OBSTACLE DETECTION FOR NAVIGATION OF ROBOT USING COMPUTER VISION AND LASER RANGEFINDER

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Abstract—Autonomous robots are intelligent machines that are able to perform desired tasks by themselves, without any human intervention. Obstacle avoidance is a primary requirement for any autonomous mobile robot. It prevents the mobile robot from collision. The robot acquires information about its surroundings through camera mounted on the robot. The obstacle detection for the mobile robot is carried out using sensors and instruments like camera, touch-sensor, sonar, laser range finder. Computer vision is a field of computer science that has been heavily researched in recent years. One of computer vision important contribute to the navigation of mobile robots is obstacle detection. The focus of the project is to propose one efficient obstacle avoidance algorithm for wheeled mobile robot using image processing and laser rangefinder. The robot has to move in given environment along a straight path where it has to avoid obstacles, which obstructs its continuous motion. The robot acquires information about its surroundings through camera mounted on the robot. Image processing techniques are used to identify the existence of obstacles. By using a laser emitter, the distance to obstacles can be calculated.

Keywords- SLAM, workspace, edge detection

I. INTRODUCTION

Autonomous robots are intelligent machines that are able to perform desired tasks by themselves, without explicit human control. In recent years, there has been an increasing interest in the field of autonomous robot navigation. Obstacle avoidance is a primary requirement for any autonomous mobile robot. It prevents the mobile robot from collision and damaging itself. For a robot to be able to successfully navigate it first requires a map of the workspace environment, from which a path that avoids collisions into static or dynamic obstacles is then constructed. The robot acquires information about its surroundings through sensors mounted on the robot. The obstacle detection for the mobile robot is carried out using sensors and instruments like camera, touch-sensor, sonar, laser range finder.

Simultaneous Localization and Mapping (SLAM) is terms used in the robotics were a representation of the workspace environment is generated by sensors mounted on the robot. As the robot moves, the map of the workspace is updated based on data received from these sensors.

Most obstacle avoidance algorithms use active sensors such as sonar, laser rangefinder and IR sensors. Visual sensors are an alternative solution for obstacle avoidance and becoming increasingly popular in robotics. Visual sensor provides better resolution data, longer ranges at faster rates than range sensors and having many other advantageous properties such as lightness, compactness and power saving ability. But image processing is very computationally expensive task. It requires complicated software and powerful computing platform or dedicated hardware module.

In this project using a single camera mounted on robot is used to provide vision based system for robot navigation. Images captured from a camera are 2-dimensional data, where information on depth is lost. Consequently, while the presences of obstacles can be identified from a 2-D image, the exact location cannot be determined. To overcome this problem, system integrated with a simple rangefinder using a laser emitter.

II. STATE OF THE ART

Computer vision is an important research area which has a broad range of applications. Different methods are used for the extraction of finding obstacles and depth from an image captured by the camera, binocular vision
and depth from defocus image, stereo vision, motion parallax and monocular vision are the methods widely used for obstacle detection for the navigation of robot in an unknown environment.

[1] Tao Hu and May Huang: A New Stereo Matching Algorithm for Binocular Vision (2010). The binocular vision is a method to capture the information of an object in three dimensional (3D) vision based on disparity among numbers of images. It can reconstruct a profile of the object and define its location in 3D space.

[2] Honig, J & Bremont, J: Visual depth perception based on optical blur (1996). Defocus is another method to obtain depth estimates. Translation along the optical axis away from the surface of best focus is called defocus. The defocused image contains depth information of the scene in optical theory and behavioral experiments revealed that depth perception. It requires high-quality images and objects with sharp boundaries.

[3] Scharstein, D, Szeliski, R: A taxonomy and evaluation of dense two-frame stereo correspondence algorithms (2002). The most commonly studied for obstacle detection is stereo vision. Stereo vision is the extraction of 3D information from digital images (2D), such as obtained by a CCD camera. The images are then processed by a series of transformations, such as rotations and scaling, to place both in the same plane.

[4] Barron: Depth-from-motion or optical flow is based on motion parallax (1994). Motion parallax is a depth cue that results from our motion. As the viewpoint moves side to side, the objects in the distance appear to move slower than the objects close to the camera is the actual phenomena carried out in motion parallax.

[5] Ke Zhang - Bin Xu (2006). This paper models the binocular vision system focused on 3D reconstruction and describes an improved genetic algorithm (GA) for estimating camera system parameters. The two-camera system model that takes into account camera radial distortion includes a total of 24 parameters.

[6] Syedur Rahman: Obstacle Detection for Mobile Robots Using Computer Vision (2005). Multi-view relations are used as the fundamental principles upon which the solution is based. Planar homography, epipolar geometry and image segmentation are used to analyse the reliability of three obstacle detection methods comparing and contrasting their performance in different scenes.

