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Path Generation for Robot Navigation using a Single Ceiling Mounted Camera

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Abstract

The paper focus on providing a novel method to find a shortest path in an indoor environment for a robot for its ease of movement, it also detects and avoids obstacles in an environment using a single ceiling mounted camera. The system generates a path given the source (being the current position of the robot) and destination and transmits the path details to the robot which moves using those details, here we only discuss the path generation and not the transmission mechanism. Here we consider only the indoor aspect and avoid any outdoor paths.

Keywords: Floor Segmentation; Robot Navigation; Path Generation; Shortest Path; GOPPA; Edge Detection; Threshold; Indoor Robot Navigation.

1. INTRODUCTION

Mobile robots which are capable of helping humans without any human interventions are of great use in robotics be it in the field of automated cars, missile guidance, hostage recognitions, detection of enemy spots, homes, hospitals etc. To achieve their tasks, mobile robots should be autonomous by nature in all aspects. One of such aspects is path planning.

An autonomous robot needs to move or traverse from point A to point B. Path planning is important for robots as it lets the robot find the shortest or optimal path between the initial and destination points. Path planning algorithms are complex and require a map of the surrounding environment and for the robot to be aware of its location with respect to the map. An additional element is for the map to have all obstacles in the path of the robot to be mapped. There are two approaches to representing the map in a computer environment: Discrete and Continuous approximation. Discrete maps are like representations on a graph, in this the map is laid out as a graph (grid) or as a differing size (rooms in a building). Every point is the node which is connected by the edges; the robot has to move from one node to the other. In a discrete or Grid map grid cells which probably may contain an obstacle can be marked.

Path planning being a basic task for a mobile robot navigation has opened up an enormous potential in the field of computational vision for robotic navigation and vision-based path planning, leading to huge amount of active studies in the last decade. The work has bifurcated itself to: 1) Indoor vision-based navigation of robot where the system has a complete information of the site and 2) Outdoor vision-based navigation of robots where there is either partial or no information whatsoever of the environment.

In this paper what is proposed is that a ceiling mounted camera is used to take an upper view of a room, this image is used to provide a path for a robot given the source and destination points in the room. It makes use of the dimensions of the robot to maintain a safe distance from the obstacle, a basic thresholding technique is used to identify the obstacles in the room.

Once the obstacles have been identified, and source and destination points have been specified, a centralized server calculates the shorted and safe (obstacle free) path from source to the destination. For better understanding for the path generated a simulation is produced.

The paper is organized as follows: Section 2 details about the survey conducted before writing this paper. It provide insight into fundamentals of path planning and different approaches. Section 3. Gives the work carried out Section 4 gives the Simulation results and finally, the paper is concluded in Section 5.

2. RELATED WORK

Deepu R , et al [1] have proposed for providing a path in an environment for a robot for its ease of movement, detecting, and avoiding obstacles in the environment using a single camera and a laser source. The robot moves by identifying free space in floor. Novel method for floor segmentation has been done. A laser source emits light that falls on an obstacle if any, and based on the position of the laser light on the obstacle and the distance of the obstacle from the robot, the robot continuous to moves in a different angle. Absence of laser light with different floor mark is treated as a hole in the floor and is skipped.

This system involves a novel approach for floor detection in an environment which does not contain line edges. Structuring element which are randomly selected floor patterns are used. The structuring elements are compared with input images block wise and the input is then fused. In the proposed system each and every element of the input image is compared with the structuring element values. Then the comparison value count is checked and if the value is more than the defined threshold (manually selected value) then it is considered as a floor point otherwise it is not.

Yinghua Xue, et al [2], have proposed an improved A* algorithm to avoid obstacles based on dynamic danger degree map. In there proposal they have proposed that the local layer can get multiple mode information of obstacles, and create dynamic danger degree map of the environment. The dynamic path planner adopts method based behavior, which can correct static path according to dynamic information. And the head for goal strategy is designed to help the mobile robot to arrive at the destination with lowest cost.

Ananya Das, et all [3] have proposed a path finding strategy in which the A* algorithm has been implemented in a grid map form of an unknown environment with static unknown objects based on the concept of the quadrant in which the goal is present. The mobile robot navigates through static obstacles and finds the shortest path from an initial position to target position by avoiding the obstacles. The proposed algorithm optimizes the path since the goal is present in any of the four quadrant. Distance, Time and Energy metric were considered to be cost function.

