Design of Autonomous Vehicle Navigation for Environment Monitoring using SLAM and Image Segmentation Algorithm

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Abstract :- In the past few year the mobile robot navigation system gained important due to the wide spread application. The Autonomous vehicles play important role its widespread applications in the field of robotic and automation. The design system being used on board camera on autonomous vehicles which used to captures the images and processing for image segmentation algorithm. On board processing of video(frames)in real time is a big challenging task as it involves extracting the information and performing the required operations for navigation. It proposes an approach for vision based autonomous vehicle navigation in indoor environment using the designed image segmentation algorithm. The vision based navigation is applied to autonomous vehicle and it is implemented using the Raspberry Pi camera module on Raspberry Pi Model-B+ with the designed image segmentation algorithm. The Raspberry Pi is the heart of the system as it is performing all the computations in real time. The image segmentation algorithm has been built using smoothing,thresholding, morphological operations, and edge detection.

Keywords: - Simultaneous Location & mapping Technique ,image segmentation Algorithm. Raspberry –Pi based embedded system.

I. INTRODUCTION

The use of robotic Navigation in last two decades has grown due to its ability in providing the destined path from source to destination. Navigation can be defined as the combination of different self-localization, path finding, and mapping. Navigation is vastly used in robotics for finding the destination and path for the same from the source or user location. It basically shows the path, self-location and distance from the current location. Robotic Navigation also finds applications in military purposes for finding the target location, in industrial purposes for transportation, in day to day life for finding any place etc. Use of navigation is promoted using the mobile phones, GPS devices in vehicles using the Global positioning system [1]. So, navigation by meaning is finding the path, distance and current or self-location from source to destination. It has become very easy to find the shortest path using navigation and determining self-location. Navigation has found application in very demanding and growing area field of autonomous vehicles.

II. AUTONOMOUS VEHICLE NAVIGATION

In recent years, the usage of autonomous vehicles have grown due to numerous applications in various fields such as the manufacturing, industrial, surveillance, military etc. Perception of the environment using different sensors is the most important task in this applications [2]. Processing of the sensor input results in particular representation of the unknown environment, which can then be used for navigating and controlling the vehicle. Autonomous vehicle navigation in a certain environment is thus a quest that many researchers have tackled over the years.

III. IMAGE REGION OF INTEREST (ROI)

In image processing certain region of image having vital information can be useful so that particular area of an image can be called as region of interest. This ROI can be extracted from the image or certain operations can be performed over those areas. Sometimes, you will have to play with certain region of images. For eye detection in images, first perform face detection over the image until the face is found, then search within the face region for eyes. This approach improves accuracy (because eyes are always on faces and performance (because we search for a small area). ROI is again obtained using NumPy indexing. Here I am selecting the ball and copying it to another region in the image:

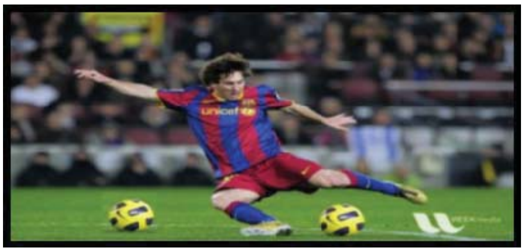


Figure 1.3 Region of Interest (Ball is copied in another region)

IV. CANNY EDGE DETECTION

The edges are detected using Canny Edge Detection and it is a popular edge detection algorithm. It was developed by John F. Canny in 1986. It is a multi-stage algorithm. Detecting real edges shoukd be maximized while probability of detecting non edge points should be minimized to maximize signal to noise ratio. To perform localization, detected edges should be as close as possible to real edges. For performing canny edge detection following operations are performed: The first step includes removal of image. To find edge gradient. To remove unwanted pixels which are not at the edges. Pixel is checked whether is at local maximum in its neighborhood in direction of gradient. Hysteresis thresholding is done to decide which edges are real edges and which are not.

