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Real-Time Trajectory Planning Method for Mobile Robot Experimentation in Random Obstacles Environment

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Abstract- This paper presents a new real-time trajectory planning method for mobile robot in random obstacles environment, aiming to give an efficient implementation for "First Global After Local" trajectory planning method that we have established earlier. First, the global path planning method is employed the target direction angle tracking modeling. Then, the recursive algorithm is used for the evaluation of sub-target point. Finally, the swarm intelligence optimization is utilized for the local trajectory planning method. The real-time trajectory planning system is built and tested on the mobile robot platform, the experimental results prove that our method is effective and can be used in the real-time trajectory planning of mobile robots.

Keywords: Mobile robot, Real-time trajectory planning, Random obstacles environment, First global after local, Swarm intelligence optimization.

I. INTRODUCTION

Autonomous Mobile robot path planning problem is mainly divided into two categories of the global path planning for the known environment and the local path planning for unknown environment, the path planning in static known environment model is attained by the global path planning method based on the optimal algorithm. The majority of the working environment of mobile robot belongs to dynamic uncertain environment, including the unknown static obstacles and the moving obstacles of the moving track.

Real-time trajectory planning compasses the ability of the mobile robot to act on the basis of given knowledge about its dynamic environment and a goal position or series of positions and sensor values so as to reach its goal positions as efficiently and as reliably as possible.

A real-time algorithm for acquiring compact three-dimensional maps of indoor environments is using a range and imaging sensors equipped with a mobile robot, and building on previous work on real-time pose estimation during mapping[1]. Jung et. al. in 2014 proposed a human detection algorithm and an obstacle avoidance algorithm for a marathoner service robot(MSR) that provides a service to a marathoner while training, the mobile robot should have the abilities to follow a running human and avoid dynamically moving obstacles in an unstructured outdoor environment[2]. New enabling technology to bring traditional robotic tools on-line with combined monitoring and control capability was proposed by Liang et. al. in 2013[3], this method is extended to manipulate the wheeled mobile robot and to carry out a variety of assembly functions. A new real-time algorithm for the autonomous navigation of mobile robots equipped with laser scanners was introduced the height information of the obstacles into the guidance process and behaves as a 2.5-dimensional angle potential field algorithm (2.5D-APF) to fulfill the navigation requirements under complex outdoor terrain conditions[4]. Real-time collision-free motion planning for nonholonomic mobile robots in unknown dynamic environments was proposed by Yuan et. al. in 2013[5], by explicitly considering a dynamic model of the robots, the coefficients of trajectories are determined by boundary conditions, optimal performance index and collision avoidance conditions. The planned trajectory is feasible and has a closed loop expression, which is efficient for real-time updating.

In this paper, a comprehensive and efficient trajectory planning method is developed for mobile robot in the random obstacles environment. We first describe the real-time trajectory planning framework based on "First Global After Local" trajectory strategy that we have proposed earlier[6], then design the real-time trajectory planning system for mobile robot platform, and finally, the proposed method is tested on experimental environment. The results from experimentation justify the usefulness and the feasibility of this method.

II. REAL-TIME TRAJECTORY PLANNING SYSTEM

Random environment formulation

We combine the old information of the known environment and unknown status, called the random obstacles environment, the assumptions for random obstacles environment are follows as: (1) the working environment is the old known environment; (2) the location of target is known and fixed; (3) the obstacles are randomly distributed in the working environment; (4) the shape and size of the obstacle have a certain limited value range.

The old known environmental information is obtained by the geographic information system (GIS), and the obstacles can be detected by sensors in the motion process. Major requirement for the path planning is the possible shortest path with a certain security. The grid size is limited to the size of mobile robot. Polar coordinates and right Cartesian coordinates are both adopted for the description of the locations of mobile robot, because the polar coordinates is convenient for optimal operation and Cartesian coordinates is more efficient for marking trajectory.

