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A Comparison of Two Approaches for Collision Avoidance of an Automated Guided Vehicle Using Monocular Vision

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Abstract. In this paper a comparison of two approaches for collision avoidance of an automated guided vehicle (AGV) using monocular vision is presented. The first approach is by floor sampling. The floor where the AGV operates, is usually monotone. Thus, by sampling the floor, the information can be used to search similar pixels and establish the floor plane in its vision. Therefore any other objects are considered as obstacles and should be avoided. The second approach employs the Canny edge detection method. The Canny edge detection method allows accurate detection, close to real object, and minimum false detection by image noise. Using this method, every edge detected is considered to be part of an obstacle. This approach tries to avoid the nearest obstacle to its vision. Experiments are conducted in a control environment. The monocular camera is mounted on an ERP-42 Unmanned Solution robot platform and is the sole sensor providing information for the robot about its environment.

Introduction

Collision avoidance is one of the fundamental behaviour in autonomous mobile robots. It focuses on changing the robot's trajectory as informed by its sensors during robot motion. The resulting robot motion is both a function of the robot's current or recent sensor readings and its goal position and relative location to the goal position. Several algorithms for a collision avoidance system had been highlighted in[1].

Among the most frequent approaches used for collision avoidance system is edge detection method. Edge detection method extracts the obstacle vertical edges and drives the robot around either one of the visible edges [2]. Although ultrasound sensor is capable enough to avoid collision, it has several weaknesses such as poor directionality, frequent misreading and specular reflection. Vision based sensor offer more accurate reading in edge detection as compared to ultrasonic sensor.[3]

On another approach, vision sensor is used to sample the floor where AGVs are in operation instead of identifying obstacles directly. Manufacturing plants commonly have dedicated path set for the AGV. This path is usually monotone. Thus, by sampling the floor, the information can be used to search similar pixels and establish the floor plane in its vision. Therefore any other objects are considered as obstacles and should be avoided.

Monocular vision loses the depth information and presents a Perspective Mapping while in the process of capturing an image. All the points in three dimensional space along a ray of light traced from the camera lens will map to the same pixel in the image [3]. Despite these disadvantages, monocular vision is chosen due to the simplicity and lower cost

Field of View and Image Mapping

Sulaiman Sabikan et. al. [4] presents a method to find the correlation between obstacles image seen by the robot and the real obstacles dimension. Their method however is only applicable to a camera setup where the whole field of view intersects with floor plane. This setup limits the field of view to a specific range only. This inadvertently creates a tunnel vision in the system.

T.Taylor et al.[3] presents a more general calculation compared to Sulaiman Sabikan et. al. [4]. However, a little modification has been made to T.Taylor et al.[3] calculation to suit the bottom up image coordinates system as oppose to the top down image coordinates.

As shown in Fig. 1, the field of view is governed by angle 2θ in the x-plane and angle 2α on the y-plane. Given the image resolution m by n pixels and the coordinates in the image plane (u , v), the real coordinates (x , y) can be derived. Using ratio, each pixel in the image correspond to an angle(ε) of 2θ(u)/(m-1) horizontally and an angle(ζ) of 2α(v)/(n-1) vertically.

In order to determine the angle θ and α the following relationships can be used based on Fig. 1. It is important to note that α, and θ are the characteristics of the camera. Therefore the value must be constant as long as the same camera is used..

$$\tan(\beta) = k / h. \tag{1}$$

$$\tan(\theta) = l / (j + k). \tag{2}$$

$$\tan(\alpha + \beta) = (j + k) / h. \tag{3}$$

The values of h, j, k and l can be measured physically. h is the height of the camera from the floor. j is the distance in y-plane from v = 0 to the centre of the image while k is the horizontal distance also in the y-plane from the camera to v = 0. The distance k is not visible in the image. This region is called the blind area. l is the horizontal distance in x-plane from the centre of the image to u = 0.

