www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 2 Issue 12 December, 2013 Page No. 3572-3575

Obstacle Locating Capabilities of Mobile Robot Using Various Navigational Aids

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Abstract— **Automatic path planning is one of the most challenging problems confronted by the autonomous robots. Generating optimal paths for autonomous robots are some of the heavily studied subjects in mobile robotics applications. The environments in which the robots operate can be structured or unstructured. In various applications, environment is detected through vision sensors like cameras. Once the information about the environment is known, then it is always convenient to build a roadmap or graph of the environment. Different algorithms exist in the field of path planning for building the roadmaps. After obtaining the convenient representation of the environment the graph search methods can be used to find the optimal paths through this roadmap. Graph search algorithms are very popular in the field of mobile robotics and finds a lot of applications in this field. This survey aims at analysis of various navigational and path planning algorithms using a mobile robot in structured environment. Along with that it involves the study of lacking behaviors of methods for efficient representation of environment. The environment is detected through camera and then a roadmap of the environment is built using some algorithms. Finally, the algorithm searches through the roadmap and finds an optimal path for robot to move from start position to goal position.**

Keywords— **Navigation, Robotics, Hybrid Navigation, Tracking.**

I. INTRODUCTION

Mobile robots are complex systems comprised of numerous sub-technologies, many of which still have a lot of potential for improvement. Navigation and mission planning, which are some of the most critical aspects of a mobile robot, are the primary subjects of this paper. Mobile robot navigation is an important field of research. Human and other animals use their visual and other sensory perceptions for their motion. But this is a complex task for a mobile robot, especially when navigating in an unknown environment. The robot can sense the environment with the sensors and instruments mounted on it like camera, touch-sensor, sonar, laser range finder, Global Positioning System. There are various issues in robot navigation like localization, turning requirements, obstacle detection, obstacle avoidance, target tracking etc. In general, navigation can be achieved by successful coordination between several key components like a localizer and a path planner. Therefore, the behavior selection should be designed based on the information provided by these navigation related components. However, as the number of components and navigation behavior increases, their relationship become difficult to manage. Therefore, a formal framework is required. Moreover, the behavior selection problem usually has nondeterministic properties. Thus, it should be solved not by predefined logics but by performance estimation in run time. To navigate effectively the robot must be able to perceive and map the surrounding world accurately. It is also absolutely critical for mission success that the robot successfully identifies all obstacles around it.

The path-planning problem was originally studied extensively in robotics and through this research, it has gained more relevance in areas such as computer graphics, simulations, geographic information systems, very-large-scale integration design, and games. Mobile robots have until recently primarily been used in industrial production and for military operations. Nowadays however the technology is progressing towards service robots, intended to assist humans in everyday life. These types of robots have been in development for years and will soon incense many aspects of our lives. Autonomous navigation in obstacle filled environments has always presented a considerable challenge. Solving this problem would allow mobile robots to move about and complete tasks such as cleaning rooms, assisting disabled people and many other missions, without the risk of damaging themselves or their environment. Path planning still remains one of the core problems in modern robotic applications, such as the design of autonomous vehicles and perceptive systems. The basic path planning problem is concerned with finding a good-quality path from a source point to a destination point that does not result in collision with any obstacles. Depending on the amount of the information available about the environment, which can be completely or partially known or unknown, the approaches to path planning vary considerably.

A major scope of this paper is to study a formal selection framework of multiple navigation behaviors for a mobile robot. In the presented paper evaluation are carried out based on the deep analysis of various navigation & path planning techniques. By using a probabilistic approach it is tried to find out, the most desirable navigation behavior and path planning strategies according to environmental conditions. Many authors have proposed various schemes for mobile robot navigation and tried to solve different problems of robot navigation, including the fuzzy logic-based *(Sven Koenig and Maxim Likhachev, JUNE 2005)*, neural network based reactive methods *(Hong Quet. Al. NOVEMBER 2009).*

II. Previous Work On Navigation

To implement the navigation strategy, the robot needs to replan a shortest path from its current vertex to the goal vertex whenever it detects that its current path is untraversable. It can utilize initial knowledge of the terrain in case it is available. If it observes obstacles as it follows this path, it enters them into its map and then repeats the procedure, until it eventually reaches the goal coordinates or all paths to them are untraversable. Following are the various methodologies being developed previously for navigation.