Real-time trajectory planning framework

New real-time trajectory planning framework is generated to use the "First Global After Local" trajectory strategy, its trajectory strategy first improve the global path planning for the known information, then the known environment is changed by local environment information of real-time itself sensor, the sub-target position is determined by recursive algorithm, the local path planning and trajectory planning is based by swarm intelligence optimization (i.e. PSO, QPSO, LTQPSO, etc.), and the local target position (sub-target) become the global starting position of the next stage. New real-time trajectory planning strategy can ensure the requirement of the mobile robot (shortest path, minimum time. etc.) [6]. The framework is shown Fig.1.

The improved trajectory planning framework for a mobile robot are composed of the global path planning system, the evaluation sub-target position system, local path and trajectory planning system and trajectory tracking system.

The global path planning system based on the target direction angle tracking modeling is used by the GIS and is became the precondition of the online real-time local planning. According to the information of itself sensor, the evaluation sub-target position system determines the feasible sub-target position and the range of the local path, and ensures the target direction for the travelling direction of the mobile robot. Local path and trajectory planning system are guarantee that the mobile robot can work out the optimal path and trajectory planning in the local environment. We have already carried out the trajectory planning simulation of the mobile robot based on the proposed trajectory planning method, and get better results than the classical method[7].

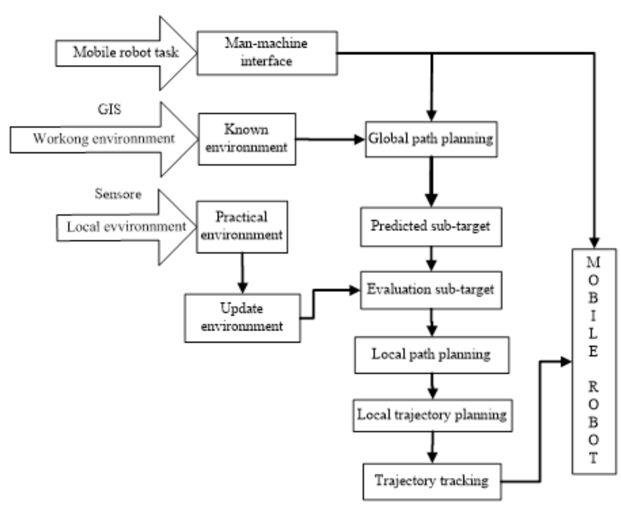


Fig. 1. real-time trajectory planning framework

Real-time trajectory planning experimental platform

The real-time trajectory planning test platform used the a differential mobile robot, and the experimental platform is shown in Fig.2.

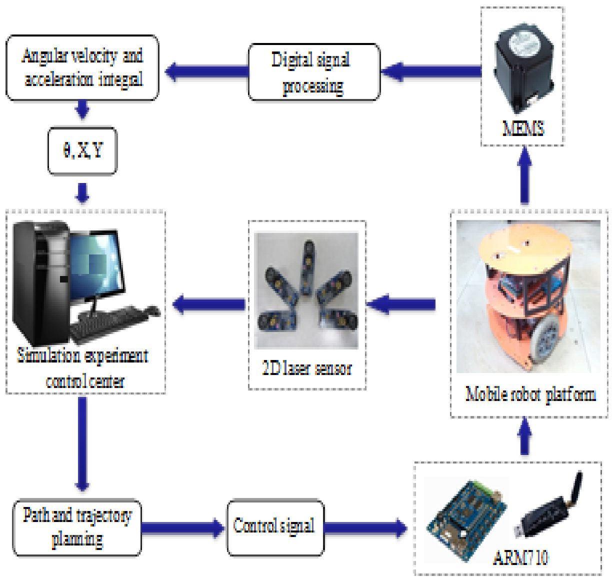


Fig. 2. real-time trajectory planning experimental platform system

Experimental platform system composes the four parts: (1) inertial measurement unit: MEMS gyroscope HMC5883l with temperature compensation of the new digital AnalogDevice company for the horizontal heading angle measuring sensor system, MEMS accelerometer ITG3205 as the X and Y direction of the system of measuring sensor by Kalman and particle filter for signal processing.

