrounding environment, the motion planning and control need much treatment. Thus to create collision free path it should have proper motion planning and controller (Phinni at el, 2008). Current researches in robotics field aim to construct an autonomous and intelligent robot, which can find its motion in a dynamic environment. A successful usage of an autonomous mobile robot relies on its controller (Phinni at el, 2008).

Many researches had been done in this filed for instance (Taixiong at el, 2004) presented the path planning problem of multiple robots with communication between each other to perform a set of prioritized tasks in a dynamic environment. (Huwedi, 2010; Huwedi, 2011) investigated a master-slave based framework for deployment of group of mobile robots in an dynamic environment in order to explore their surrounding within a good exploration time. The framework architecture and the algorithms were carried out without taking into account the path planning problem in (Huwedi, 2010; Huwedi, 2011) and thus it is presented in (Budabbus, 2013) to complete the algorithms proposed in (Huwedi, 2010; Huwedi, 2011). It solved the problem of multi-robots path planning in static environment. The solution depends on decoupled approaches which are typically two categories: priorities and coordination of path planning.

Researches which had been carried out on mobile robot motion planning and control problems are still in progress. Some researches deal with multi robot without or with taking into consideration either the path planning problem or multi objective optimization. The work has carried out in this paper is to complete the proposed approach in (Bashra at el, 2014; Bashra et al, 2014) with taking into account the multi mobile robot, path planning and multi objective optimization. Moreover, six objective functions are used to minimize travelling length, time, smoothness and security for optimal planned path and trajectory. In addition reducing the energy consumption for mobile robots by using Cubic Spline interpolation curve fitting for optimal planned path and avoiding the collision risk between mobile robots by Sugeno fuzzy controller.

The rest of this paper is organized as follows. In section 2, the problem description is described. In section 3, the proposed approach to solve multi objective optimization of motion planning and motion controller problem is provided. After that, the simulation results are given in section 4 and finally, in section 5, we conclude and point out some possible research topics as the future work.

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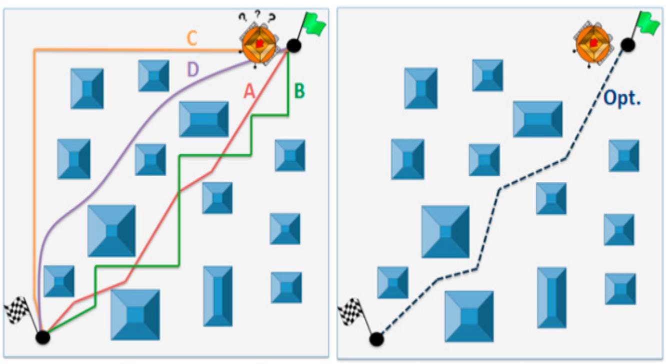
2. PROBLEM DESCRIPTION

The goal of this study is to drive multi mobile robots from the start point to the target point with the possible multi objective optimal path with avoiding the collision risk among them ant the static in the environment as in Fig. 1 and Fig. 2.



Path	Length	Smoothness	Security	Time
A	High	Medium	Low	Medium
B	Medium	Low	High	Low
C	Low	High	Low	Medium
D	Medium	Medium	Low	High
Opt.	High	Medium	Medium	High

Fig. 1. Motion planning in static environment

As it can be seen in Fig. 1, despite that path **A** is the shortest one, it has the lowest security performance. On the other hand, the best smoothness performance path is **C** with minimum total angles of all vertical line segments; however, it is the longest path. Although the best security performance is in path **B**, its length and smoothness are not the best. Path **D** has a minimum-time smooth trajectory and minimum energy consumption; nevertheless, it has the lowest security performance. Thus, the multi objective optimal trajectory planning of mobile robot is the dotted blue path, as shown in on the right of Fig. 1. It represents a trade off among multi criteria by taking the advantage of multiple solutions that can be obtained in a single run. In Fig. 2 shows the multiple mobile robots in static environment and each robot has to follow the optimal pre-planned path and to avoid the collision risk with another robot.

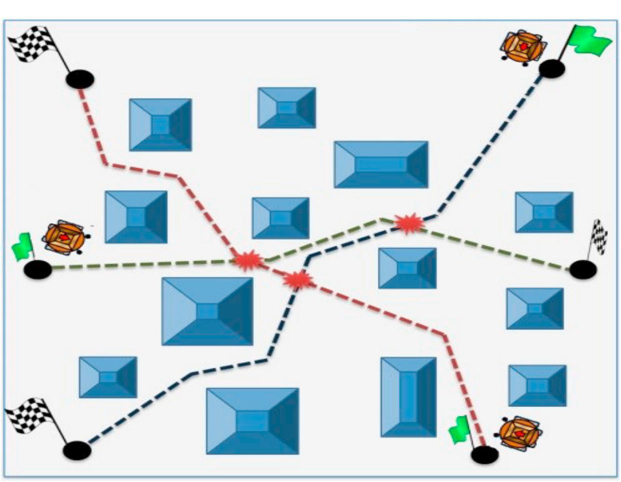


Fig. 2. Multi robots in static environment

3. PROPOSED MODEL

The proposed model includes two stages: the first is motion planner, which used to generate multi objective optimal path and trajectory for each robot independently from the start to the goal position using the **MGA** with **A***. The second one is motion controller, which used to establish a movement strategy to let the robots drive around with avoiding the collision with each other using Sugeno fuzzy controller. The general scheme of proposed approach is presented in Fig. 3.

3.1 Motion Planner

The motion planner which is introduced in (Bashra at el, 2014; Bashra et al, 2014) based on performing classic search and modification of **A*** to find sub-optimal path as initial population, to improve the performance and the search ability toward optimal solution of robot's movement. By applying the **MGA** the search for the optimal solution in term of multi objective optimal path and trajectory will be obtained for mobile robot navigation in complex static environment. Five objective functions are used to minimize travelling length, time, smoothness, security and trajectory and to reduce the energy consumption for mobile robots by using Cubic Spline interpolation curve fitting for optimal planned path. Hence, the basic **GA** operators, deleted operator and enhanced mutation operator with **A*** are used in **MGA** which are defined in (Bashra at el, 2014; Bashra et al, 2014). Accordingly the robot will not waste time by taking unnecessary steps and avoid getting stuck at "local optima".

3.2 Motion Controller

The Sugeno fuzzy controller has attracted the most attention because it is suitable for modelling and controlling the dynamics of complex nonlinear systems. The Sugeno inference has more computational efficiency and works better than Mamdani with optimization and adaptive techniques (Takagi and Sugeno, 1985; Zhang, 2006). Therefore, the first order Sugeno fuzzy inference model will be constructed to estimate the velocity of the robot. In this section we proposed the Sugeno fuzzy motion controller that contains the collision risk avoidance strategy and it is the second stage in our approach. It has two inputs, the first one is the optimal velocity ***V*** from the motion planner with 7 linguistic variables {**Max**: Maximum, **VH**: Very High, **H**: High, **M:** Medium, **S**: Slow, **VS**: Very Slow, **Min**: Minimum} and the second one is the distance difference between two mobile robots ***D*** with 5 linguistic variables {**VF**: very far, **F**: far, **M**: Medium, **C**: Close, **VC**: Very Close}. The output of the controller is the final velocity for the ground robot and it is linear Sugeno function given by the following:

$$f_i = a_i V_i + b_i D_i + c_i \quad (1)$$

Where a, b, c are the Sugeno linear parameters. The typical Sugeno rule is given by the following:

IF V_i is A_i AND D_i is B_i THEN *Final Velocity* is $f_i = a_i A_i + b_i B_i + c_i$.