A. View Based Approach

The view-based approach *(SanemSariel-Talayet. Al. APRIL 2009)* consists of an offline collection of images sampled over a space of poses. In offline collection the images are being saved before the actual robotic motion. The offline images consist knowledgeable information about object and the landmarks for differentiating and locating the targeted objects. The landmarks consist of encodings of the neighborhoods of salient points in the images, obtained using an attention operator. Landmarks are tracked between contiguous poses, and added to a database if they are observed to be stable through a region of reasonable size, and sufficiently useful for pose estimation according to an a priori utility measure. Each stored landmark is encoded by learning a parameterization of a set of computed landmark attributes. The localization is performed by finding matches between the candidate landmarks visible in the current image and those in the database. A position estimate is obtained by merging the individual estimates yielded by each computed attribute of each matched candidate landmark.

B. Navigation by Landmark Recognition

Navigation by landmark recognition *(Sourabh Bhattacharya et. Al., FEBRUARY 2007)* is also possible without knowledge of the locations of the landmarks in a map of the environment. In this the robot knows only the image location of the landmarks in a collection of model views of the environment acquired at known positions and orientations. One such approach is the LC technique. The authors proved that if a scene is represented as a set of 2-D views, each novel view of the scene can be computed as a linear combination of the model views. From the values of the linear coefficients, it is possible to estimate the position from which the novel view was acquired, relative to that of the model views.

C. Hybrid Navigation

In the hybrid navigation controller *(Pablo Sal et. Al. APRIL 2006)* the model-based path is fused with the obstacle-avoidance behavior in order to achieve the optimal path. However, the resultant path may deviate considerably from the real optimal path in a real environment with unknown objects, as the path planned can no longer serve as the reference path in this situation *(Sven Koenig, and Maxim Likhachev, JUNE 2005).*

Methods have also been developed to combine multiple unreliable observations into a more reliable estimate. Measurements from various sensors, data acquired over time, and previous estimates are integrated in order to compute a more accurate estimate of the current robot's pose. In every sensor update, previous data is weighted according to how accurately it predicts the current observations. This technique called sensor fusion. It has been applied to the problem of localization by *(Ray AK et. Al. JUNE 2008)* from sonar data obtained over time.

III. Path Planning Methodologies

The definition of a good-quality path usually depends on the type of a mobile device (a robot) and the environment which has fostered the development of a rich variety of path-planning algorithms, each catering to a particular set of needs. Computational geometry plays a special role in path-planning developments. Extensive methodologies that rely on geometric representation of the space reveal topological properties of the agents and allow the efficient dynamic position tracking and updates have been brought forward from computational geometry to solve a specific set of path-planning problems. Such problems usually have a well-defined and deterministic set of objectives, regular geometric space representation and specific functions that describe robotic movements. The problems also include planning a path and studying the behavior of a network of mobile robot agents *(Sherman Y. T. Lang and Yili Fu, DECEMBER 2000).* The traditional computational geometry-based approaches to path planning can be classified into mainly three basic categories: the cell decomposition method *(YangshengXu and Samuel Kwok-Wai Au, JUNE 2004)*, the roadmap method *(Robots et. Al. JULY 2011)* and the potential field *method (Aurelio Piazzi et. Al. OCTOBER 2007).*

A. Cell Decomposition Method

The cell decomposition method uses non-overlapping cells to represent the free-space connectivity. The decomposition can be exact or approximate. An exact decomposition divides exactly *(YangshengXu and Samuel Kwok-Wai Au, JUNE 2004)*. It decomposes the free space recursively, stopping when a cell is entirely in free-space connectivity or entirely inside an obstacle. Otherwise, the cell is further divided. Because of memory and time constraints, the recursive process stops when a certain degree of accuracy has been reached. The exact cell decomposition technique is faster than the approximate one, but the path obtained is not optimal.

