Robotic Path Planning for Multiple Goals in Dynamic Environment

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Abstract - *Path planning is an important aspect of any mobile navigation to find a hazard-free and an optimal path. Nowadays, mobile robots are widely used in various applications and fields. The aim of the research is to plan a trajectory and minimize the path length with collision avoidance for a mobile robot in dynamic environment. A new methodology is presented to optimize trajectory of the path for mobile robots using improved Rapidly-Exploring Random Graphs (RRG). The positions of the dynamic environment will be changed randomly by considering different scenarios. Finally, simulation results confirm that the proposed RRG Algorithm is better than A* algorithm in terms of accuracy, feasibility and optimality.*

Key Words: **Path Planning Problem, Rapidly-exploring Random Tree(RRT), A* Algorithm, Multiple Goals.**

1. INTRODUCTION

Autonomous robots are mostly used in many industrial, agricultural and military applications. Research in the path planning is one of the most important aspects in mobile robot domain. Path planning for a mobile robot need to find a collision free path in dynamic environment from the specified start location to a desired (target) goal location while satisfying certain optimization conditions. Existing path planning methods like graphical methods such as visibility graph, the potential field and the cell decomposition are designed for dynamic environments, in which there are dynamic obstacles. In practical systems such as Marine Science Research [4], Mobile Robots in Industry, and military combat applications, robots usually face dynamic environments where both moving and stationary obstacles exist. The concept of Rapidly-exploring Random Tree (RRT) as a randomized data structure (graph) is designed for a broad class of path planning problems [2]. While sharing many of the beneficial properties of existing randomized planning techniques, RRTs are specifically designed. It does not depend on the velocities or any higher order derivative with respect to time (including dynamics) and high degrees of freedom. RRT is iteratively expanded by applying control inputs that drive the system slightly toward randomly-selected points, as in the probabilistic roadmap approach [1]. The goal of this research is to plan a trajectory and minimize the path length with collision avoidance for a mobile robot in dynamic environment [3].

2. LITERATURE SURVEY

To solve the navigation problem for the robot, researchers have proposed various methods. In conventional navigation methods such as cell decomposition (Latombe, 1990) [5] and road map (Wang. 2000) [6], due to the high volume of calculations, solving problems in complex environments is tedious task. Artificial potential field method (Shi, 2009) [7],The artificial potential field method assumes the robot moving in an abstract artificial force field. The goal position produces an attractive force which makes the mobile robot move towards it. Obstacles generate a repulsive force, which is inversely proportional to the distance from the robot to obstacles and is pointing away from obstacles. The robot moves from high to low potential field along the negative of the total potential field. But due to stop at local minima, this method will fail. In recent years a series of intelligent ideas, such as genetic algorithms and particle swarm optimization because of the robust and ability to the simultaneous calculations to solve the navigation problems are used. Ghorbani et.al proposed (Ghorbani, 2009) [8], the genetic algorithm for solving the problem of mobile robot navigation, this work shows the possibility of using genetic algorithms in mobile robot navigation. The autonomous robot has a map of the room it moves within and some simulated sensors including range sensors to measure the distance between the robot and the other objects in the room. The location estimation method is based on minimizing the fitness function that depends on the measured data and the environment model by a genetic algorithm. Sugiwara et.al proposed (*Sugawara,* 2004) [9], ants colony algorithm to solve the problem of navigation in a dynamic virtual environment. The problem-solving capability of the system includes path planning and collision avoidance of a ship in the open sea as well as in restricted waters. The developed system enhances automation of the safe ship control process. It can also be employed in Unmanned Surface Vehicles (USVs) control system, what will contribute to enhancement of their autonomy. The following issues includes the developed navigational DSS architecture and the path planning and collision avoidance problem definition.

3. PROPOSED WORK

Path planning in dynamic environment for mobile robot from single source to multiple goals is proposed.

Applying multi-goal approach in various fields for monitoring and surveillance purposes in which an optimal path is planned for a mobile robot. The problem is to find a collision-free trajectory for a mobile robot, starting from given source to multiple goals, where the journey completes in desired time. The mobile robot must not collide with any obstacles in dynamic environment at any time. The objective is to minimize the cumulative travel time. The function returns set of points in the configuration space which are occupied by robot when placed at position. The travelling speed of the robot is constant.