[7] Thomas Lemaire: Vision-Based SLAM: Stereo and Monocular Approaches (2007). This article presents two approaches to the SLAM problem using vision: one with stereovision, and one with monocular images. Both approaches rely on a robust interest point matching algorithm that works in different environments. The stereovision based approach is a classic SLAM implementation, whereas the monocular approach introduces a new way to initialize landmarks.

[8] Robert S. Allison: Geometric and induced effects in binocular stereopsis and motion parallax (2003). This paper examines and contrasts motion-parallax analogues of the induced-size and induced-shear effects with the equivalent induced effects from binocular disparity. During lateral head motion or with binocular stereopsis, vertical-shear and vertical-size transformations produce induced effects of apparent inclination and slant that are not predicted geometrically. With vertical head motion, horizontal-shear and horizontal-size transformations produced similar analogues of the disparity induced effects. Typically, the induced effects were opposite in direction and slightly smaller in size than the geometric effects. Local induced-shear and induced size effects could be elicited from motion parallax, but not from disparity, and were most pronounced when the stimulus contained discontinuities in velocity gradient. The implications of these results are discussed in the context of models of depth perception from disparity and structure from motion.

[9] Pomerleau: An autonomous land vehicle in a neural network (1989). Monocular vision and apprenticeship learning (also called imitation learning) was used to drive a car. Monocular vision is vision in which each eye is used separately. The field of view is increased.

III. RELATED WORK

Stereo vision and motion parallax are the technique used for obstacle detection. But it requires finding similarities between points in multiple images separated over time. The Process by which for searching image similarities can be computationally costlier and error prone we searched. It also requires highly structured roads and highways with clear markings and high-quality images and known camera parameters.

In this paper monocular vision is used to navigate the robot. Monocular vision is vision in which each eye is used separately. The field of view is increased. Monocular cues provide depth information when viewing a scene with one eye.

IV. PROPOSED TECHNIQUE

Image processing is a form of signal processing where the input signals are images such as photographs or video frames. The output could be a transformed version of the input image or a set of characteristics or
parameters related to the image. The computer revolution that has taken place over the last 20 years has led to great advancements in the field of digital image processing.

The proposed method is using MATLAB for processing the images captured by camera. The whole system consists of a personal computer, laser beam emitter, camera and mobile robot.

A camera and laser beam emitter is mounted on the mobile robot, camera continuously capture images and transfer to personal computer for processing the corresponding image. The laser beam emitter creates a spot on the obstacle, camera capture the image including laser beam spot. From the captured image identifies the obstacle and calculate how far it is from the robot.

Second part of the project is to find the distance between obstacle and robot by using the laser range finder. Laser range finder device can directly give the distance between the obstacle and robot. One method will be used to find distance is right angle triangle technique.

- Edges found by looking neighboring pixels.
- Region boundary formed by measuring gray value differences between neighboring pixels

Ed= edge(I) takes a greyscale or a binary image I as its input, and returns a binary image Ed of the same size as I, with 1's where the function finds edges in I and 0's elsewhere. By default, edge uses the Sobel method to detect edges but the following provides a complete list of all the edge-finding methods supported by this function:

- The Sobel method finds edges using the Sobel approximation to the derivative. It returns edges at those points where the gradient of I is maximum.
- The Prewitt method finds edges using the Prewitt approximation to the derivative. It returns edges at those points where the gradient of I is maximum.
- The Roberts method finds edges using the Roberts approximation to the derivative. It returns edges at those points where the gradient of I is maximum.
- The Laplacian of Gaussian method finds edges by looking for zero crossings after filtering I with a Laplacian of Gaussian filter.
- The zero-cross method finds edges by looking for zero crossings after filtering I with a filter you specify.
- The Canny method finds edges by looking for local maxima of the gradient of I. The gradient is calculated using the derivative of a Gaussian filter. The method uses two thresholds, to detect strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges. This method is therefore less likely than the others to be fooled by noise, and more likely to detect true weak edges.
V. EXPERIMENT RESULT

The workspace environment image is first captured by the camera. The presence of obstructions must be identified before a path for the robot to traverse on can be determined. Image segmentation techniques are used to identify the presence of obstructions.

The captured images are first converted from RGB to grayscale. In the RGB format, every pixel is represented by a level of each of the three primary colors: red, blue and green. In the grayscale representation, every pixel would only be represented by one gray level. The grayscale converted image carries only intensity information. Images of this sort are composed exclusively of shades of grey, varying from black at the weakest intensity to white at the strongest. The image contrast enhancement has improved the perceptibility of objects in the scene followed by RGB to gray conversion. Down sampling is applied to contrast enhanced image which usually reduce the data rate or the size of the images. Finally apply image segmentation on these pre processed image. In image segmentation technique we usually apply the sequence steps. The first step is to mark the foreground objects use opening by reconstruction and closing by reconstruction. These operations give flat maxima inside each object. Opening is erosion followed by dilation. Complement the image inputs and output and compute background markers. Watershed segmentation is applied to these pre processed image to obtain the result. The presence of obstructions is then identified by finding the black part of the processed image. This sequence of image processing is depicted in Fig. 2, where (a) is the original RGB image, (b) is the grayscale transformed image, (c) is the image after having gone through the segmentation and (d) is the actual image and obstacle images are superimposed.
Graph (1): The graph shows the result of different input images having different pixel values and bytes. The graph indicates the different tested images. The tested images including solid obstacle and transparent obstacle are used. Even though the transparent obstacles are successfully extracting the obstacle from the robot workspace the image pixels and size are different than the solid obstacle images, which are clearly visible from the graph (1).