B. Potential Field Method

Here is the other method of planning the path with an introduction of the potentialities called as potential field method of path planning. The idea behind the potential field method of path planning is to assign a function similar to the electrostatic potential to each obstacle and then derive the topological structure of the free space in the form of minimum potential valleys. The robot is pulled toward the goal configuration as it generates a strong attractive force. In contrast, the obstacles generate a repulsive force to keep the robot from colliding with them. The path from the start to the goal can be found by following the direction of the steepest descent of the potential toward the goal *(Aurelio Piazzi et. Al. OCTOBER 2007).*

C. Road Map Method

The roadmap method attempts to capture the free-space connectivity with a graph. This approach has several variations. This method represents the free-space connectivity with a graph whose vertices are generated randomly in free space and connected to the k-nearest neighboring vertices such that the connecting edges do not cross any obstacle. The roadmap method is very promising for dynamic path planning where the obstacles and hurdles are in a motion, as a big advantage of the same is that its complexity depends mostly on the difficulty of the path and to a much lesser extent on the global complexity of the environment or the dimension of the configuration space. A recent algorithm based on the roadmap method for a dynamic environment can be found in *(Robots et. Al. JULY 2011).* Some of the other popular roadmap-based approaches are based on computational geometry structures such as the visibility graph for the shortest path and the Voronoi diagram for a maximum clearance path.

D. Voronoi Diagrams

The advantage of using a Voronoi diagram over alternative methods, among which the visibility graph prevails, is its efficiency. A Voronoi diagram is a fundamental computational geometry structure and is defined as the partitioning of a plane with n points or generators into convex polygons such that each polygon contains exactly one generator and every point in a given polygon is closer to its generator than to any other. The Voronoi diagram is also a well-known roadmap in the path-planning literature, which has edges that provide a maximum clearance path among a set of disjoint polygonal obstacles. The authors *(Paolo Salariset. Al. JUNE 2008)* combine the Voronoi diagram, visibility graph, and potential field approaches to path planning into a single algorithm to obtain a tradeoff between the optimal by safe and the shortest paths. Another recent work on reducing the length of the path obtained from a Voronoi diagram *(KetanSavlaet. Al. JULY 2008)* involves constructing polygons at the vertices in the roadmap where more than two Voronoi edges meet. Here the authors create a new diagram called the VV diagram (the Visibility-Voronoi diagram for clearance c). The motivation behind their work is similar to ours i.e. to obtain an optimal path for a specified clearance value.

IV. Lacunas Of Previous Methodologies

In outdoor and open environments, knowing the environment is a challenging task, which could possibly be achieved through global positioning system, land marks, laser sensors, ultrasonic sensors, and various other sensors. Some approaches for real-time navigation of mobile robots have no explicit global path-planning algorithms. These employ human-like or biologically inspired strategies. Such as view based method *(SanemSariel-Talayet. Al. APRIL 2009)* where the robot movement is determined by the real time sensor measurements and only simple local path planning is available, focuses on map building and thus is computationally expensive. The landmark here contains the encoded information of the salient features of neighboring environment. The landmarks are added into the data base only if they seem to be stable in terms of their region size and sufficiently useful for pose estimation. If the environment consists of landmark with very low intensity and low stability, this algorithm will not be detecting those landmarks and it will directly be neglected to round off. The problems also include planning a path and optimizing it based on selected criteria such as the length, the smoothness, the cost, etc. solving problems involving evolutionary algorithms. Local target switching is presented here but the technique it uses does not elaborate the modeling issues with complex environmental condition. No attention has been given to the size of the landmark database.