In this, the system provides a solution to the path planning problem for a robot in an unknown environment using a modified version of A* algorithm over GA based algorithm to optimize energy, time and distance. In a grid map the robot has to find its way from source or initial point to the destination or target point navigating obstacles in an optimum route. To do that the robot generally moves in four directions (neighboring squares on a grid) vertically or horizontally. The proposed solution states that instead of moving in all four directions, the robot will first ascertain the quadrant in which the goal is situated, thereby skipping three quadrants at each step of the movement. This way the robot will have to consider only two possible neighbors in the axis point. This optimizes the computational time to finding the shortest path to the goal. To find the position of the goal (quadrant in which the goal is situated), the robot computes the quadrant of the goal by subtracting the goal coordinate point and the initial coordinate point.

Shahed Shojaeipour, et all [4] have proposed a method to navigate a mobile robot using a webcam using a method to determine the shortest path for the robot to traverse to its target location, while avoiding obstacles along its way. The proposed methodology involves capturing the image with a webcam, and using Voronio Diagrams VD(s) method, identifying the existence of locations with obstacles, and eliminating the corresponding Voronio cells. The method then proceeds to identify the shortest path for the remaining Voronio cells.

In their experimentations Shahed Shojaeipour, et all [4] have used a robot fitted with a webcam which records images and sends it to a PC. The images received are segmented and the segmented images are converted into grayscale image to reduce the computational workload involved in image processing. By using image processing methods in MATLAB and the following steps, the existence of obstacles are identified; generating input video, previewing the image from the webcam video, setting the brightness level of the image, capturing the still image, removing the input device from memory, converting RGB to grayscale, edge detection, filtering noise. For path planning using Voronoi diagrams the first step would be to capture image, second to convert image to 3D using spectral fractal dimension (SDF), the third to use cell decomposition and by eliminating the obstructed paths using the Voronoi Diagrams.

Tongxiang He, et all [4] have proposed an algorithm based on fuzzy logic which uses a fuzzy control table. The proposed algorithm tries to resolve the deadlock problem by implementing a deadlock prevention mechanism, in which the robot detects dangerous obstacle field which possibly causes the deadlock. The robot uses the deadlock prevention mechanism and tries to travel along the edge of the object, to escape the object. And in the event the deadlock can not be avoided the deadlock prevention algorithm, it is proposed that the deadlock resolution strategy be adopted.

The proposed system uses a fuzzy logic controller, which takes two inputs and gives one output. The inputs are the distance between the robot and the object in front and the directional angle between the forward direction of the robot and the target point. The resulting output is the steering angle. The robot is programmed to move a fixed steps after each planning.

Certain basic ideas are implemented in the logic, when the robot encounters a target point on the left (right) side of the robot it moves towards the left (right). When the distance between the robot and the target point is less and the target point is the rare of the obstacle then the robot turns left or right based on the distance, if the distance between the left obstacle is greater than the right obstacle the robot turns left else it turns right. A fuzzy control table is constructed using the Mamdani fuzzy reasoning method and the result is defuzzied using Centroid method.

M.Vijay et al [5], have proposed an array architecture based hardware solution for complete path planning based on the binary image of the environment. The different operations in path planning are decomposed into simple local neighborhood operations, and these local neighborhood operations are combined to design a processing element of the architecture. The path obtained will be the shortest path in terms of the number of steps.

In this methodology, a distance map for the binary form of the image to determine a collision free region is constructed from the environment image captured. The shortest path is then constructed in the collision free region. For a binary image of obstacles, the Euclidean Distance transformation (EDT) and nearest neighbor transformation (NNT) of the image is first computed. The EDT converts the binary image to a multivalued image in which each pixel is assigned the Euclidean distance between the pixel and the nearest object pixel. The distance vector (number of rows and number of columns by which a pixel is displaced from its nearest object) for each pixel is calculated. The distance vector of the object pixel is initialized at (0,0) and is computed iteratively starting from the origin and moving away from it. A flag is set at each pixel as iterations are done thus forming the distance map. This distance map is used to find the collision free region for the robot. If this is treated as a graph the construction of the shortest collision free path involves the construction of the breadth first search tree with the root being the goal pixel. The construction of the breadth first search tree is continued till the start pixel is encountered. The path is traced by following the parent node from the start pixel to the root. This gives the shortest path in terms of the pixel. The robot can move from one pixel to the other by aligning its center of rotation to each pixel.

Shahed Shojaeipour et all [6], have proposed a method to navigate a robot using webcam, in which the image of the environment is recorded and sent to a PC, the images received are segmented and the segmented images are converted into grayscale image to reduce the computational workload involved in image processing, by using image processing methods in MATLAB and the following steps, the existence of obstacles are identified; generating input video, previewing the image from the webcam video, setting the brightness level of the image, capturing the still image, removing the input device from memory, converting RGB to grayscale, edge detection, filtering noise. Cell Decomposition methods are used for path planning, by adjusting the brightness of the cell obstacles are identified (if the quantity variables are more than 0.3 then they are considered as obstacles).