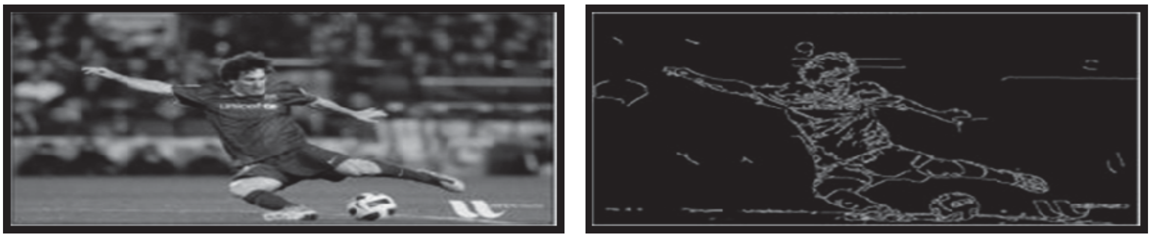


Figure 1.4 a] Original Image b] Edge Image

V. INDOOR NAVIGATION

Some of the first vision systems developed for mobile robot navigation relied heavily on the geometry of space. Other metrical information for driving the vision processes and performing self-localization. The mobile robot navigation can be done using different techniques which can be classified as:

VI. MAP- BASED NAVIGATION

Map-Based Navigation consists of providing the robot with a model of the environment. These models may contain different degrees of details, varying from a complete CAD model of the environment to a simple graph of interconnections or interrelationships between the elements in the environment [1]. The robot can use the provided map to estimate the robot's position (self-localization) by matching the observation (image) against the expectation (landmark description in the database).The computation involved in vision-based localization can be divided into the following four steps:

- Acquire sensory information
- Detect landmarks
- Establish matched between observation an expectation
- Calculate position

The basic idea of their approach is to recognize in the camera image those entities that stay invariant with respect to the position and orientation of the robot as it travels in its environment. The below figure 5. shows the indoor environment that with different positions of robot after the movements. Localization is achieved by a multiple landmark detection algorithm. This algorithm searches for multiple landmarks, compares the landmarks with their pre-stored templates, tracks the landmarks as the robot moves, and selects new landmarks from the map to be tracked. As the landmarks are matched with the templates, their 3D pose is calculated using stereo vision. The position of the robot is estimated through a comparison between the calculated landmark position and the landmark position in the map

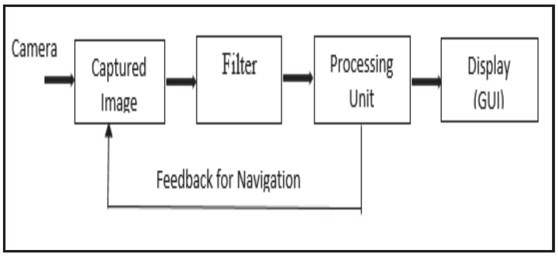


Figure 3.1 Block diagram of proposed system

Camera: The Microsoft LifeCam is used to capture the video frames at the rate of 24fps. The captured frame are then given to the filter before it is used by processing unit.

Filter*:* The captured video is processed frame by frame such that each frame is filtered to remove the noise from it.

Processing Uni*t:* The Raspberry-pi is used as the processing unit for the complete image segmentation algorithm such that each frame is given to it and applies the image segmentation algorithm.

Display*:* The original video is resized and the segmented video along with the ultrasonic output is displayed on the remote desktop by forming the wireless connection using the Wi-Fi adapter and Wi-Fi router.

Feedback for Navigation*:* The ultrasonic sensor output is continuously given to the system even when the system is processing the images. The corrected images are used as the feedback to the system for performing the image matching so that the navigation is performed using the reference images or markers.

VII. CAPTURING VIDEO

The video is capturing using the Microsof Lifecam which is used in the proposed system and connected to the raspberry pi on-board. The video is captured at the frame rate of 24fps. Each frame is then processesed by applying the image segmentaton algorithm. Each frame is processesed to track any frame containing the reference image of the markers so that it acts for performing the navigation. Every reference image of markers has some action related like for right arrow marker the autonomous vehicle takes 90 degree right turn. Similarly, there are other reference images that are used in the system and they are shown below. Fisrtly, the autonomous vehicle will operate in the indoor environment where it tracks the reference image captured using the camera and then image segmentation algorithm to it. The camera is interfaced to the raspberry pi and it performs processing in real time. The complete processing is done by raspberry pi in real time which onboard the vehicle.