VI. DISTANCE MEASUREMENT

The laser range finder is made up of a laser pointer, working together with the camera. The laser pointer used to emits a beam of 670nm wavelength. The laser illumination is isolated from ambient lighting by using a 670nm band pass filter. The laser rangefinder is calibrated to point parallel to the camera’s viewing direction, this means that the laser will always hit objects near the centre of the camera field of view. Knowing the vertical distance between the laser-pointer and webcam, the distance to the object can be determined from the location of the pixel that is hit by the laser returned by the object. In order to correctly identify the object by the edges obtained from the image processing steps, the edges are clustered using the k-means technique. Figure 3 shows the arrangement used to measure the distance to the obstruction.

\[
\tan \alpha = \frac{h}{D}
\]

\[
D = \frac{h}{\tan \alpha}
\]

Where, \( \rho \) = number of pixels from the centre of the focal plane, \( R \) = radians per pixel pitch, ‘rad’ is radian compensation for alignment error.

\[
\alpha = \rho \times R + \text{rad}
\]

\[
D = \frac{h}{\tan \left( \rho \times R + \text{rad} \right)}
\]

The centroid is then taken as target points for the laser beam to be emitted. The laser emitter projects a beam onto the object which is in the camera field of view. The whole scene, including the point where the laser beam hits the object, is captured by the camera. The laser beam point is then isolated from the rest of the image using the band pass filter. A Band Pass Filter allows a specific frequency range to pass, while blocking lower and higher frequencies. It allows frequencies between two cut-off frequencies while attenuating frequencies outside the cut-off frequencies.

The transfer function of a band-pass filter is then:
\[ H(s) = \frac{H_0 \omega^2}{s^2 + \frac{\omega}{Q} s + \omega^2} \]

\(\omega_0\) is the frequency at which the gain of the filter peaks. 

\(H_0\) is the gain and is defined:

\[ H_0 = \frac{H}{Q} \]

\(Q\) has a particular meaning for the band-pass response. It is the selectivity of the filter. It is defined as

\[ Q = \frac{F_0}{F_H - F_L} \]

Where \(F_L\) and \(F_H\) are the frequencies where the response is \(-3\) dB. The bandwidth (BW) of the filter is described as the resonant frequency (Fo) is the geometric mean of \(F_L\) and \(F_H\)

\[ BW = F_H - F_L \]

The pixel location after isolated by using band pass filter from the rest of the corresponding to the laser beam point is identified. The figure 4 shows the laser beam object edge.

Figure 4: Object edge.

VII. DISTANCE MEASUREMENT ERROR

There are many sources of error in triangulation systems which reduce the maximum resolution available for a given configuration. In many instances a solution can be found by compromising cost and convenience. However, a full understanding of all the contributing sources of error is necessary for a given design to be optimized. An optical triangulation system is made up of mechanical and optical components, some of which are amenable to design considerations such as choice of laser-pointer, camera and materials. Other parameters are beyond the capabilities of the designer to adjust, such as the reflectivity of the surface to be measured and the nature of the medium through which light is transmitted and received. The graph indicates the comparison between rangefinder measurements and measured distances in Graph (2) and table(1). The errors concentrate on the factors. Which are outside the control of the measuring system such as the transmission medium, laser-pointer error and base line expansion. These errors are both random and systematic in nature. In future, each of these errors will be analyzed with reference to its effect on the accuracy of the measurements.

<table>
<thead>
<tr>
<th>Test</th>
<th>Measured distance</th>
<th>Range finder distance</th>
<th>Error in distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>61</td>
<td>5</td>
<td>2</td>
</tr>
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</tr>
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<td>3</td>
<td>-1</td>
</tr>
<tr>
<td>6</td>
<td>75</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

All distance are in CM

Table (1): comparison between rangefinder measurements and measured distances

Graph (2): Comparison between rangefinder measurements and measured distances

VIII CONCLUSION

This paper provides a framework for a measurement system with which a mobile robot could identify obstacles and distance from obstacles using a single robot mounted webcam and a laser rangefinder. Using images captured by the webcam, the presence of obstacles are first identified. Then measure the distance between obstacle and robot by using the laser rangefinder. Future work would be the system would also be further developed for use in real outdoor settings with videos captured by the webcam.

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