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A Survey of the Various Path Planning Techniques Used in the Navigation of Autonomous Mobile Robot

KEYWORDS: Autonomous mobile robots, obstacle avoidance path planning, path planning methodologies

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ABSTRACT *Navigation of autonomous mobile robots in a complex and uncertain environment is a complicated issue and a big challenge due to the various obstacles that mobile robots have to detect in their path of travel to navigate safely without colliding with them. A number of efficient techniques and algorithms were developed by researchers for path planning of mobile robots. This paper presents an overview of the path planning techniques developed for autonomous mobile robots to navigate through a collision free shortest path. The main aim of the paper is to review the available path planning techniques aimed at generating the shortest path and to conclude with describing the most optimal technique satisfying all necessary criteria.*

I. INTRODUCTION

Autonomous mobile robots are the heart of the development scope now days. These types of robots are widely used in a variety of applications. The application areas include manufacturing industries, assembling industries, exploration, spying, monitoring and so on. The main objective of mobile robots is that they have to navigate in an environment autonomously (1, 2, 3, 4, 5). Hence in turn they need to obtain a collision free path to traverse. With the advancements in the generation of autonomous mobile robots, the concept of path planning is of primitive importance as it lets the robot find the optimal path between two points (1,2). The navigation of mobile robots is a complicated issue due to the fact that a variety of obstacles have to be detected and a collision free path must be chosen. Basically path planning is the term used to describe the process of determining a collision free path meaning that a robot should plan a reliable path between the source and the target without colliding with the dynamic and static obstacles found in its environment either complex or uncertain. This was done in real time by developing algorithm using various techniques. A lot of approaches were proposed for the planning algorithms. The major aim of these planning algorithms was to make the robot optimize the shortest path. Every proposed algorithm aimed at providing the robot an intelligence that satisfies this need. Thus path planning is of utmost importance as far as mobile robots are concerned. A variety of approaches have been introduced to implement path planning for a mobile robot. The approaches are according to environment, type of sensor, robot capabilities and so on. We shall discuss about the various techniques in the following sections.

II. PATH PLANNING TECHNIQUES

Path planning can be divided into two broad categories as global and local path planning. And the path planning algorithms can be classified as single-solution algorithms and population-based algorithms. Global path planning is the one that requires a completely known environment and a static terrain. In this type of path planning, the algorithm develops a complete path from the source point to the target point before the robot starts its motion. On the other hand, in local path planning, the environment is completely unknown to the mobile robot and the algorithm is capable of developing a new path to reach the target point. Path planning techniques can be classified into two broad categories as classical methods and heuristic methods.

III. CLASSICAL METHODS

1. Roadmap Methodology:

In the roadmap approach, the mobile robot connects the source point to the target point by curved or straight lines (1). In this approach path planning is reduced to connecting the starting and final points of the robot to the road network, and then finding a chain of serial roads from the starting robot point to destination that are obstacle free. There are two types of road map approaches. They are the visibility graph and the Voronoi diagram (2). In a visibility graph each node in the graph represents a point location, and each edge represents a possible connection between them that is collision-free. That is, if the line segment connecting two points or nodes does not pass through any hindrance, an edge is drawn between them in the graph. In the visibility graph, the path to be traversed by the mobile robot is very close to the obstacle and it therefore results in minimum path distance solutions. In the Voronoi Diagram, the mobile robot stays away from the obstacle as much as possible. Here the nodes of the graph are the start and destination points whereas the vertices of the configuration space are obstacles. All nodes which are visible from each other are connected by straight-line segments, defining the path to be traversed by the mobile robot.

2. Cell Decomposition Method:

The basic idea behind cell decomposition is to show the difference between the areas or cells that are free and the areas that are occupied by obstacles in the real world environment. An important characteristic feature of the cell decomposition method is the placement of boundaries between cells. Based on this cell decomposition approach is classified into two types as exact cell decomposition where the boundaries are a function of the structure of the environment, in such a way that the decomposition is loss-less and approximate cell decomposition method where decomposition is an approximation of the actual map of the environment of the robot.

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3. Artificial Potential Field Method:
The artificial potential field method was first developed by Khatib (1985). In this approach the artificial forces generated by the obstacles and target, are provided to the robot as inputs to make decisions in order to move about the environment collision-free. The obstacles are assigned a repulsive force and the target is assigned with an attractive force in this technique respectively. This encourages the robot to move towards the target while being 'pushed' away from the obstacles. The major disadvantage of the potential field methodology is that trap situations can occur due to the presence of local minima. A new form of repelling potential was proposed later in order to reduce oscillations and avoid conflicts when the target is close to obstacles. According to this new method, a rotational force was integrated, allowing for a smoother trajectory around the obstacles leading to safe robot navigation. The major disadvantages of the artificial potential field approach are that trap situations occur as a result of local minima and passage between closely spaced obstacles is forbidden.

