Path Planning for Mobile Robot Navigation using Image Processing

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Abstract - In this paper, wavefront based algorithms are presented to create a path for a robot while detecting and avoiding obstacles of different shapes in indoor environment. Here an overhead camera is used to acquire an image of the environment. The image analysis is based on general processing in MATLAB. On that basis, 4 point and 8 point connectivity based algorithms are presented for the purpose of path generation.

Keywords: Robot Navigation, Path Planning, Vision based Navigation, Wavefront Algorithm, 4 point connectivity, 8 point connectivity, Image Concatenation.

1 INTRODUCTION

Vision based robot navigation has long been a fundamental goal in both robotics and computer vision research. For a mobile robot to navigate successfully to a goal whilst avoiding both static and dynamic obstacles is a challenging problem. While the problem is largely solved for robots equipped with active range-finding devices, for a variety of reasons, the task still remains challenging for robots equipped only with vision sensors. Vision is an attractive sensor as it helps in the design of economically viable systems with simpler sensor limitations. It facilitates passive sensing of the environment and provides valuable semantic information about the scene that is unavailable to other sensors. Several different approaches to avoiding obstacles have been developed in recent years, some of which are computationally intensive. With the help of an overhead camera, a path can be generated for the robot by capturing and processing real time images.

1.1 MOTIVATION

Autonomous robots which work without human operators are required in robotic fields. Nowadays, mobile service robots in indoor environments such as houses, offices, hospitals, are introduced widely. These mobile robots have to be equipped with a capability to navigate in dynamic environments to execute a given task while avoiding obstacles. A number of sensors – such as laser finders, ultrasonic sensors, stereo-camera-based range sensors, and etc – are used widely in order to detect obstacles in natural environments. However, most of these sensors are too expensive to apply for low-cost service robots like vacuum cleaning robots or guide robots. Hence, visual navigation took much attention after web cameras were introduced a few years ago since their cost is attractive as compared to the previous sensors. In order to achieve tasks, autonomous robots have to be intelligent and should decide their own action. When the autonomous robot decides its action, it is necessary to plan optimally depending on their tasks. More, it is necessary to plan a collision free path minimizing a cost such as time, energy and distance. When an autonomous robot moves from a point to a target point in its given environment, it is necessary to plan an optimal or feasible path avoiding obstacles in its way.[1]

1.2 RELATED WORK

Shahed Shojaeipour, et al present a method that determines the shortest path for the robot to transverse to its target location, while avoiding obstacles along the way using a webcam. Image processing methods are performed on captured environment to identify the existence of obstacles within the environment. Using the Voronoi Diagrams VD(s) method, locations with obstacles are identified and the corresponding Voronoi cells are eliminated. From the remaining Voronoi cells, the shortest path to the goal is identified. The program is written in MATLAB with the Image Processing toolbox.[2]

Akihisa Ohya, et al describe a vision-based navigation method in an indoor environment for an autonomous mobile robot which can avoid obstacles. In this method, the self-localization of the robot is done with a model-based vision system, and nonstop navigation is realized by a retroactive position correction system. Stationary obstacles are avoided with single-camera vision and moving obstacles are detected with ultrasonic sensors.[3]

The standard algorithm for finding optimal paths on terrain with a known cost map is a dynamic-programming "wavefront propagation" Terrain is modelled by a uniform "grid" or tessellation of cells of uniform size and shape. Each cell has an associated cost which represents an average cost-per-unit-traversal-distance for the terrain within the cell. The algorithm works by expanding a

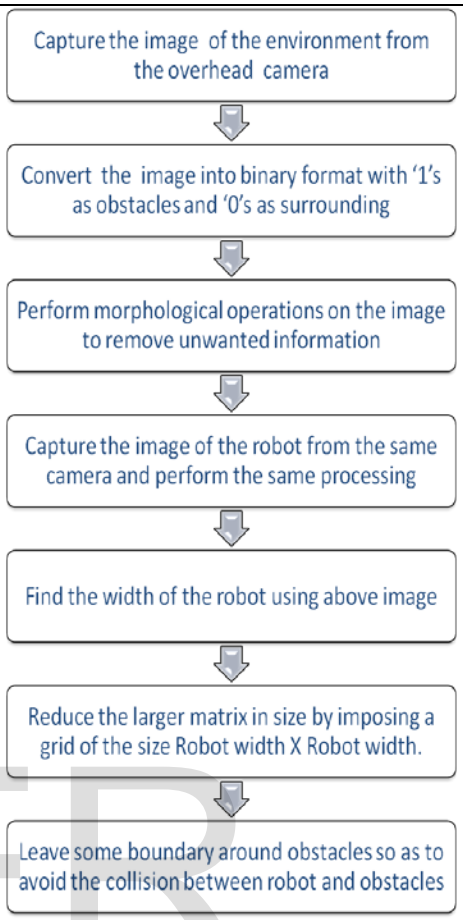
wavefront (initially approximately circular) about the start point, much in the way that a stone dropped in a smooth pool of water creates ever-expanding ringlets of disturbance in the surface of the water. In the algorithm, the wavefront is expanded at varying rates along its circumference in a way proportional to the reciprocal of the traversal costs for the underlying cells, so the wavefront moves more slowly through high-cost cells. The algorithm stops when the goal point is encountered, and back pointers are used to recover the path that was taken from the start point to that goal point as the wavefront expanded.