(2) 2D laser sensor: the detection of obstacles by laser scanning, the processing of local environmental signal and update map. (3) the simulation experiment control center: the NXP based on ARM7TDMI core of high performance mainstream LPC2148 processor, all the operation and processing algorithms and hardware peripherals control are achieved by the core processor. (4) communication unit: this system is independent of the mobile robot navigation and realize the real-time high speed serial communication between the mobile robot and the PC (e.g. robot upper controller).

III. EXPERIMENT AND ANALYSIS

In this real-time trajectory planning experiment, the main experimental objective is to verify validity and availability of the proposed method. The real-time trajectory planning experiment for the mobile robot are simulated in the laboratory environment, and the experimental software are carried out in the MATLAB R2010b GUI/ Simulink. The actual laboratory space is 3m·3m, the random obstacles is 0.1m·0.1m size and is nine number.

According to the our research results for robot path planning based on swarm intelligence optimization, local path and trajectory planning based on LTQPSO algorithm and basic parameter estimation equation with the average initial distribution were implemented on a PC with Intel Core i3 CPU540, 3.07 GHz, RAM 2.0GB running Win7 32bit. The mobile robot platform size is 0.4m·0.3m, the starting position is at (0,0) and the target position is at (10,10). The acceleration coefficient is set as c1=2, c2=2.1, the compression-expansion coefficient decreases from 1.5 to 0.5 linearly when the algorithm is running. The local and the global path planning dimension are respectively D=5, 10, the detection distance of the laser sensor is 0.7m.

Fig.3 to Fig.13 and Tab. 1 shows the true trajectory of mobile robot platform with experiment result. Fig. 3 to Fig.9 shows the running process and local path, actual trajectory variation curve, path planning result(total divided course into 6 part) for mobile robot platform under the laboratory environment, from Fig.10 to Fig.13 shows two wheel speed change value, X, Y position maximum variation value, course angle change value and the true trajectory of the mobile robot platform.

