Comparative Analysis of Different Approaches for Navigation and Path Planning

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Abstract- **An autonomous robot's navigation consists of two essential components known as localization and planning whose goal is to move the robot to a target place through a collision-free path in a known, unknown or partially known environment. In most of the realistic situations, the mobile robot cannot take the most direct path from the start to the goal point. So, we use path planning techniques in this situation, and the simplified kinds of planning mission involve going from the start point to the goal point in a way that minimizes the path cost such as time spent, chance of detection, or fuel consumption. Several approaches have been proposed to address the problem of motion planning of a mobile robot. This study is a review of approaches which focuses on introducing various path planning approaches and investigates their achievements in search optimization problems. The methods with their strengths and drawbacks are discussed.**

Index Terms - **Autonomous robot, Dijkstra, hybrid, genetic algorithm, path planning, robot navigation.**

1. INTRODUCTION

Optimal path is a route which not only covers the least distant but also takes precaution of cost. It could be the path that minimizes the amount of turning and the amount of braking. The cost saving specifications may vary for different applications. Before an algorithm determines a path to the target, a robot should have the information about the environment and its current location. Depending on the environment, the path planning methods can be classified into the two types, static environment which contain only the static obstacles in the map and dynamic environment which has static and dynamic obstacles in the map. Mobile robot path planning and navigation has been a challenging task since its emergence and significant number of approaches has been suggested which lead to solutions according to the environment type. The main concerning areas of the path finding problem involves the efficiency and safety. The path finding problem can be overcome by combining global path planning and local path planning. Local Path planning takes care for local obstacles and global approach concerns to final path selection. Different famous algorithms and approaches are discussed here with their capabilities.

2. ALGORITHMS FOR PATH PLANNING

We have gone through many papers and based on information and knowledge collected by them following algorithms and approaches are discussed here:

- Genetic Algorithm
- Hybrid Genetic Algorithm
- Multi-strategic Approach
- Hybrid Intelligence
- OAC Algorithm
- Dijkstra Algorithm
- Extended Dijkstra Algorithm
- Virus-Genetic Algorithm

All of these have been detailed below one by one.

2.1 Genetic Algorithm

In a paper proposed by Pu Shi and Yujie Cui [1], a dynamic path planning scheme based on genetic algorithm (GA) has been presented for navigation of mobile robot under unknown environment. GA is a stochastic search technique analogous to natural evolution. As genetic algorithm is inspired by nature, it follows the natural process of genetic modification by searching for the fittest chromosome. Potential solutions of a problem are encoded as chromosomes. These chromosomes form a population. Each individual of the population is evaluated by a fitness function. A selection mechanism based on the fitness function is applied to the population and the individuals strive for survival. The unique coding technique decreases the conventional computational complexity of genetic algorithm. It also speeds up the execution of searching by projecting two dimensional data to one dimensional data, which reduce the size of search space. The fitness function of genetic algorithm takes full consideration of three factors: the collision avoidance path, the shortest distance and smoothness of the path. The specific genetic operators are also selected to make the genetic algorithm more effective. The simulation experiments are made under the VC++ 6.0 environment. The unique coding, fitness function and specific genetic operators are designed to accelerate the convergence of the algorithm

and improve the accuracy of operation. The simulation results show that the genetic algorithm has strong adaptability of dynamic and unknown environments and verify the proposed method is highly effective.

2.2 Hybrid Genetic Algorithm

A paper presented by Yong Zhang, Lin Zhang and Xiaohua Zhang [2] deals with global path planning with possibly incomplete or imperfect knowledge of working environments which is expressed by grid model to establish 2-D workspace environment using digital potential field generated initial path population. To optimize the path planning and find the shortest path, individual evaluation function were processed with fitness function for both feasible path and unfeasible path, and then genetic operators are applied to meet the requirement of avoiding obstacles and to smooth the curves in the path planning. The genetic algorithm used in this paper this paper can achieve satisfying planning results within unknown environment. Experiments show that the genetic algorithm has strong adaptability of various environments.

2.3 Multi Strategic Approach

Giovanni Bianco and Riccardo Cassinis [3] have proposed a multi-strategic approach for path planning in unknown environment. The classical approach is applicable only in static environment. This system uses several strategies to reach the target which makes it applicable to plan a path in dynamic environment. The strategy is planned for each cell and not the path. The robot learns from previous experience and improves its performance in further travelling. Robot changes its strategy from one to another whenever the previous strategy fails or a loop is discovered. Since it is not using a single approach, it may be applied to static, fully dynamic or partially dynamic. The major drawback of proposed method is that it needs to have information of its current position while changing its strategy.

2.4 Hybrid Intelligence

An algorithm proposed by O. Hachour [4] allows a mobile robot to navigate through static obstacles, and finding the path in order to reach the target without collision using a hybrid approach. The proposed path finding strategy is designed in a grid-map form of an environment. The author uses fuzzy logic and genetic algorithm combined together and using human intelligence to avoid collision. This navigation approach has an advantage of adaptability such that the AMR approach works perfectly even if an environment is unknown. Algorithms are implemented in Borland C++, afterwards tested with Visual Basic and DELPHI programming language; whereby the environment is studied in a two dimensional coordinate system. This proposed approach has made the autonomous vehicle capable to achieve these tasks: avoiding obstacles, deciding, perception and recognition. The results are promising for next future work of this domain. The author has tried to make the algorithm simple and computationally efficient.