3.1. Rapidly Exploring Random Graphs

The proposed algorithm maintains a graph structure called Rapidly-exploring Random Graphs (RRG). Each node of the graph may be connected to one or more nodes. The following are the properties of graph:

- The complete graph may be interconnected, or may consist of disconnected sub-graphs.
- Minimum distance between any two nodes is r which avoids too many nodes being produced close to each other resulting in high computational costs with minimal increase in quality. r is roughly of the order of stepsize. Here, stepsize is the distance by which a node is expanded to produce a new node.
- Each node has a location and a color. Location specifies the position in the configuration space, while the color indicates about the origin of the node that is the initial node by continuous expansion of whose children the node is produced. Every child node takes the color of the parent, whose expansion produces the child.
- Each node is connected to every node at a distance where the connection between them is collision free.

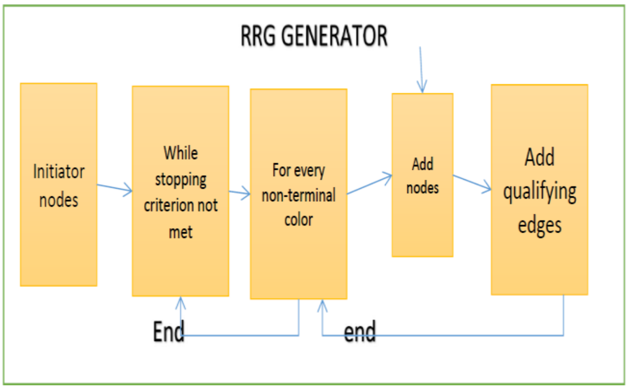


Fig 1: RRG generation

Initially a set of initiator nodes are added to the graph, which are the only vertices in the graph. All initiator nodes are disconnected from each other. All points are given a distinct color. The default choice is to take the set single source and multiple goals of the mobile robot as the set of initiator points. Redundant points or points less than a distance of *r* are taken as one.

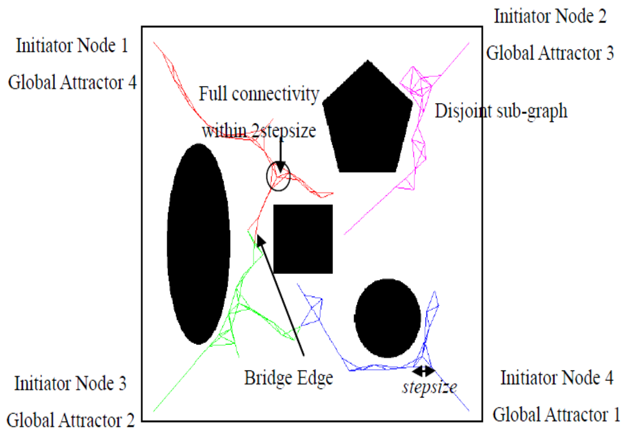


Figure 2 : A sample RRG

3.2 Expansion strategy

The graph (RRG) is iteratively produced by constantly adding nodes, and finding the nodes with which the newly produced node must be connected edges. All the colors in the graph are iterated. A color denotes a sub-graph which may or may not be connected to other sub-graphs depending upon the presence of bridge edges. The sample is randomly chosen out of the entire configuration space. For every color *c*, a sample is generated, closest node is found in the colored sub-graph. The node *V* is expanded towards *S* by a magnitude of *stepsize* to produce a new node (*N*) which takes the same color as *V* ($color(N) = c$). The node *N* is added to the *RRG* only if no other node already lies in *RRG* close enough to *N* and *N* is collision free. After the addition of node, new edges need to be added. Edges are all undirected. *N* is connected to any node *p* by an edge *e* if $|| N - p || < 2stepsize$. Collision checking is additionally performed. The edge *e* is called as a bridge edge if $color(N) \neq color(p)$.

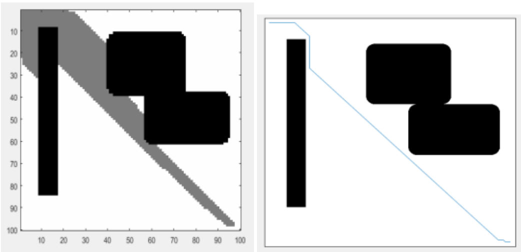
3.3. Post Processing and Path Planning

The stopping criterion of the algorithm may be based on execution time, number of iterations, maximum number of nodes, or maximum number of failures in adding a node. As the algorithm proceeds certain colors may reach their threshold of expansion, wherein their covers either merge with the covers of other colors or limits of the configurations space. Failures to add nodes for every color are monitored, and if a set threshold is crossed termination for expansion of a particular color is set. Paths are post-processed with local optimization. This gives the final trajectory $\tau i(t)$.