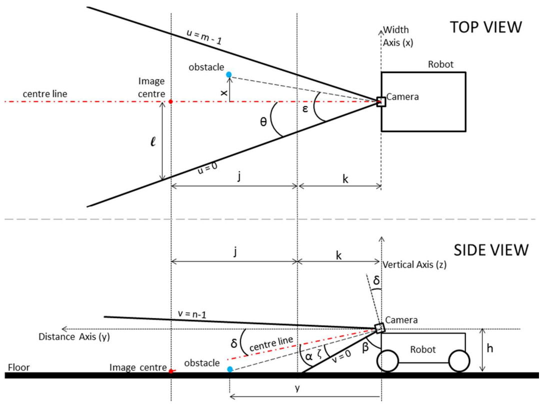


Fig. 1. The camera's field of view

The values of α, β and θ can be obtained by calculation using the Eq. 1, Eq. 2 and Eq. 3. In this research the values of h, j, k, l, α, β and θ are 21.5cm, 66cm, 34cm, 48cm, 19.6°; 58.4° and .25.5° respectively.

From Fig. 1, it can be derived that object coordinates (x, y) can be express in terms of image coordinates (u, v) by using tan(ε – θ) and tan(β + ζ) respectively. Eq. 4 and Eq. 5 show the results of the derivation

$$y = h * \tan(\beta + (2\alpha(v)/(n-1)). \tag{4}$$

$$x = y * \tan(\theta(2u-m+1)/(m-1)). \tag{5}$$

It is to be noted that x is calculated from the image centre line. Therefore x value can hold positive or negative values. Positive x values indicate the distance from the centre towards the most right while negative x values indicates distance towards the left most.

As n-1 do not intersect the floor plane, it indicates that at a certain value of v, the corresponding value of y approaches infinity. Above this v value, all the data from this region is deemed irrelevant. It is safe to assume that any pixels in this region are on the wall and can be ignored in collision avoidance planning since the assumption is all obstacles have its base on the floor plane.

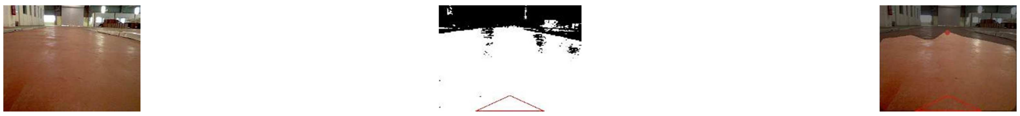
The irrelevant region can be reduced by manipulating angle δ. Angle δ is the angle of tilting camera against vertical axis. As the angle δ increases, the value of , j, k, l, and β are reduced. Eq. (6) shows the relation of δ to angle β.

$$\alpha + \beta + \delta = 90°. \quad (6)$$

Approaches

Floor Sampling Approach The floor sampling approach begins with a specified sampling area right in front of the robot. The pixel in this area is matched with similar pixels in the whole image. The pixels that matched are presented as white colour while the pixels that did not matched are presented in black colour. Fig. 2(b) shows the effect of floor sampling from the image in Fig. 2(a). The image is negative before filled with white pixels from the bottom side to the top from the leftmost column and stops when it found a white pixel.

The image is then eroded to erase narrow columns. This narrow column represent an opening that is too small for the robot to pass. The highest point from the bottom is marked as shown in fig. 2(c) and the position of this marked point is relayed to the robot controller for the navigation. This marked point henceforth known as image navigation point.



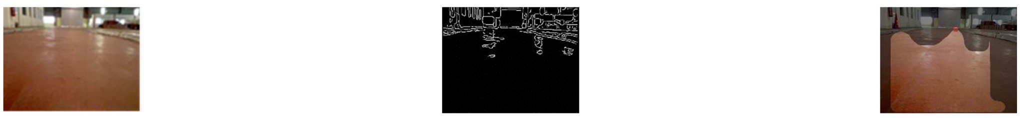
(a) (b) (c)

Fig. 2. (a). Image before processing, (b). Image after floor colour sampling, (c). Point to identify navigational path using floor sampling

Canny Edge Detection Approach. The Canny edge detection method allows obstacle edges to be highlighted. It can be said that this approach is more obstacle oriented as oppose to floor oriented in the floor sampling approach. Further image processing is similar to the floor sampling approach. The difference is that in Canny edge approach, the image does not need to be negative since the edges in the image is represented in white pixel as shown in Fig. 3(b). Fig. 3(c) shows the end result of the image processing from the original image in Fig.3(a) for this approach.

Experiments, Result and Disscussion

The Effect of Ambient Lighting The objective in this experiment is to determine whether ambient lighting can cause image processing failure. In the morning, the source of light comes from natural light through the windows and from artificial lighting that illuminates the warehouse. While at night the source of light comes only from the artificial lighting 20 meters from the floor.