2.5 OAC Algorithm

The research paper presented by Nabeel K. Abid Al-Sahib and Amenah A.H. Salih [5] propose an algorithm that deals with *global* path planning. It uses a wireless camera that provides the desired image for the unknown environment. It is based on the observation and analysis of the obstacles that lying in the straight path between the start and the goal point by detecting these obstacles, analyzing and studying their shapes, positions and points of intersection with the straight path to find the nearly optimal path and thus this algorithm has been named as OAC (observation, analysis and conclusion). This optimization takes concern of length of the path and number of segments or turns incorporated with that path. Also it considers a Clearance Factor to avoid obstacle with a margin. The theoretical part includes building a MATLAB program which is applied to environment image to find the nearly optimal path. By using a camera it first does a job of image processing using MATLAB. Then MATLAB-C++.NET interface is accomplished then to supply the path information for C++.NET program which is done for programming the pioneer mobile robot to achieve the desired path. This paper has introduced a security factor which may be altered by the programmer based on environment. This algorithm has better performance than genetic algorithm and potential field algorithm in static environment.

2.6 Dijkstra Algorithm

If we try to connect any two nodes in a given static graph, there may be many ways to do so. The shortest path problem is to find a path between two distant nodes such that the total weight of all the edges, through which the path traverses, is minimum. Dijkstra's algorithm is an algorithm that solves the single-source shortest path problem for a static graph with nonnegative edge weights. This algorithm was proposed by Edgser W. Dijkstra and still extensively used in path finding applications. It works starting from the source node and calculates the shortest path on the whole network. This algorithm has applications in graph theory, artificial intelligence, computer network and other network related protocols. Using it in designing of transportation systems for routing like finding least distant path between two cities or between two places within a city and. Although this is an efficient algorithm, searching the whole graph where thousands of nodes and edges are to be encountered (for example in a road network [8]) to find the shortest route will still take a long time and so it is also wasteful in terms of computation. The reason is that, if we have to find the route towards north, there is no use of entertaining the roads going southward. But it is still a simple method and used for this reason in graph related problems.

2.7   Modified Form of Dijkstra

As Dijkstra algorithm has proved itself as most simple algorithm to be used in static environment and graph based path finding networks, many alternatives has been developed to overcome the non-beneficial aspects of this algorithm such as calculation time and unnecessary consideration of nodes. Masato Noto and Hiroki Sato [9] have suggested to perform the path finding from both directions. This algorithm starts path finding from both the directions, from source and from goal and when the nodes become common it calculates the cost of optimum path using common nodes found. This method halves the number of nodes to be entertained as compared to conventional Dijkstra which takes lesser computational time.

2.8   Virus-Genetic Algorithm

Hitoshi Kanoh has proposed a Genetic Algorithm based path planning method using viral infection [11]. The result generated by Dijkstra algorithm in a car navigation system has a major drawback of finding the route without considering other constraints like traffic lights and problem of jamming. Also these heuristic algorithms do not guarantee that they meet deadline. The suggested algorithm not only guarantees the meeting to deadline but also considers the amenities like number of traffic lights and turns on path, real time traffic density, number of lanes etc. The viral function used here help in finding shortest path. Kanoh has tabulated some amenities and has provided some penalties regarding those amenities. These penalties are considered in fitness function of routes. So the fitness function becomes sum of penalties and path length and travelling time. In this way, a travelling purpose specific route can be decided. Different travelling styles and objectives may give different results. For a leisure driving, the road condition and traffic density are not much bothering, but for a politician's vehicle or any emergency vehicle like ambulance and fire bridged only time is important and so a clear road with less path holes, turns, tolls and less traffic density is covetous.

3.   RESULTS AND DISCUSSIONS

A table to conclude various algorithms discussed is given below-

Algorithm Used	Remarks
Genetic Algorithm	Can be used in unknown environment
Hybrid Genetic Algorithm	Works in various environments. Better performance than GA.
Multi-strategic Approach	Cell based path planning. Robot should know its current position. Less affected by changes in environment.
Hybrid Intelligence	Uses Fuzzy logic and genetic algorithm which makes it computationally efficient.
OAC Algorithm	Uses camera, MATLAB for image processing and C++.NET to handle robot.
Dijkstra Algorithm	Simplest and greedy algorithm to find path having least cost.
Extended Dijkstra Algorithm	Applies Dijkstra from two sides. Hence faster than conventional Dijkstra.
Virus- Genetic Algorithm	Short path finding is done using viral infection.

Table 1 Comparison between approaches

As we see Genetic Algorithms are very much adaptive in all the situations whether it is known or unknown environment. Joining GA with other algorithm gives a Hybrid GA which gives better performance. Global Path Planning gives an advantage of having the knowledge of whole environment and helps in better planning of trajectory. As we come to static environment, Dijkstra's algorithm proves to be the best and with continuous improvement going on in it, it will always be the best in static shortest path finding approaches. An extended Dijkstra algorithm starts searching from both end and thus reduces the calculation work and saves time. But the main drawback of Dijkstra algorithm is that it does a local path planning and the path generated may not be the shortest path on global approach. Also if we apply this in real life road conditions, it may not give you the best result. So GA again becomes advantageous when it comes to dynamic environment implementation. Virus-GA approach not only considers the basic requirements but also other amenities too. So we have to apply an algorithm based on the environment type and capability of system involved in it. As it always the case in real world that every system has its pros and cons, path finding algorithms also has some advantages and disadvantages. We have to use algorithm based on condition.

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