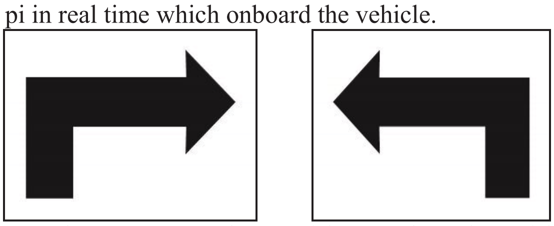
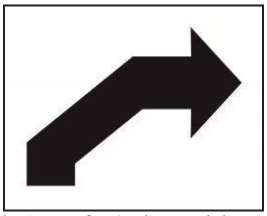
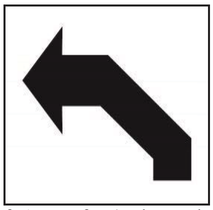


Figure 3.3Reference Imgaes(Markers) a) Right Arrow for 90 degree right turn
b) Left Arrow for 90 degree left turn





c) Right Arrow for 45 degree right turn d) Left Arrow for 45 degree left turn

e] STOP to abort the vehicle

VIII. IMAGE SEGMENTATION ALGORITHM

The image segmenatation algorithm is designed to track the different refernce images that are used in the system for performing the navigation in the indoor environment. The camera continuously captures the video(frames) and gives them for processing using the designed algorithm. The raspberry pi is mounted on the autonomous vehicle alonwitht the camera module so that it is possible to perform the real time processing using the segmentation algorithm. Once the image is tracked and arrow edges are matched then the autonomous vehicle moves accordingly in the designed path from source to destination autonomously. The ultrasonic sensors also gives input to the raspberry pi which detects for obsacles and the algorithm is implemented accordingly. The complete flow chart of the main loop of image segmentataion algorithm is shown in fig 3.4. The former loops is for finding the rectangukar area and contour while the later loop is used for finding the region of interest inside the rectangale.

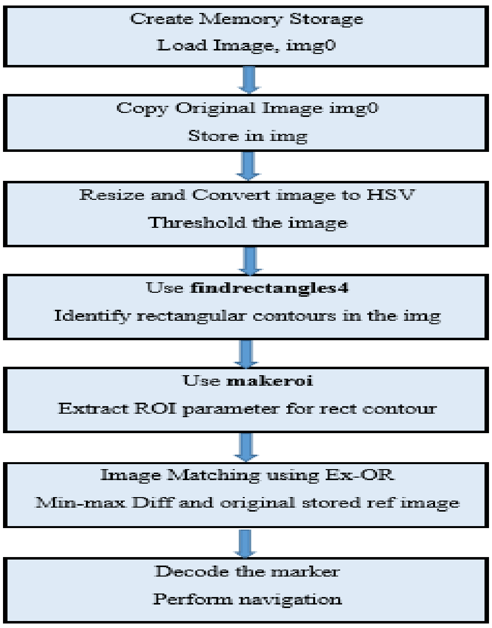


Figure 3.4. Flowchart of Image Segmentation Algorithm

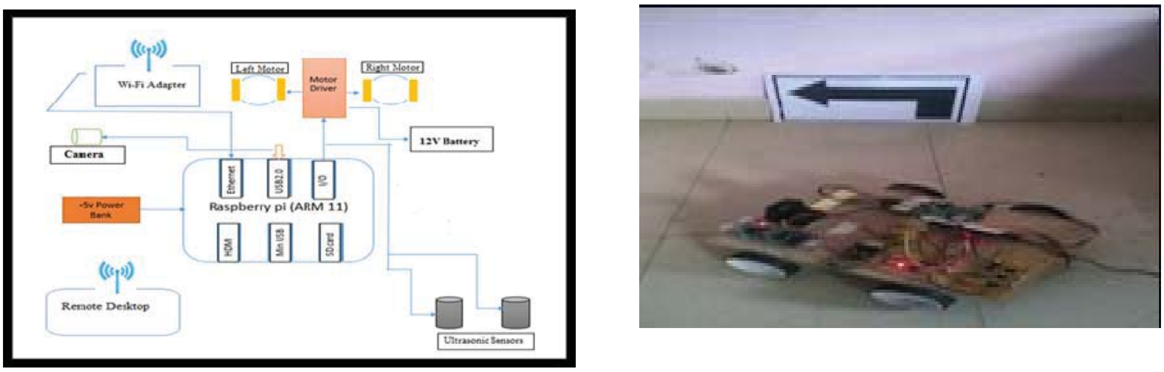


Figure 5.1 System Design

The final design of the system can be seen in figure 5.1 above where all the devices used are connected and forms the Autonomous vehicle navigation using raspberry pi. All the devices are connected on-board the vehicle to the raspberry pi.Raspberry Pi: It is the device where the whole project revolves around and this device is a small computer with a great variety of functions. I-FI Adapter: This is the unit, which enables the user to remotely share the screen on the remote desktop. Webcam: -This is the eye of autonomous vehicle robot in this project. Ultrasonic Sensors: This is used to detect the obstacles in the environment.
DC Motors: Two 10 rpm DC gear motors are used in the system to run the autonomous vehicle. 10 rpm motors are used because the system is performing the real time image operations so it takes time or there is delay in processing each

