2011 International Conference on Computer Science and Information Technology (ICCSIT 2011)
IPCSIT vol. 51 (2012) © (2012) IACSIT Press, Singapore
DOI: 10.7763/IPCSIT.2012.V51.07

Path Planning for IMR in Unknown Environment: A Review

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Abstract. Path planning has attracted much attention because of the importance to obstacle avoidance for IMR. The solution approaches in known environment are abundant. Nowadays, a lot of approaches are presented to solve path planning of robots in the unknown environment and path planning approaches under the unknown environment are current research hotspots and future direction. In this paper, the several common unknown environmental path planning methods and their current research progress are reviewed and the future direction of navigation and path planning are prospected.

Keywords: Mobile robot, Path planning, Integrated approach, Unknown environment

1. Introduction

An intelligent mobile robot (IMR) is a robot system, including environment perception, decision-making, planning, motion controlling[1], which can move autonomously in the environment including obstacles and achieve scheduled tasks, acquiring the environmental information though the sensors. The topic of navigation is one of the focused points in the correlation technique of IMR. Path planning is an essential aspect of the research for navigational technique which the task is to guide the robot towards the goal point without a collision with obstacles. Design of a fast and efficient procedure for navigation of IMR in the presence of obstacles is one of the essential problems. The more and more IMR is applied in more and more complex unknown environment. Although there have been a lot of path planning approaches in total known environment according to the current research achievement, the research of path planning approaches in unknown environment is meaningful and significant. In this paper, we review two categories approach used to solve path planning problems in unknown environment. The reminder of this paper is organized as follows: In the Section 2and 3, the classic local planning approach and intelligent path planning approach are introduced. In the Section 4, we conclude this paper.

2. Classic Path Planning Approach

The local path planning approach is more efficient in robotic navigation in real application when the environmental information is totally unknown or only partially known. IMR utilizes the data provided by sensors to tackle the problem of SLAM using the uncertainty of environmental information. There are some common methods: Dynamic Window Approach, heuristic search approach, Potential Field method.

2.1. Dynamic window approach (DWA)

Dynamic Window Approach is usually used in unknown environment [2]. In 1999, Oliver Brock proposed the global *DWA* in [3] which combines real-time obstacle avoidance and motion-based planning to allow a mobile robot to navigate safely and at high speeds to reach a goal position without prior knowledge of the environment. I-DWA[4] combines the Lyapunov stability criteria into the objective function, which

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improves the original DWA (Fig.1). Although the proposed settles the convergence drawbacks of DWA, it doesn't be considered in larger real environments. DWA*[5] is presented to solve the collision avoidance problem. With the region analysis and the look-ahead verification, the DWA* algorithm can utilize environmental information effectively to navigate in complex environment without stop or deceleration and overcome the local minima problem.

2.2. Heuristic search

Heuristic search is another classic approach to solve local path planning problem. A^* search is the earliest heuristic search. In Differential A^* algorithm [6], the graph topology, transition costs, and start/goals may change simultaneously, so it improved A^* search. Focused Dynamic A^* Lite (D^* Lite) [7] is a substitution of Focused Dynamic A^* that the navigation strategy is the same but the algorithm is different, which is simpler, easier and more efficient. The core of hierarchical D^* algorithm [8] is to use a down-top strategy and a set of recalculated paths (materialization of path costs) in order to improve performance. Maxim Likhachev et al. present an A^*-based anytime search algorithm [9] that produces significantly better solutions than current approaches, while also providing suboptimality bounds on the quality of the solution at any point in time and an extension of this algorithm which is both anytime and incremental.

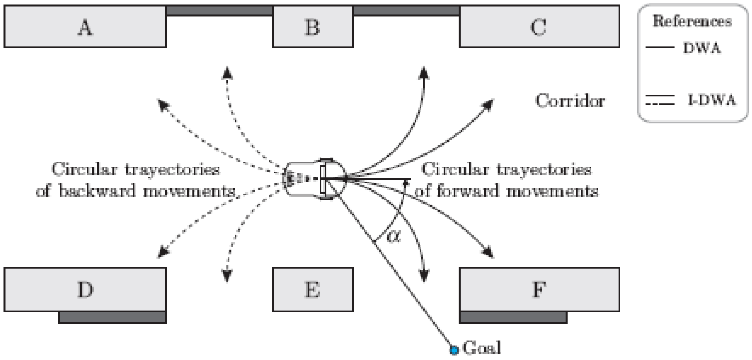

Fig.1. Illustration of DWA and I-DWA.(from [4])

The extension improves its current solution while deliberation time allows and is able to incrementally repair its solution when changes to the world model occur. A number of theoretical and experimental results and the effectiveness of the approaches in a robot navigation domain involving two physical systems are showed in Fig.2,3,4.