IV. HEURISTIC METHODS

1. Fuzzy logic method:
Fuzzy logic is a formal technique representing and implementing human experts' heuristic knowledge and perception-based actions. It was developed by Prof. Lotfi A. Zadeh in 1965. In fuzzy logic technique, the navigation problem is broken down into simpler tasks (independent behaviors) and each behavior is composed of a set of fuzzy logic rule statements intended at achieving a well-defined set of objectives(2,8). Generally control is established by providing the distance of the obstacle from the robot in all directions and heading angle input to the fuzzy controller, and the output from fuzzy controller is given to the wheels or legs of the robot (i.e., to the motors associated in robot navigation).

It is found that the fuzzy logic controller utilizing Gaussian membership is best among techniques for navigation of multiple mobile robots. Although their implementation details varied greatly, it is found that both traditional and fuzzy logic-based algorithms give good collision-free path results.

2. Neural Network technique:
Robot navigation in the real-world environment is planned via the dynamic activity landscape of the artificial neural network without searching for free space or obstacle-free paths, explicitly optimizing any cost function, any prior knowledge of the dynamic environment, any learning process, and any local collision checking procedures(4). Because of their highly distributed and modular nature, artificial neural networks exhibit a high level of fault tolerance which is one of their major advantages. If one particular component or a group of components fails, certain functions cannot be performed. However the capabilities of the intact components are retained and the network doesn't fail completely. The fault tolerance capability is best put to use in the self-repair of a neural network. This involves the inevitable cum surviving part of the network to detect any fault or disruption and attempt to repair the failed components using retained data about the overall network.

This is one of the major applications of neural networks in artificial intelligence and saves a lot of effort in debugging the network, because most of the crashes are handled by the network itself. Adaptivity is another major advantage that artificial neural networks possess.

3. Neuro- Fuzzy technique:
Humans are a remarkably competent group in implementing a wide variety of physical and mental tasks without any explicit measurements or computations. Neural networks and fuzzy logic serves (10) as a means to accomplish this characteristic feature in robot. Neuro-fuzzy was proposed by J. S. R. Jang. Fuzzy logic provides an explicit methodology for representing and implementing human expert heuristic knowledge and perception-based actions. The attributes of human reasoning and decision-making can be methodologically created by a set of simple and intuitive IF-THEN rules that are coupled with easily understandable and natural linguistic representations with the use of fuzzy logic framework. Neural networks can be trained using different patterns as per the application's requirement and the trained neural network can be efficiently used for problem-solving.

The Neuro-fuzzy technique comprises a neural network which does the work of a preprocessor for a fuzzy logic controller. Learning algorithms based on neural network technique can be developed for the fuzzy membership functions parameter tuning, which smooth the trajectory generated by the fuzzy logic system. The major advantage of neuro-fuzzy system is that it is a universal approximation with the ability to solicit interpretable IF-THEN rules. The strength of the neuro-fuzzy systems depends on two contradictory requirements in fuzzy modeling: interpretability and accuracy.

4. Genetic Algorithm technique:
In implementing Genetic Algorithm to the mobile robot path planning problem, we need to develop an appropriate 'chromosome' for the robot path, a path direction mechanism, a technique to satisfy the demand for obstacle avoidance and an appropriate constraint definition providing mechanisms to minimize path length as well as provide collision-free paths(5). Genetic algorithms help in the minimization of a nonlinear cost function in real time, avoiding the complex training process of the neural networks and fuzzy algorithms. The determination function of a chromosome is the objective cost function's measure. Fitness is found by using the distance of a path indicated by the chromosome. And fitness should increase as distance decreases. The major advantage of genetic algorithms is that it is easily understandable and does not require any mathematical knowledge. The disadvantages include that certain optimization problems cannot be solved using GA due to poorly known fitness functions which generate bad chromosomes blocks in spite of the fact that only good chromosome blocks cross-over.

5. Ant Colony Optimization technique:
The main aim of the Ant Colony Optimization technique is to search for an optimal path in the dynamic environment for the robot to navigate, and to solve many combinatorial optimization problems. In this approach the robot uses the principle of the ants where in case if they find any obstacle present in their way, they move along the contours of the obstacles on either sides and find their path to the food source. Thus the robot which appears as an artificial ant makes movements based on the attraction of pheromone. As the concentrations of pheromones are more along the shorter path, ants accumulate more pheromone in a given time interval along the shorter path. Thus the shortest path that also appears collision free can be chosen by using ACO methodology for robot navigation. The direction of the mobile robot has eight selections as follows, forward, right, right-up, right-down, left, left-up, left down and

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backward. The mobile robot must avoid obstacles to select an optimization motion path moving to the target position in the unknown environment. The advantages of ant colony optimization include inherent parallelism and positive feedback accounting of rapid discovery of good solutions.