Soh Chin Yun, et all [7], have proposed a Genetic Goal Oriented Path Planning Algorithm (GOPPA) for acute obstacle avoidance in mobile robot navigation. The proposed navigation technique is capable of re-planning the optimum collision free path in the event the robot encounters any dynamic obstacles. The proposed algorithm is Goal oriented and hence reduces unnecessary search time. The proposed algorithm does the following; initialize, by activating the Goal Heading Algorithm the collision free path is calculated from the starting point to the destination or Goal, using the Remove Redundant Point Algorithm after the collision free path is determined, the unnecessary neighboring coordinates are screened out to remove the unnecessary points, by using the Path Optimization Algorithm the obstacle free path is recalculated, the Detect Obstacle Algorithm is used to identify if there are any obstacles when the robot is traversing according to the new collision free path planned after the previous processes, if there are no more obstacles the robot is guided to the destination or the goal, in the event a dynamic random obstacle is encountered the current position is taken as the new starting point. The original goal still remains the desired goal. The steps are iterated again and again till the robot reaches the goal.

Shahed Shojaeipour et all [8], have proposed a method to navigate a robot using webcam and a laser emitter, in the proposed method the image of the environment is recorded and sent to a PC, the images received are segmented and the segmented images are converted into grayscale image to reduce the computational workload involved in image processing, by using image processing methods in MATLAB and the following steps, the existence of obstacles are identified; generating input video, previewing the image from the webcam video, setting the brightness level of the image, capturing the still image, removing the input device from memory, converting RGB to grayscale, edge detection, filtering noise. The presence of obstacles are identified by using Canny edge detector. The laser pointer is calibrated to point parallel to the camera's viewing direction, knowing the vertical distance between the laser pointer and the webcam, the distance to the object can be determined. The whole scene including the point where the laser hits is captured by the camera. Band pass filtering is used to isolate the laser from the rest of the image, the distance is then calculated. By using a combination of the webcam

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and a laser the obstacle and its distance are measured, thereby planning an optimized path for the robot.

The D* algorithm is a dynamic version of the A* algorithm. Daniel Cagigas [9] proposed an extension to the D* algorithm. This hierarchical D* algorithm uses bottom-up approach and a set of pre-estimated paths which gives optimum solution and low computation time. Hierarchical graphs are updated and adapted to help online path planning with materialization of costs and multiple hierarchical levels.

3. PROPOSED WORK

This projects focus is on providing a novel method to find a shortest path in an indoor environment for an indoor vision less robots for its ease of movement. It also detects and avoids obstacles in an environment using a ceiling mounted camera; it does not make use any of the sensors to identify the obstacles or to plan a path.

What is proposed is that a ceiling mounted camera is used to take an upper view of the room; this image is processed based of thresholding techniques to differentiate between floor and obstacles. Once the image is processed and obstacles are identified the source and destination points are marked and a centralized server calculated the shorted and safe (obstacle free) path from source and destination.

In this work, frames captured from the camera are transmitted to the system where every nth frame is segmented. Here initially the image in subjected to Tsallis entropy thresholding. The object of interest is segmented out and its pixels account to its resolution, which is standardized and used.

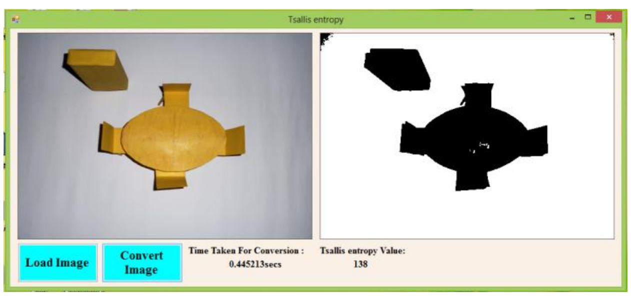


Figure 1 Output of Tsallis entropy thresholding

3.1 PATH GENERATION AND OBSTACLE AVOIDANCE.

As mentioned in the above method the floor is segmented by doing so we also identify the obstacles, once floor segmentation is achived to the desiered degree and then the image in converted to a binar image where the floor becomes the threshold value.

The path is generated maily based on two points the source and the destination, and also with parameters such as width, length, turning radius of the robot which are given by the user.

Steps in Path Planning.