2.3. Potential field methods

Potential field method (PFM) is first proposed by Khatib[10] and has been widely used in obstacle avoidance cases [11]. In spite of its simplicity, PFM has three problems: First, local minimum could occur and cause the robot to be stuck. One of the solutions to overcome these problems is proposed in [12]. The key idea is to present a new repulsive potential functions to solve the problem of goals non-reachable with obstacles nearby; second, it is difficult to find the force coefficients influencing the robot's velocity and direction in an unknown environment. The solution is to choose the appropriate attractive and repulsive potential function [13]; and the third, it tends to cause unstable motion in the front of obstacles. And [14] demonstrates the ability of the harmonic potential field (HPF) planning method to generate a well-behaved constrained path to solve the unstable motion problem for a robot with second order dynamics in a cluttered environment.

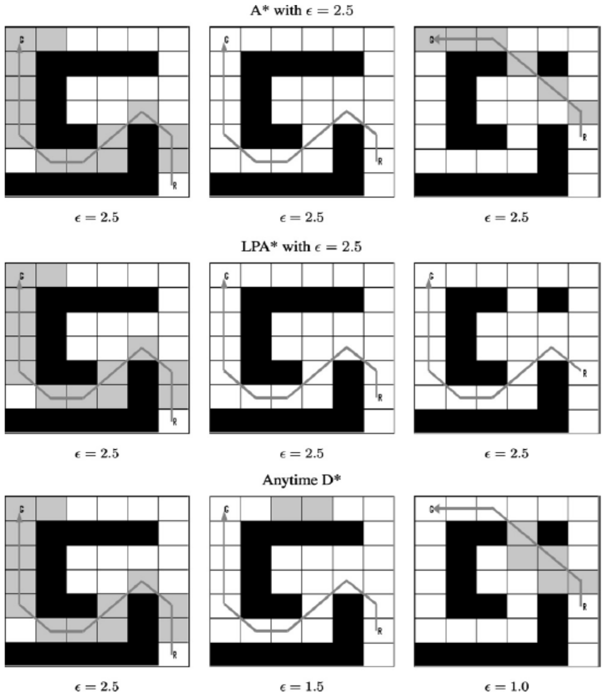

Fig.2. An example of planning with A* with an inflation factor ε = 2.5, LP A* with an inflation factor ε = 2.5, and AD*.(from [9])

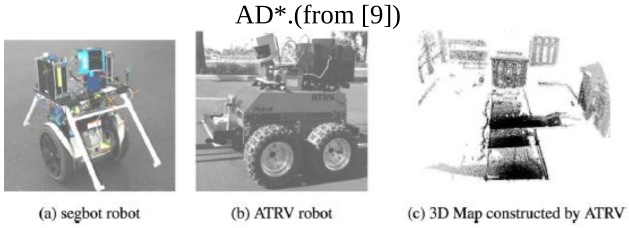

Fig.3. Some the robotic platforms that used AD* for planning. (from [9])

Fig.4. A run by an ATRV robot in an initially unknown environment. Figure (a) shows the ATRV navigating in the environment, which was a parking lot full of cars. Figure (b) shows the initial map and the initial plan AD* constructs. Figures (c–e) show the updated map and the plan generated by AD* at different times. Figure (f) shows the map constructed by the robot by the time it reaches its goal. (from [9])

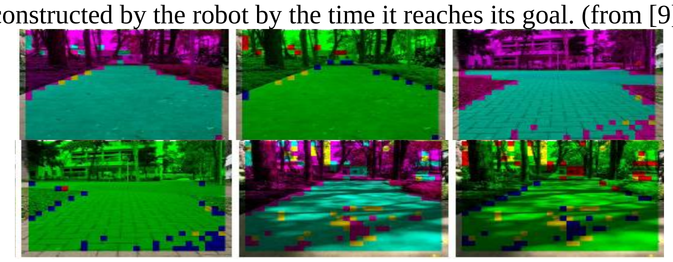

Fig.5. The result has been obtained to RGB entropy and mean. (from [16])