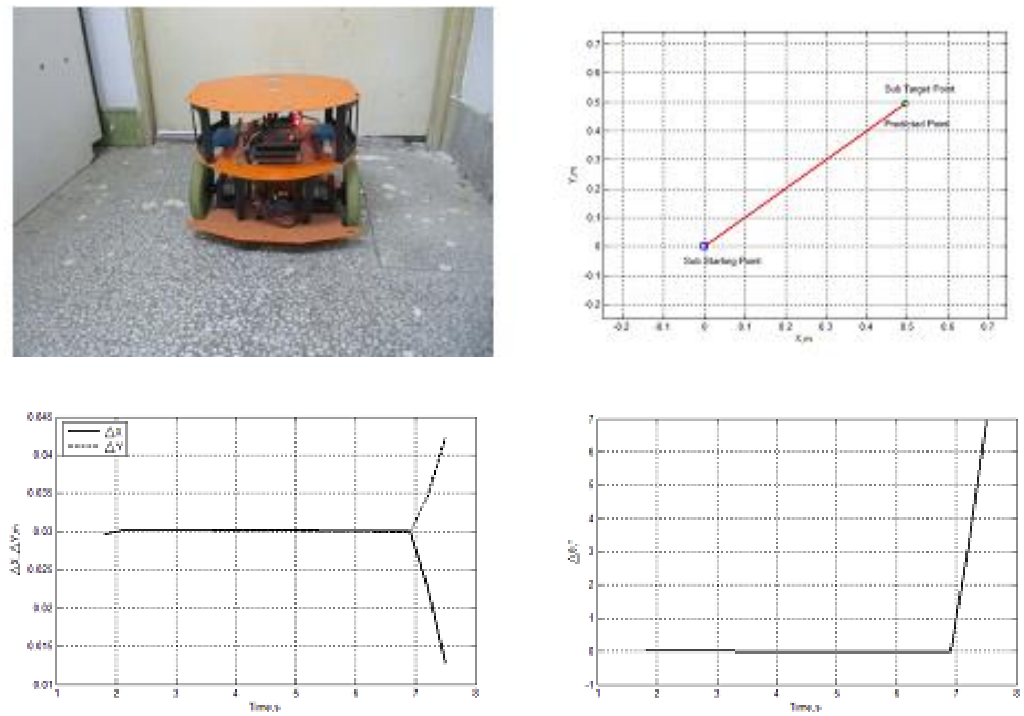


Fig. 3. When first part, experimental trajectory result

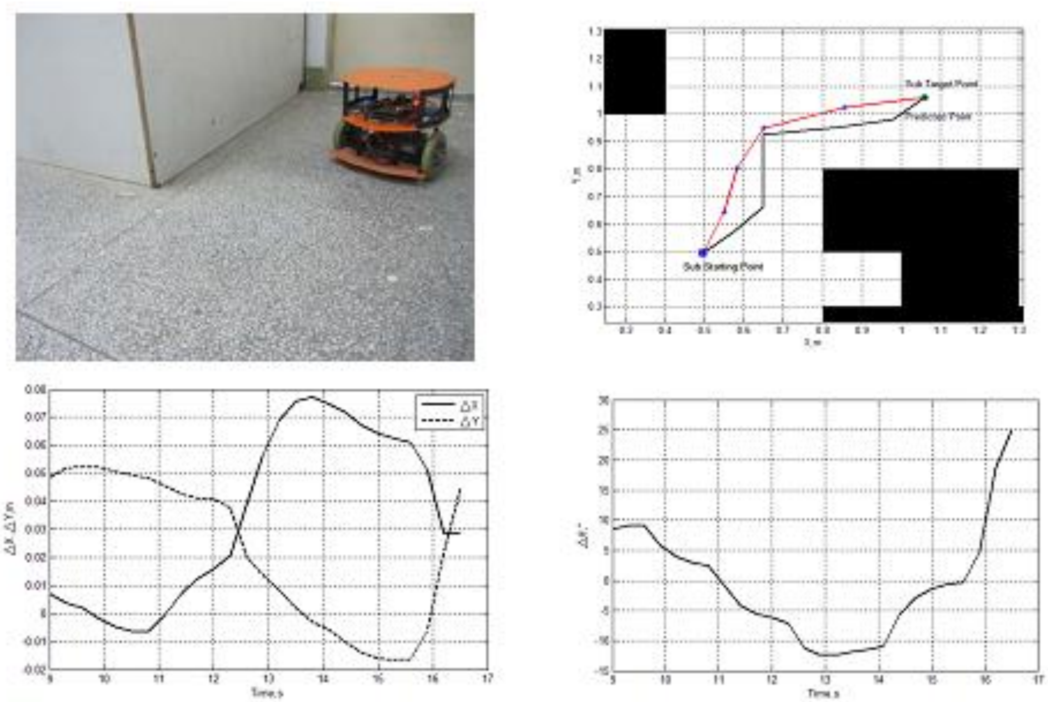


Fig. 4. When second part, experimental trajectory result