1) Wait it all the parameter are provide.
2) Once the parameter are all provide, use the source and destination points and calculated the angle between the two points using

$$dx = x2 - x1;$$

$$y = y2 - y1;$$

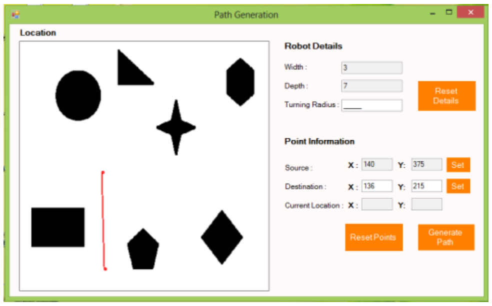
$$angle = Atan2(dy, dx) * 180 / PI$$

3) Using the angle to draw a virtual line between the two points.
4) Once the line is drawn identify the obstacle on that path
5) Identify a shortest path to move around the obstacle and join back to the virtual line.
6) Continue the same procedure on all the obstacles lying on the path.
7) To identify the shorted path around the obstacle calculate the intrusion of the obstacle in both the direction and using the direction which has the least intrusion factor.
8) When calculating the path around the obstacle we have to consider the turning radius and also the length of the robot such that there is no collision with the obstacle when making a turn, to achieve this the length of the robot plus a buffer value is consider as a distance buffer factor between the robot and the obstacle before making a turn.

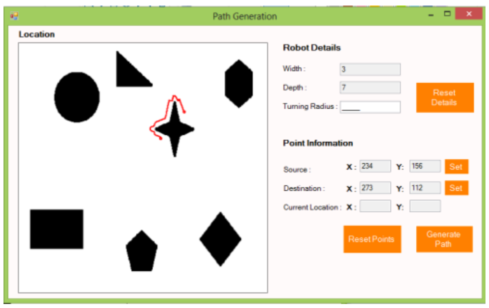
The final result of the path generation will give the path in which the robot has to moves. For better understanding of this method a simulated image has been given in the following section.

4. RESULTS AND DISCUSSION

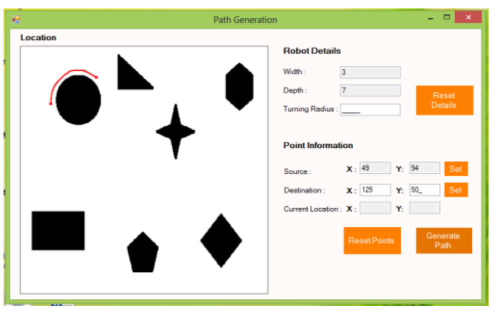
The following screen shots gives the details on how the system works and each phase in the system



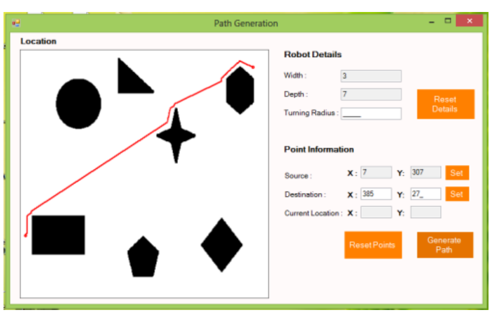
(a)



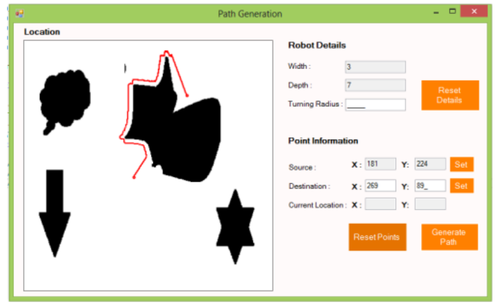
(b)



(c)



(d)



(e)

Figure 3 (a)-(e) gives path generation and path simulation under different criteria's. Figure 3(a) gives the path generation when there is no obstacle between source and destination. Figure 3(b-c) gives path generation between source and destination with different geometric shapes, this is shown to depict that the system is able to handle any of such situations. Figure 3(d) gives path generation between source and destination with multiple obstacles in between the source and destination and also with different geometric shapes. And to provide a closure to all, Figure 3(e) depicts path generation between source and destination when the obstacle between them is a random shaped object.

5. CONCLUSION AND FUTURE WORK

With all the above test and results it can be finally shown that the project has been able to achieve that it had set to achieve. This project has shown that even though a robot might not have any sensors or a cam mounted on it can still be guided to move in an indoor environment without colliding into any obstacles. This system not only generates the path for given a pair of points, but also makes sure that it is the shortest path for that pair of points. It also considers the robot information such as the turning radius, the depth and width of the robot to make sure that the system provide path information in such a way that the robot will be able move without any problems. This system can not only be used to guide one robot but can be used to guide n-number of robots. This system is not restricted by the type or specification of the robot. This system can be scaled to produce a path to any kind of robot. The Future of this project would be to scale this system to able to identify dynamic obstacles and find a path to make sure it does not collide with the dynamic obstacle. Another extension would be that the system be able to process videos and not just images. Another extension to this project is, to make the system remember the path that was taken for the same set of points, and use it to check if there are any obstacles in that path or is that same path viable at that time. This system can further be advanced to build an autonomous navigation system for indoor robots with vision as it guider and make it one step closer to teaching it to be more human.

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