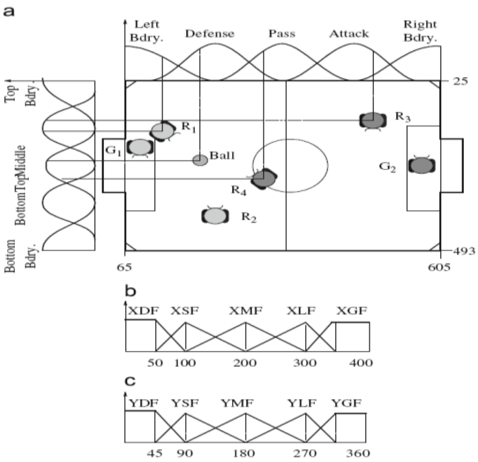

Fig.6. (a) Fuzzified robot soccer field for rule generation, (b) fuzzification of the force of hit along field length, and (c) fuzzification of the force of hit along field width. (from [19])

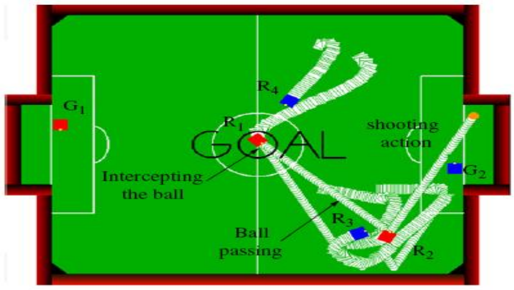

Fig.7. Robot soccer simulation exhibits ball passing and shooting behavior. (from [19])

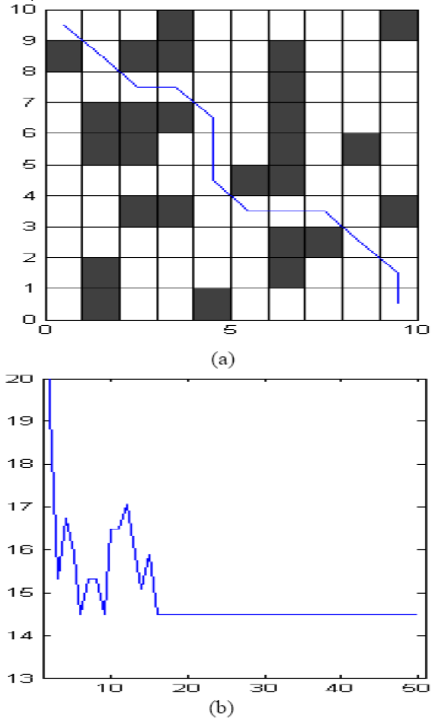

Fig. 8. Searching result of the improved ant algorithm proposed in [25], (a) shows the final path and (b) shows the average and best path length at each iteration. (from [25])

3. Intelligent Path Planning Approach

Due to the weaknesses of existing methods in path planning research, more and more researchers have focused on the intelligent path planning approaches based on neural network, fuzzy logic, genetic algorithm, ant colony optimization, and particle swarm optimization in the unknown environment in recent years.

Neural network and fuzzy logic are non-linear modeling tools which are usually used to model complex relationships between inputs and outputs or to find patterns in data. The method of self-organizing incremental neural networks (SOINN) [15] is used in the topological map matches well with the environment for robot vision-based navigation and the benefit is the algorithm requires no complex computation or much computation time. Patrick et al. propose a method[16] using NN and vision information that is different combinations of network topologies have been evaluated in realistic environments to solve the problem of identification navigable areas in the environment, the results are presented in Fig.5. The strategy for behavior-based navigation using a fuzzy logic approach for IMR is proposed [17]. Some approaches combining fuzzy logic with neural network appear in recent years. A neurofuzzy-based approach combining sensor information and a state memory strategy is proposed for real-time reactive navigation [18]. Another fuzzy neural network approach for a mobile robot in a robot soccer system is proposed in [19], which proposes an intelligent task planning and action selection mechanism for a mobile robot in a robot soccer system through a fuzzy neural network approach (Fig.6). Simulation results indicate that the proposed approach is simple and has the capability in coordinating the multi-agent system through selection of sensible actions (Fig.7).