1.3 ORGANIZATION OF THE PAPER

The remainder of the paper is organized as follows: Section II gives an idea about the image acquisition and the processing required for applying the wavefront technique. In Section III we discuss the wavefront algorithm used.

2 IMAGE ACQUISITION AND PROCESSING

An image of the environment is acquired in which the robot has to be navigated by an overhead camera. Basic morphological operations are performed on this image to get rid of the noise and unnecessary detail. The final image so obtained is used to determine if there is any obstacle in the given environment. The steps given below are followed to obtain the final image



The images obtained during the processing are as follows

Fig. 1. Original Image

Fig. 2. Binary Image

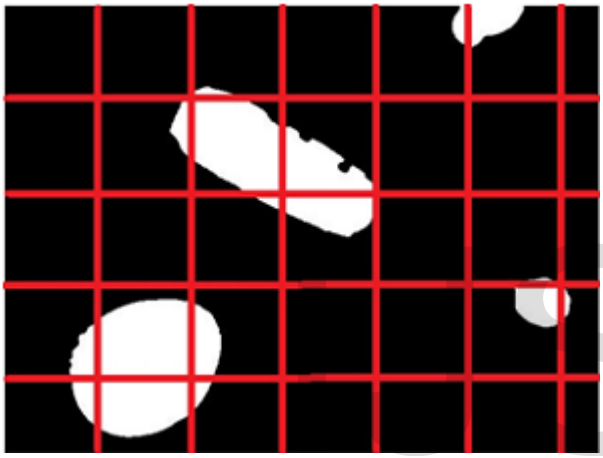


Fig. 3. Image with grid imposed

Fig. 4. Virtual object boundaries obtained after leaving some space around obstacles

3 WAVEFRONT TECHNIQUE

The wavefront technique mapping algorithm leads to a very simple and efficient implementation that generates a path for the robot with minimum time complexity.

3.1 OVERVIEW

- The wavefront algorithm involves a breadth first search of the graph beginning at the destination point until it reaches the start point. First, obstacles are marked with a 1 and the goal point is marked with any small number other than 1 like 2.
- Wavefront matrix is generated either by adopting 8 point connectivity or 4 point connectivity.
- The obstacle avoiding path is defined by any uninterrupted sequence of decreasing matrix element values that lead to the goal.

3.2 WAVEFRONT BASED ON 4-POINT CONNECTIVITY

Step 1: Assign a value greater than '1' to the goal point. Say '2'.Then assign the value '3' to four adjacent points of goal and '4' to the four adjacent points of value '3'.

0	0	0	0	2	0	0
0	0	0	1	0	0	0
0	0	0	1	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Step 2: Continue this until the start point is reached.

Step 3: After completion, the final matrix generated will be as shown below:

6	5	4	3	2	3	4
7	6	5	1	3	4	5
8	7	6	1	4	5	6
9	8	7	6	5	6	7
10	9	8	7	6	7	8

Step 4: Once the start point is reached, trace the numbers in reverse fashion in decreasing order until the goal point is reached. Thus, we get two paths as follows:

-	-	-	-	2	3	4
-	6	5	1	-	4	5
-	7	6	1	-	5	6
-	8	7	6	-	6	7
-	-	-	-	-	7	8

3.3 WAVEFRONT BASED ON 8-POINT

CONNECTIVITY

Step 1: This step is same as that used in 4-point connectivity. Except for, we check the eight adjacent points of the goal instead of four.

0	0	0	0	2	0	0
0	0	0	1	0	0	0
0	0	0	1	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Step 2: After following the same steps as in the previous case, the final matrix generated will be as shown below:

6	5	4	3	2	3	4
6	5	4	1	3	3	4
6	5	5	1	4	4	4
6	6	6	7	5	5	5
7	7	7	7	6	6	6

Step 3: Mention the start point and trace the numbers in reverse order until the goal point is reached.

6	5	4		2	3	4
6	5	-	1	3	3	4
6	5	-	1	4	4	4
6	-	6	7	5	5	5
-	7	7	7	6	6	6

3.4 REVESRING THE GRID

These algorithms are being implemented on smaller matrix obtained out of grid technique. Now the path constructed on this matrix has to transform onto the original scenario.For this we are implementing reverse grid technique in which each path element will get expanded to Robot-width X Robot-width size in original image.