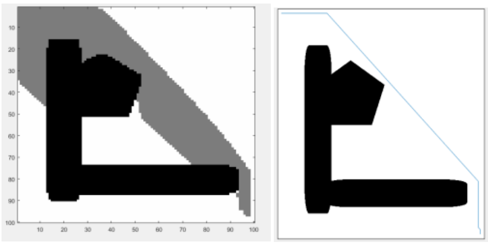
4. SIMULATION RESULTS

A* algorithm is a well-known method in motion planning problems which can find the optimum path between two point in a finite time. In contrast, the RRT family algorithm, by random sampling from the environment, converges to a collision-free path. By simulating these algorithms in complex environments by using MATLAB, it is concluded that RRT family algorithms are significantly faster than A* algorithm however the paths which are found by RRT algorithms are longer than A*.Figures below representing Simulation Results for A*

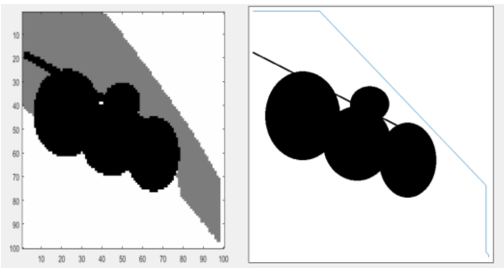
Graph **Path**



Graph **Path**



Graph **Path**



Graph **Path**

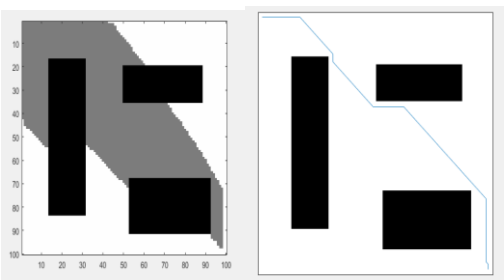


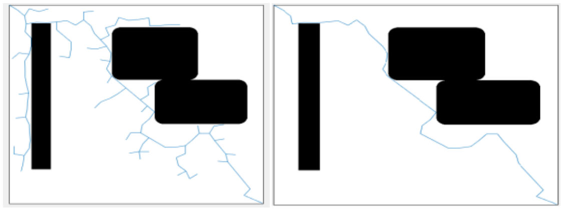
Figure 3. Simulation Results for A*

Sl.No.	Path Length	Processing Time(secs)
1	719	1.184
2	743	1.816
3	757	1.719
4	763	1.189

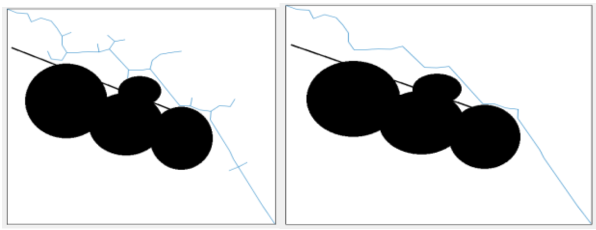
Table 1. Path length and processing time of A* algorithm

Figures below representing Simulation Results for RRT algorithm

Tree **Path**



Tree **Path**



Tree **Path**

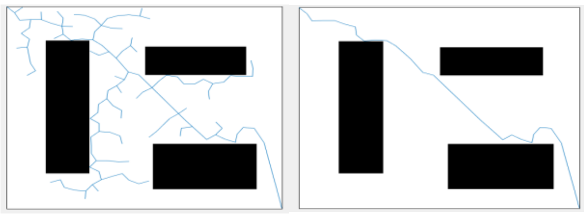


Figure 4. Simulation Results for RRT

Sl.No.	Path Length	Processing Time(secs)
1	914	0.484
2	840	1.249
3	812	1.074
4	853	1.390

Table 2. Path length and processing time of RRT algorithm

5. CONCLUSION AND FUTURE WORK

The proposed method is able to deal simultaneously with both global and local planning requirements. The advantages of the approach can be summarized by the fact that the trajectories obtained are smooth and safe, and at the same time, free of local traps. The method is easy to implement, the algorithm is very fast and works in dynamic environments with any obstacles. As demonstrated along this work, the method can perform in all types of environments without restrictions in the form of the dynamic environments.

The proposed approach is flexible for changing any parameters, control the degree of importance of avoiding or moving toward the multiple goals. The experiments are carried out in various dynamic environment scenarios by implementing RRT as a graph to find the collision free path for a mobile robot to move from single source to multiple goals which is compared against the A* algorithm. The proposed algorithm may be enhanced in future to make use in the applications where multiple robots work to achieve some desired goal by adding heuristics that are used for assigning priorities to the robots, and introduce some better coordination techniques to improve the efficiency of multi-robot systems.

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