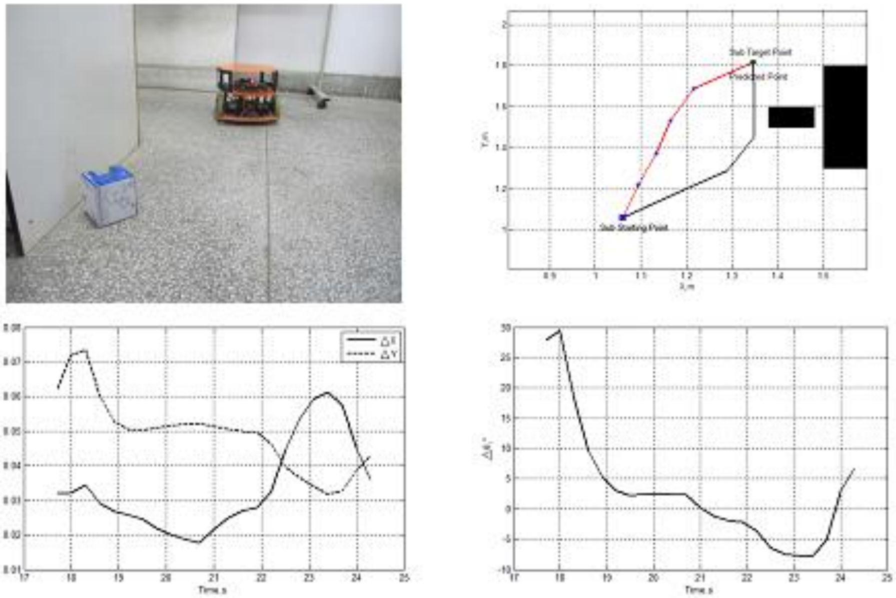


Fig. 5. When third part, experimental trajectory result

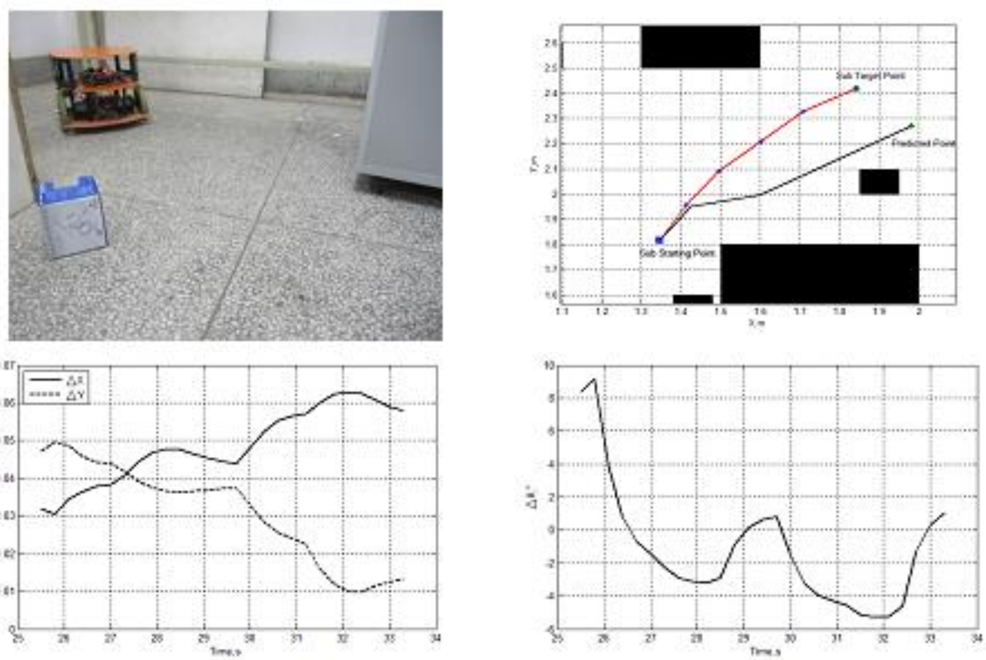
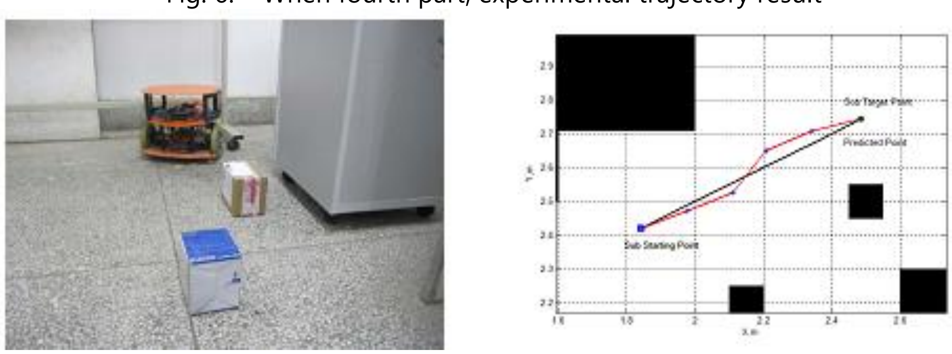