Genetic algorithms (GA) are heuristic optimization methods [20], which have mechanisms analogous to biological evolution. And in [21], a genetic algorithm-based path planner has been presented. The proposed method keeps the accuracy of the global path planning methods. There are some integrated approaches based on fuzzy logic and genetic algorithmic for path planning of IMR [22], [23].

Ant colony optimization (ACO) is a technique that optimizes problems through guided search of the solution space. A novel ACO algorithm is proposed to solve the global path planning problems, called Heterogeneous ACO (HACO) algorithm [24]. The contribution of HACO algorithm is that the researchers can consider the robot size and apply to the non-holonomic of car-like mobile robot. Another improved ACO in which the distance cost is adjusted at run-time during the searching process is proposed in [25] for robot obstacle avoidance (Fig.8). The proposed algorithm can effectively alleviate the local optimum problem. [26]proposes a new arithmetic called heuristic bidirectional ant colony algorithm (HBACA) by combining with the merits of ACO, Dijkstra algorithm, and heuristic algorithm to find the shortest path of the skeleton topology.

Particle swarm optimization (PSO) is an approach for the optimization of nonlinear functions and comes from two main component methodologies [27]. One example using PSO for path planning is showed in [28].The point is the proposed method can be applied to any form of obstacles regardless of their shape and size. The “self-configurable particle swarm optimization algorithm (SCPSO)” [29] can control a system in where each particle can makes decision to find optimum position by itself and can work autonomously even in unpredictable situations. The simulation results of the proposed algorithm show that it can be used in large environment. Fig.9 shows Simulation environment of PSO-FastSLAM in [30]. And other application using PSO for path planning are [31]

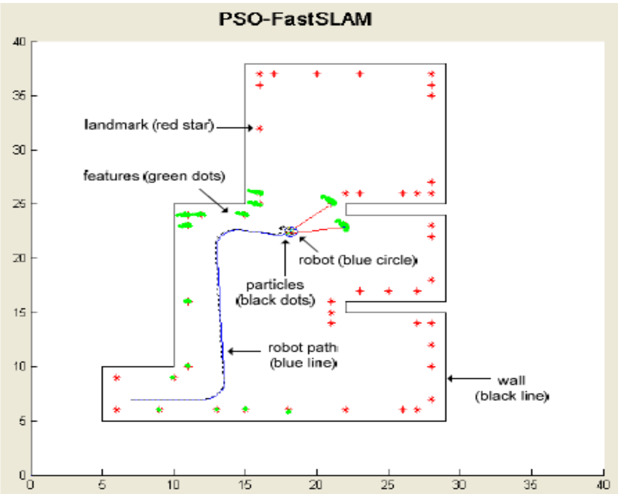

Fig.9. Simulation environment of PSO-FastSLAM in [30].

4. Conclusion

IMR navigation means a robot has the ability to decide how to travel through a given environment. A robot and obstacles both exist in the navigation environment. A good or feasible path from the starting to the target implies that IMR avoids collisions with obstacles. The purpose of path planning is to generate and optimize a good or feasible according to the current environment.

In this paper, several local approaches for path planning in unknown environment and current research progress have been briefly summarized. Due to the several weaknesses of each existing methods in local path planning research, i.e, the convergence drawbacks is a kind of weakness of DWA and it couldn’t be used in larger real environments, there is no uniform discipline to design proper cost function for heuristic search, the local minimum problem and unstable motion in the front of obstacles have to be considered during designing PFM, more and more researchers have focused on studying the intelligent path planning approach in the unknown environment. As two future directions, integrated path planning approach and intelligent space-based path planning approach are current research hotspots. Using the integrated path planning approach can effectively resolve the drawbacks of single path planning approach. And there are lots of achievements about applying the intelligent space-based approach for path planning of domestic or indoor environments in recent years. Although path planning approaches under the unknown environment are current research hotspots and there are fruitful achievements in recent years, there still are lots of problems to solve.

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