In Navigation by Landmark Recognition *(Kim and Woojin Chung, JULY 2007)*, navigation is achieved by localization in a view based fashion, in which the robot knows only the image location of the landmarks in a collection of model views of the environment acquired at known positions and orientations. A technique called as LC technique is developed in which the scene is represented as a set of 2-D views, each view can be computed as linear combination of the model views. Inspite of the fact of linear combination in this paper there is not a single issue that concerns the size of the landmarks.

In Hybrid Navigation *(Paolo Robuffo Giordano et. Al. OCTOBER 2006)* model the resultant path deviate considerably from the real optimal path in the real environment with its unknown introduction of objects as obstacles because, the path is fused with obstacle avoidance mechanism to achieve optimal path. This path cannot be termed as the planned path and thus it proves invalid. Here the kinematic constraint of robotic assembly is not taken into account as this approach is defined by the integro-differential equation, in this algorithm there is no provision of addition or noticing kinematic effect on the robot.

In the cell decomposition method of path planning *(YangshengXu and Samuel Kwok-Wai Au, JUNE 2004)* the non-overlapping cells are used to represent the free-space connectivity. The approximate cell decomposition can yield the optimal paths by increasing the grid resolution, but the computation time will increase drastically. There is also the known problem of digitization bias associated with using a grid. This stems from the fact that while searching for the shortest path in a grid, the grid distance is measured and not the Euclidean distance.

In the Potential Field Method *(Aurelio Piazzi et. Al. OCTOBER 2007)*, a function similar to the electrostatic potential is assigned to each obstacle and then the topological structure of the free space is derived in the form of minimum potential valleys. The strength of this approach is that path planning can be done in real time by considering only the obstacles close to the robot. Information on the locations of all obstacles is not required beforehand. However, as only local properties are used in planning, the robot may get stuck at local-minima and never reach the goal.

However, in general, Road Map based approaches *(Robots et. Al. JULY 2011)*, being probabilistic in nature, do not meet any optimality criteria. There has been research on planning algorithms coordinating motion of multiple robots. A path obtained directly from the Voronoi diagram *(Paolo Salariset. Al. JUNE 2008)*, *(KetanSavlaet. Al. JULY 2008)* may be far from optimal. It usually has many unnecessary turns, and the length of the path may be undesirably long at regions where the obstacles are far apart. In fact, it is worth noting that minimizing the path length and maximizing the clearance seemingly contradict each other, as increasing the clearance results in a longer path whereas reducing the path length necessarily reduces the clearance from obstacles.

V. Conclusions

The techniques studied above lack the basic fundamental criteria in same or the other manner. All the above methodologies have both effects i.e. in favor and in opposition. The maximum algorithms may be combined with their counter parts and they can produce the fruitful result but also adds up the complexity behavior in manifolds. Some algorithms are not in state to be get fused with the other ones, though they exhibit the same behavior, working procedures etc, the difference is in terms of their assumptions which is made compulsorily to be followed under every scenarios. These scenarios may be the prohibiting limits of the other algorithms and thus it makes the algorithms complete in infusible state. Here are some point being forecasted which are extracted after glancing the algorithms, for proposing the new methodology that can be free from unnecessary assumptions and will be compatible for fusion with other algorithms. The technique has to be able to generate near-optimal paths with less time. The paths have to be shortest possible while maintaining just the amount of clearance required. The algorithm has to conjecture that the obtained path is satisfactory in the homotopy sense, i.e., it can be continuously transformed to the true-optimal path without crossing any obstacles. The obtained approximation has to be always refined to a near-optimal path. Experimental results support this conjecture. Another interesting property of the algorithm has to be that the optimal path obtained has to be extraordinarily smooth when going around smooth obstacles. The smoothness only seems to help reduce the path length in such cases.

AKNOWLEDGEMENT

I gratefully acknowledge the unmatchable, helpful knowledgeable kind comments of Prof.MohanAwasthi for improving the clarity of the paper and crystal clearing the work.

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