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Dynamic path planning of mobile robots with improved genetic algorithm ☆

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A B S T R A C T

In this study, a new mutation operator is proposed for the genetic algorithm (GA) and applied to the path planning problem of mobile robots in dynamic environments. Path planning for a mobile robot finds a feasible path from a starting node to a target node in an environment with obstacles. GA has been widely used to generate an optimal path by taking advantage of its strong optimization ability. While conventional random mutation operator in simple GA or some other improved mutation operators can cause infeasible paths, the proposed mutation operator does not and avoids premature convergence. In order to demonstrate the success of the proposed method, it is applied to two different dynamic environments and compared with previous improved GA studies in the literature. A GA with the proposed mutation operator finds the optimal path far too many times and converges more rapidly than the other methods do.

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1. Introduction

Recently, interest of researchers on autonomous vehicles has increased with technological developments. There are many studies in the literature about autonomous vehicles. One of the main subjects in autonomous vehicle research is path planning. Path planning tries to find a feasible path for mobile robots to move along from a starting node to a target node in an environment with obstacles [1].

The path planning environment can be either static or dynamic. In the static environment, the whole solution must be found before starting execution. However, for the dynamic or partially observable environments re-plannings are required frequently and more planning update time is needed. Generally, the major problems for path planning of mobile robots are computational complexity, existence of local optima and adaptability. Researchers have always been searching alternative and more efficient ways to solve these problems [2].

There are many studies on robot path planning using various approaches, such as the grid-based A* algorithm, road maps (Voronoi diagrams and visibility graphs), cell decomposition, and artificial potential field. Some of the previous approaches that use global methods to search the possible paths in the workspace, normally deal with static environments only, and are computationally expensive when the environment is complex [3]. Each method differs in its effectiveness depending on the type of application environment and each one of them has its own strength and weaknesses. For example, the artificial potential field method can give only one solution route that may not be the shortest path, even in a static environment. Ajmal Deen Ali et al. [4] investigated the effectiveness of genetic algorithms (GAs) on the study of collision free path planning of manipulators to reduce search time and improve the quality of the solutions. The results from this approach are found to be better than the conventional A* search, both in the distance traveled and in computation time. Chen and Zalzala [5] compared the GA with the modified A* method in mobile robot path planning. It was observed that although the modified A*

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method can obtain a solution quicker than the GA, the modified A* method can easily fall into some local minima, while the GAs can always reach the global optimum or a near global optimum.

Compared to traditional search and optimization methods, such as calculus-based and enumerative strategies, the evolutionary algorithms are robust, global and generally more straightforward to apply in situations where there is little or no prior knowledge about the problem to be solved [6]. One technique that outperforms the others in path planning is the GA method because of its capacity to explore the solution space while preserving the best solutions already found [7]. In the last decade, GAs have been widely used to generate the optimal path by taking the advantage of its strong optimization ability [8]. GAs have been recognized as one of the most robust search techniques for complex and ill-behaved objective functions. The basic characteristic that makes the GA attractive in developing near-optimal solutions is that they are inherently parallel search techniques [9]. They can search all working environment simultaneously in a parallel manner and so they can reach a better solution more quickly.

In recent years, lots of GA based path planning has been implemented by means of customizing genetic operators and most of these were at the same time improved approaches. They have succeeded in achieving better solutions. While conventional random mutation operator in simple GA can cause an infeasible path, the proposed mutation operator in this study increases the diversity of the population and avoids premature convergence.

This article is organized as follows: In Section 2, we explain how the GAs are applied to the path planning problems of mobile robots; Section 3 analyzes the mutation operators which were reported previously and proposed in this article; Section 4 evaluates the experimental studies and results; and in Section 5 we summarize the main findings of the article.

2. Path planning with genetic algorithm

GA is a parallel and global search technique that emulates natural genetic operators. Because it simultaneously evaluates many points in the parameter space, it is more likely to converge to the global optimal. It is not necessary that the search space to be differentiable or continuous [10–12].

2.1. Representation of environment

Many path planning methods use a grid-based model to represent the environment space as shown in Fig. 1. It has been determined that calculation of distance and representation of obstacle is easier with grid-based representation. The grid-based environment space is represented in two ways, by the way of an orderly numbered grid [1,13–15] or by the way of (x,y) coordinates plane [9,16,17]. It has been found that in the literature the orderly numbered grid representation is widely used, therefore this representation method is used in the present study.

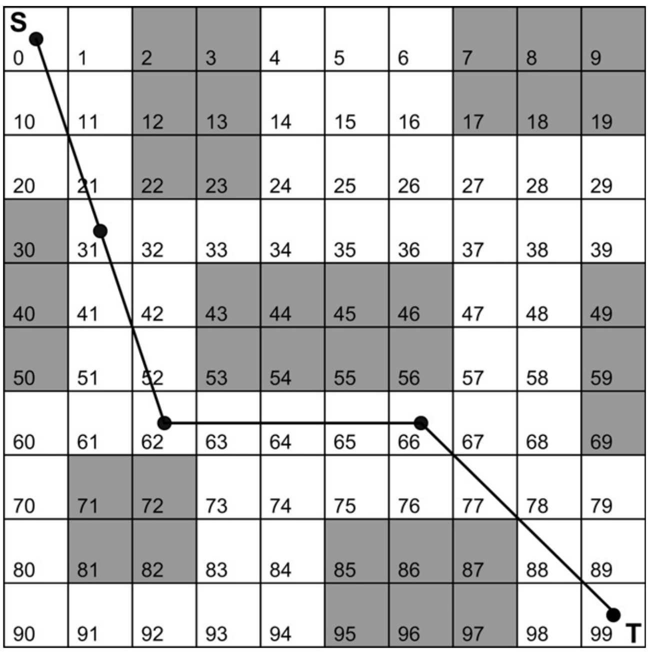

Fig. 1. Grid-based environment representation.

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