Figure 5.2 Components implemented on Autonomous Vehicle

IX. RESULTS OF AUTONOMOUS VEHICLE NAVIGATION USING DIFFERENT REFERENCE IMAGES

Figure 6.4Autonomous vehicle Navigation using different Reference Imgaes
a] Return b] Right (90 degrees) c]Left(90 degrees)

d] Right (45 degrees) e] Left (45 degrees) f] STOP

The different reference images are shown in figure 6.3 for which the autonomous vehicle navigation is shown in the above figures. For right (45 degrees) and left (45 degrees) the autonomous vehicle moves in 45 degrees in respective directions. For STOP, the system finally stops and aborts all the operations when STOP image is detected and tracked.

IX. Autonomous Vehicle Navigation on Predefined Path

The autonomous vehicle was tested on the predefined path using the reference images of markers used in the implementation of the navigation. The source and destination are shown using green and red color boxes. The yellow line denotes the path of autonomous vehicle as predefined. For the various predefined paths as shown below the graph of distance versus time is shown in figure 6.8.

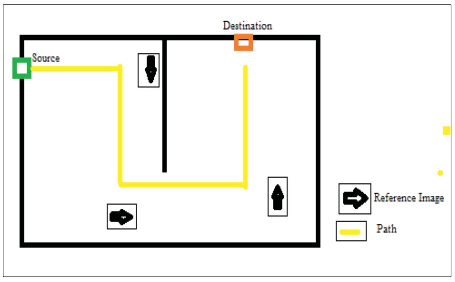


Figure 6.6 Path Without obstacle in Indoor Environment

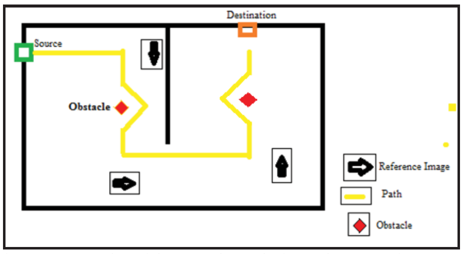


Figure 6.7 Path With two obstacle in Indoor Environment

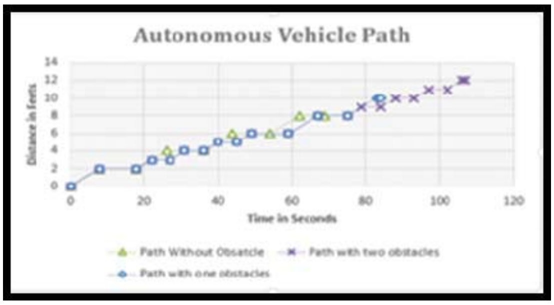


Figure 6.8 Graph of Distance versus time of autonomous vehicle on predefined path

X. CALCULATED DISTANCE AND TIME ON PROJECTED PATH

Projected Path	***No. of Obstacles***	***Distance(Feet's)***	***Time(seconds)***
Reference path	0	8	69
	1	10	84
	2	12	107

Table No -4 Calculated Distance and Time

The above distance-time are calculated by demonstrating the vehicle on the predefined paths like ideal path where there is no delay, without obstacle by using the reference images and with obstacle. Note: The constant distance between any two points shown in graph is the delay or time required for the autonomous vehicle to take turn in various directions according to the reference images.

XI. CONCLUSION

The designed image segmentation algorithm successfully performed the navigation of autonomous vehicle from source to destination by detecting the reference images of the arrows or markers which have different actions defined in raspberry pi for each reference image. The autonomous vehicle detected the obstacles using the ultrasonic sensors but it can also be implemented using the segmentation algorithm. It takes time when done using the segmentation technique. The navigation on the predefine path in indoor environment was tested with distance and time was evaluated. The navigation for projected paths with no obstacles, single obstacle and two obstacles using autonomous vehicle, the distance and time are calculated. The time required for two obstacle path is more compared to single obstacle path and it is found to be 107seconds for covering 12 feet's. For no obstacle the distance covered was 8 feet's and time 69 seconds which are the projected values. The system performed the navigation autonomously without any manual support. The image segmentation algorithm for the proposed technique of detecting the reference images (arrows) or markers was performed successfully to do the navigation.

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