The final path obtained is as shown below.

Fig. 5. Path generated using 4-point connectivity

Fig. 6. Path generated using 8-point connectivity

4 INCREASING THE AREA OF OPERATION

Increasing the area under operation may be desirable in some cases. This can be done using image concatenation. Images obtained from more than one cameras are processed in such a way that a continuous scenario image without overlapping the common regions can be obtained.

The algorithm used for image concatenation is explained below

Step 1: Capture images from two collinear and equally horizontally aligned overhead cameras with same resolution and convert them into binary images.

Step 2: Find the starting of the overlapping region of the two images.

Images taken from the two cameras are

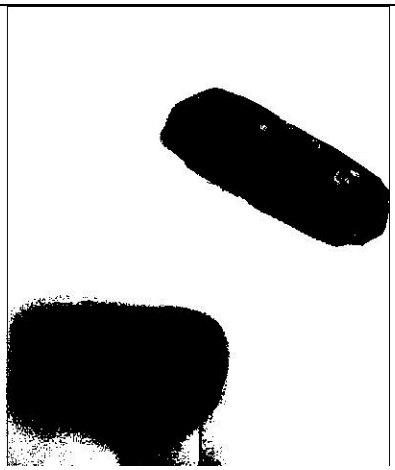


Fig. 7. Image obtained from first camera

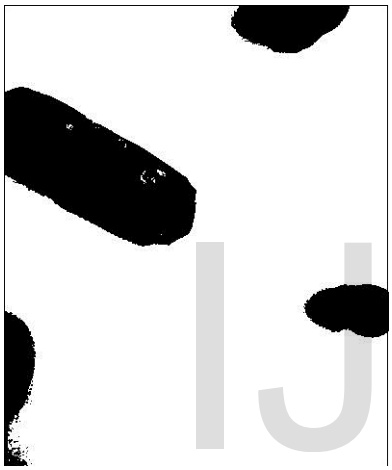


Fig. 8. Image obtained from second camera

Step 3: If no overlapping region is found, then, just append the second image on the first image. Else, append the remaining part of the second image after the overlapping region on first image.

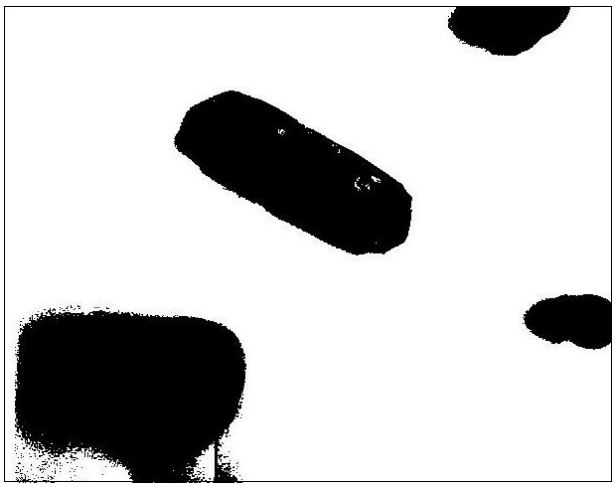


Fig. 9. Final image obtained after concatenation

5 LIMITATIONS

This technique may not always give the shortest path for navigation.

Increasing the area of operation is costly as the processing time and complexity increases with increase in the number of cameras used to capture the image of the scenario.

The suggested algorithm is tested for indoor environments only.

6 CONCLUSION

A path is generated for traversing from the user defined source to user defined goal using 4-point and 8-point connectivity.

The comparison of the two algorithms yields the following results

1. Use of 8-point connectivity gives a shorter path length as compared to 4-point connectivity
2. Use of 4-point connectivity reduces the code complexity as compared to 8-point connectivity.
3. The execution time for both the algorithms is almost same with a negligibly greater time required for implementing the 8-point connectivity algorithm.

Therefore both the techniques are suggested here and it is left to the user to decide which algorithm he wants to use.

7 FUTURE SCOPE

In future, the range of operation can be increased further by increasing the height of the overhead camera.

Also, the same algorithm can be extended for navigation through video processing.

Overhead camera and mounted camera on the robot can be used simultaneously to determine the exact spacing between two obstacles to avoid critical collisions during navigation.

Here for the obstacle detection, their colour difference with the surrounding is used, but, if the objects and surrounding are of the same colour then, more efficient algorithms need to be implemented to distinguish between them. Once it is done, the robot can navigate perfectly through rough surfaces also.

By using the SLAM technique for robot localization , navigation can be more efficient.

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