(a) (b) (c)

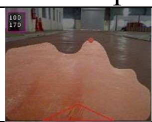
Fig. 3. (a). Image before processing, (b). Image after Canny edge detection.
(c). Point to identify navigational path using Canny edge detection.

From Table 1, it can be seen that the light from the windows cause several extreme bright spots on the floor. In the floor sampling approach, these spots have different luminosity from the sample area. This caused the algorithm detect it as an obstacle even though in reality it is not an obstacle. Using the Canny edge detection approach, the extreme bright spots produce edges and it was detected as obstacles too.

During the night, the artificial lighting produces uniform luminosity throughout the test track. Therefore when the floor is sampled in floor sampling approach, almost the whole image is returned with the same pixels in the sampled area especially white surfaces. This has made the floor sampling approach failed in this condition. However, applying Canny edge detection, most of the edges are still detectable but with the advantage of the non existence of extreme bright spots. Without the extreme bright spot acting as false obstacle the navigation point appears in the straight line region.

From this experiment, it is learned that the navigation can be disrupted by intense bright light, and white and off white surrounding colours. Furthermore, Canny edge detection approach work best in uniform luminosity.

Table 1: Comparison of navigation point between floor sampling approach and Canny edge detection approach in the morning and at night.

Time	Floor Sampling	Canny Edge Detection
Morning		
Night		

Obstacle Size. The objective of this experiment is to determine whether the AGV can avoid different size of obstacles. The big and the small obstacles have 44cm and 15cm base width respectively.

It can be seen in Table 2, the big obstacles are large enough to block the incoming light from the windows to be detected by camera. The shadows for the obstacle are cancelled out by the natural light from the back of the AGV through open door. Therefore the obstacles were detected accurately for both approaches. In the small obstacles, the lights from the window interfere with the obstacle detection. It can be seen that the obstacles on the left are avoided due to existence of the extreme bright spots surrounding the obstacles.

However from Table 2, it can be seen that all four images give indications that the AGV should turn right to avoid the obstacles. Therefore it can be concluded that both approaches are capable for avoiding obstacles of any size even though the ambient lighting may interfere with the navigation.

Table 2: Comparison of navigation point between floor sampling approach and Canny edge detection approach on big, small and thin obstacles

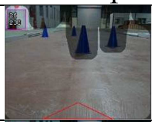
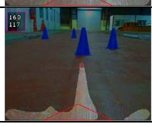
Size	Floor sampling	Canny Edge Detection
Big		
Small		

Image Saturation The objective of this experiment is to determine how colour saturation influence the outcome of the navigation process. The experiment begins with the default setting of saturation provided in the software. The saturation value will then be increased to double, and quadrupled the default values.

From Table3 it can be seen at default saturation values, floor sampling approach did not set the navigation point accurately. This is due to the detection of white pixels in the sampled area. On the other hand the Canny edge detection approach can determine the navigation point accurately although some of the edges detected are the obstacles shadow instead of the real edges of the obstacles.

As the saturation value are double, the floor sampling approach maps the floor more accurately. As a result the navigation point appears in a much more suitable place for the AGV to avoid the nearest obstacles. However in the Canny edge detection approach some texture on the floor began producing detectable edges. As a result of this, there appears to be a quite big valley on the right side of the image.
By increasing the saturation value further to quadruple of the initial value, it can be seen in both approaches that the surface texture on the floor has become too much of interference in order to produce a meaningful navigation point.
From this experiment it can be concluded that even though the image saturation can improve the position of navigational point especially under a constant artificial light, it has to be treated cautiously as oversaturated image can increase the visible texture on the rough floor surface.

Table 3: Comparison of navigation point between floor sampling approach and Canny edge detection approach with increasing saturation values

Saturation multiplier	Floor sampling	Canny Edge Detection
Default		
Double		
Quadruple		

Conclusion

The experimental result shows that although both approaches can produce a reliable navigation point, Canny edge detection approach however is more versatile compared to floor sampling approach. This is due to the fact that edges can easily be seen in almost all lighting conditions whereas sampled area can sampled wrong pixel values to compare with other pixel in the image.
The three experiments in the paper are presented to show that in order to avoid collision successfully using only vision as a sensor, these three factors must be taken into consideration. Surrounding lights, obstacles condition and camera settings.

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