Fig. 6. When fourth part, experimental trajectory result



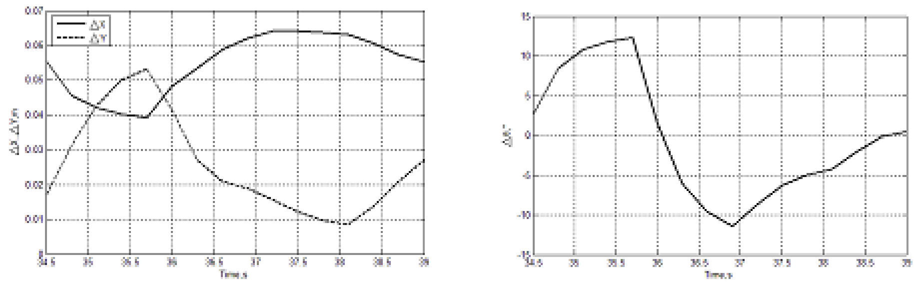


Fig. 7. When fifth part, experimental trajectory result

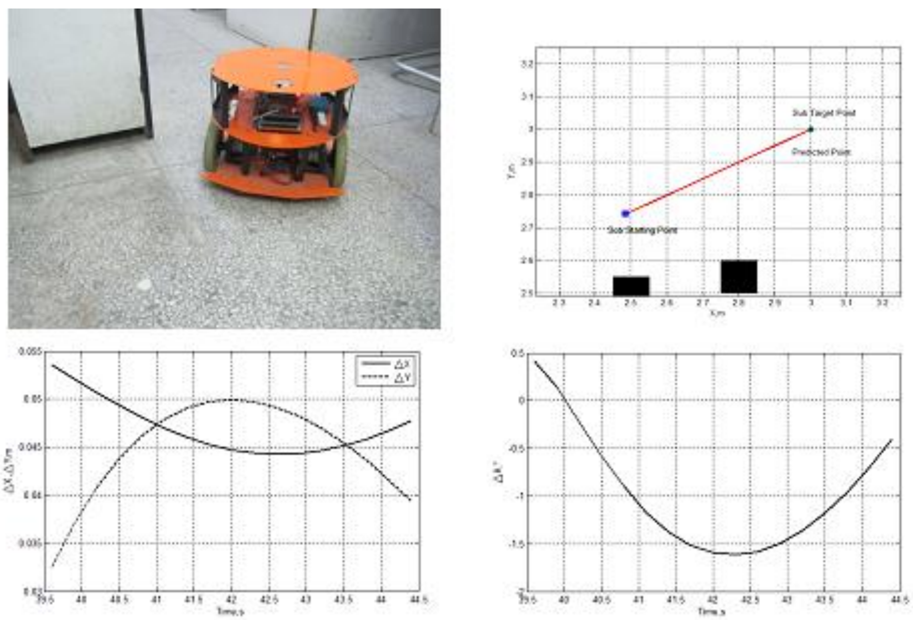


Fig. 8. When sixth part, experimental trajectory result

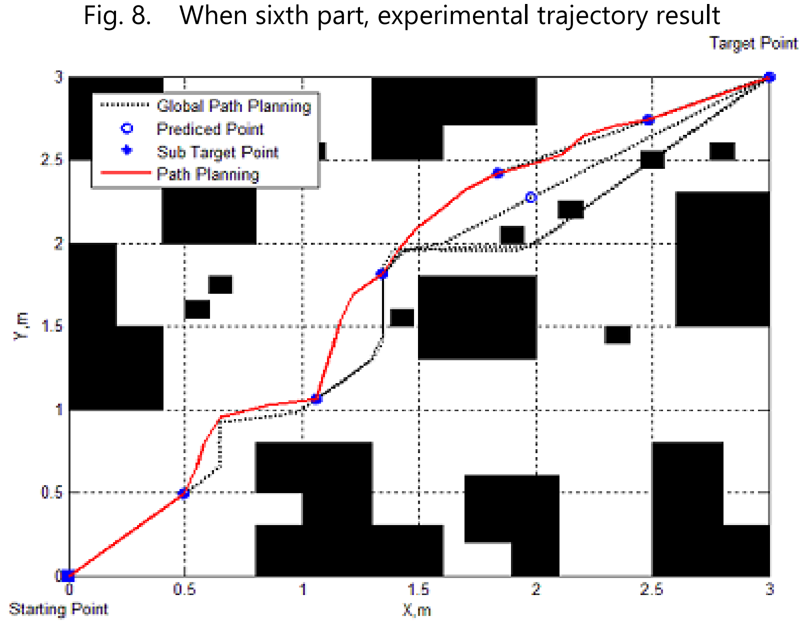


Fig. 9. Experimental path planning results

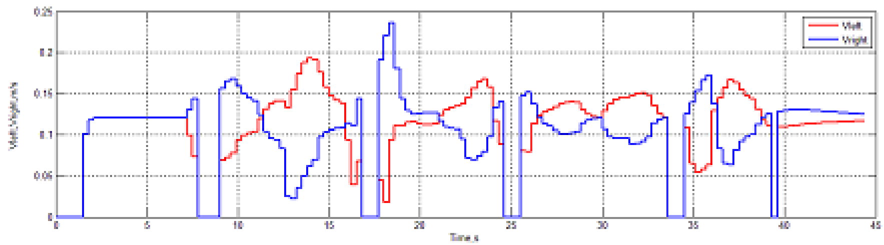


Fig. 10. Two wheel speed change value

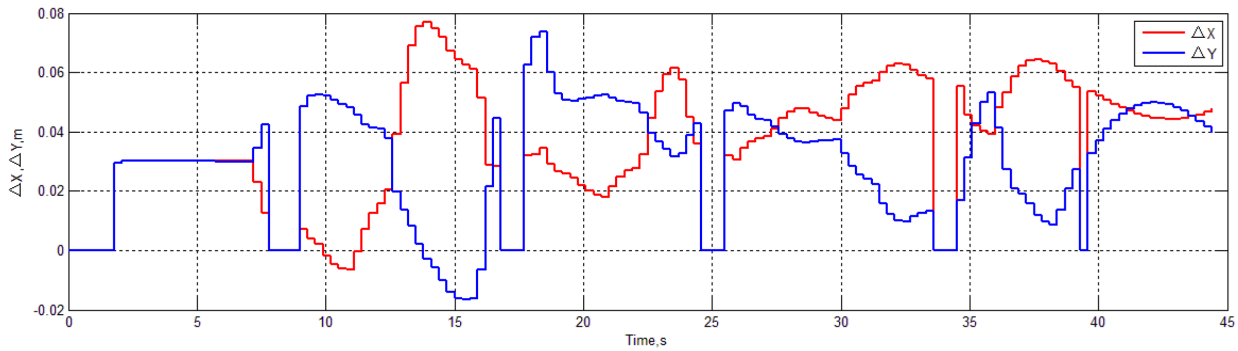


Fig. 11. X, Y position maximum variation value

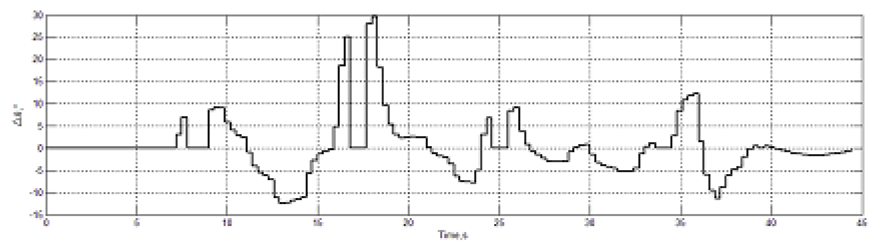


Fig. 12. Course angle change value

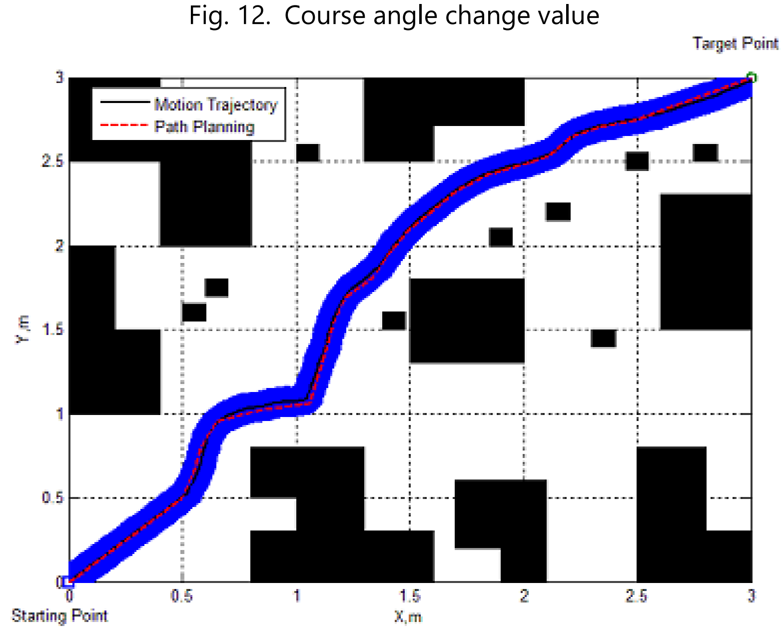


Fig. 13. The true trajectory of the mobile robot platform

TABLE 1. EXPERIMENT RESULTS

Part No	Global time ,(s)	Local path planning		Experiment		Total time ,(s)
		Route ,(m)	*Time ,(s)*	*Track ,(m)*	*Time ,(s)*	