6. Artificial Immune Network technique:

The immune network theory was proposed by Jerne in 1973. The basic concept is that the immune system maintains an idiotypic network of interconnected B-cells for antigen recognition. These cells both stimulate and suppress each other in certain ways that leads to the network's stabilization (7). Two B-cells are connected if the similarities in character that they share exceed a certain threshold, and the connection strength is directly proportional to the affinity they share. We now discuss reactive immune networks inspired by the biological immune system for robot navigation (target-reaching and obstacle-avoidance) in stationary environments. Here an antigen described in the immune networks concept is the environment perceived by the robot's sensors and camera at any given time and condition. Antigen presentation proceeds from information extraction to the perception translation and then the antigen deliver the reports about the current location and position of the mobile robot and obstacles. As the antigen is a combination of various environment situations, it can interact with various antibodies (obstacle) but only one antibody can bind to the antigen. To implement the artificial immune system for a mobile robot navigation application, four decisions have to be made and they include encoding, similarity measure, selection and mutation. Drawbacks include handling unobserved low-level alerts that comprise an intrusion scenario, handling optional prerequisite actions and handling intrusion scenario variations.

V. CONCLUSION

Thus this paper describes the various techniques applied for intelligent mobile robot navigation. By the end of this survey it is concluded that the heuristic approaches (Fuzzy logic, neural networks, neuro-fuzzy approach, genetic algorithms, particle swam optimization methodology, ant colony optimization and artificial immune systems approach) especially the hybridized technique 'neuro-fuzzy approach', provides suitable and effective results for mobile robot navigation in an unknown and dynamic environment compared to classical techniques. Thus it is obvious that using the heuristic approach the autonomous mobile robots can navigate safely among the obstacles without colliding with them. These techniques are also helpful for the solution of optimization problems. Future work is recommended in this field to survey other heuristic techniques used for path planning for autonomous mobile robot in order to recognize the most optimal technique that can adapt with dynamic changes in all respect.

REFERENCE [1] Buniyamin N., Wan Ngah W.A.J., Sariff N., Mohamad Z. A Simple Local Path Planning Algorithm for Autonomous Mobile Robots, International Journal of Systems Applications, Engineering & Development, Issue 2, Volume 5, 2011. | [2] Gireesh Kumar T., K.J Poornaselvan and M. Sethumadhavan, Fuzzy Support Vector Machine-based Multi-agent Optimal Path | Planning Approach to Robotics Environment, Defense Science Journal, Vol. 60, No. 4, July 2010, pp. 387-391 © 2010, DESIDOC. | [3] Damion D. Dunlap, Charmane V. Caldwell, Emmanuel G. Collins, Jr. and Oscar Chuy (2011). Motion Planning for Mobile Robots Via Sampling-Based Model Predictive Optimization, Recent Advances in Mobile Robotics, Dr. Andon Topalov (Ed.). | [4] P. Payeur, H. Le-Huy, C. Gosselin. Robot Path Planning Using Neural Networks and Fuzzy Logic, Proceedings of IEEE 1994. | [5] O.Hachour, Path planning of Autonomous Mobile robot, International Journal of Systems Applications, Engineering & Development, | Issue 4, Volume 2, 2008. | [6] Mohd Azlan Shah, Abd Rahim and Illani Mohd Nawi. Path Planning Automated Guided Robot, Proceedings of the World Congress on Engineering and Computer Science 2008 WCECS 2008, October 22 - 24, 2008, San Francisco, USA. | [7] G. N. Tripathi and V.Rihani, Motion Planning of an Autonomous Mobile Robot Using Artificial Neural Network, Natarajan Meghanathan, et al. (Eds): SIPM, FCST, ITCA, WSE, ACSIT, CS & IT 06, pp. 367–373, 2012. © CS & IT-CSCP 2012. | [8] Yong Taek Kim, Hyun Chan Cho, Jae Yong Seo, Hong Tae Jeon and George J. Klir. Intelligent path planning of two cooperating robots based on fuzzy logic, International Journal of General Systems 2010. | [9] Tang Sai Hong, Danial Nakhaeinia and Babak Karasfi (2012). Application of Fuzzy Logic in Mobile Robot Navigation, Fuzzy Logic - Controls, Concepts, Theories and Applications, Prof. Elmer Dadios (Ed.).R |