1	1.239	0.7	0	0.711	6.3	7.5
2	0.535	0.909	0.657	0.906	7.8	9.0
3	0.212	0.828	0.599	0.823	6.9	7.8
4	0.123	0.796	0.672	0.973	8.1	9.0
5	0.114	0.739	0.708	0.568	4.8	5.7
6	0.265	0.575	0	0.615	5.1	5.4
Total	2.488	4.547	2.636	4.596	39	44.4

From experiment results, we can know that X position maximum variation value is 0.077m and minimum variation value is -0.006m, and Y position maximum variation value is 0.073m and minimum variation value is -0.016m, also, course angle maximum variation value is 29.526° and minimum variation value is -12.472°.

Tab. 1 shows that the total global path planning time is 2.488s and the total local path planning time is 4.596s, actual driving time 44.4s. The actual trajectory is longer 0.049m than total route, and each global path planning time is less than 0.6 s without the initial time, each local path planning time is also less than 1s, the each mobile robot platform driving time is 5s~8s. So we can find that the real-time trajectory planning method has validity and availability.

IV. CONCLUTIONS

In this paper, a new real-time trajectory planning method has been developed and successfully applied to mobile robot in the environment with random obstacles. This method build up the real-time trajectory planning strategy based on "First Global After Local" modeling. The experimental results show that the proposed method has better rapidity and serviceability for laboratory environment. Observations from the results show that this method and algorithm have great potential applications in the optimization problems of autonomous navigation for mobile robots.

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