Ptolemy

AmigoBot

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***Abstract*—Navigation is one of the key aspect in mobile robots. There are many techniques by which we can estimate the current position and make the robot to move to desired position. Using odometry we have made the Amigobot to move to some set of point, which are obtained from the image captured, which has an arbitrary shape drawn on it. Using image processing and OpenCV the contour of the object is obtained and the Amigobot is made to move in that shape in a region where we can visually observe the shape being made by the robot.**

I. Goal

This project is divided in two main parts namely image processing using OpenCv and odometry. In simple terms, an image with an arbitrary shape drawn is captured using the webcam of the laptop which is then supplied to the code which has an image processing which gives out the contour of that arbitrary shape. This contour consists of arrays of X & Y coordinates which are given to the odometry part where the robot divides them into series of goals and reaches them one after the other to form that shape. This shape can be observed in the Rviz of the simulator which maps the movement of the robot making the covered path of the robot visible.

II. Related Works

Recent advancements in the mobile robots has made the use of navigation techniques important and robust. An autonomous navigation system plays a major role in the path following or reaching a goal avoiding the obstacles, especially in the indoor environment there are many aspects which are needed to be considered to avoid damage to the robot and to achieve high success rate with least possibility of errors. [1] Normally, indoor environments are considered those untrusted places where human beings work (offices, rooms, corridors, etc.) and contain several objects (tables, chairs, wardrobes, etc.), so an autonomous vehicle moving in must interact with that kind of potential obstacles.

Location is a basic need for navigation. As described in [2] various techniques have been proposed for estimating the position and orientation of a vehicle, out which odometry, position estimation form known landmarks and localization with respect to global environment are main. In [5] odometry is stated as the most widely used method for determining the momentary position of a mobile robot. In most practical applications odometry provides easily accessible real-time positioning information in-between periodic absolute position measurements. Odometry is a type of Dead reckoning. [10] states that Dead reckoning is widely used for pose estimation and that serves as the backbone for many navigation systems as it is based on mathematical principles that help to estimate the current pose based on the previous pose. [3] This type of methods is based on the estimate of the relative position with respect the last one, so, in long term routes, it is impossible to avoid accumulation of error caused by wheels slippage or roughness of the floor.

[7] describes the most direct approach to tracking robot' pose is to use the encoders, FOG and tilt sensor to measure the angular velocity of the wheels, the heading, the pitch and the roll, respectively. Nevertheless, FOG is commonly installed in the robot platform and its output is the rotation angle ϖ_{gyro} around Z_r axis in robot coordinate system $\{O_r\}$ that is different from the definition of the heading above. Consequently, it needs to gain the heading θ in world coordinate system $\{O\}$ by rigid-body transformation. This paper establishes rigid-body transformation of dead reckoning which helps in the complex terrains where the errors of odometry/dead reckoning are more i.e. getting the pervious pose is tough.

Visual odometry is used in paper [9] which uses feature tracks to estimate the relative incremental motion between two frames that are close in time. They are retriangulating after each frame so to calibrate the stereo camera. The IMU and the wheel [9] encoders are also used to fill in the relative poses when visual odometry fails. This happens due to sudden lighting changes, fast turns of the robot or lack of good features in the scene.

The DLR Crawler [7] is a six-legged actively compliant walking robot which was developed as a prototype of an autonomous robot for rough terrain. Since each kind of sensor has disadvantages under certain conditions, the information of all available sensors must be combined so that robust pose estimation is possible. This robot used the combination of stereo camera and odometry to create error free locomotion to reach a specific task.

In [4] the papers revolve around a technique which has two parts teaching and playback navigation systems using various sensors. This paper states that in last few years many researchers have used an omni-directional image sensor, which can acquire a 360-degree view around the robot for their navigation system. Similarly, in [2] landmark based position was stored in a database and then it was checked with the image taken from a stereo camera to match and confirm. An extended Kalman filter can be used to update a position estimation from single observation. Stated in [2] the estimates of the position provided by the two sensor systems are combined, at every step, by means of linear Kalman filter (LKF).

One of the first systems which was able to autonomously navigate on rough terrain was the Autonomous Land Vehicle (ALV) developed at the Hughes Artificial Intelligence Center in 1987 [8]. It used a laser scanner to build a navigation map and marked areas which would cause invalid vehicle configurations as un-traversable. NASA's Jet Propulsion Laboratory developed the Rocky rovers, which were test platforms for mostly sensor-based navigation algorithms [8]. They were prototypes for the Sojourner mars rover, which arrived on mars in 1997. Using a camera and a laser striper, it was able to detect and avoid obstacles along its way [8]. However, these systems only used a binary representation of the environment consisting of obstacles and free space.

The use of cameras and image processing to extract the features from the environment and navigate or working according these features has increased. The edge is the most basic feature of an image, which refers to the set of pixels that have a sudden change in the gray level. Edge detection is a basic method to recognize and segment the edges of images based on gray discontinuous points. [11] The image is firstly denoised by using the Gauss Smoothening Filter [12]. Non-edge elements are eliminated, and two thresholds are selected. If the amplitude of the pixel position is higher than the high threshold, the pixel is reserved as an edge pixel. If the amplitude of the pixel position is less than the high threshold, the pixel is excluded. [11] The contour of the image can be obtained using this. Fine SNR(Signal-to-Noise), is that the probability of the edge-point to must be low; Good performance of positioning, is that the detected edge-point should be at the center of real edge to its best possibility; Single edge response, is that the single edge has only one response.[13]With the adaptive Otsu threshold method to get the high and low threshold [14]and the more effective edge can be processed. As mentioned in [15], Moving target detection method based on video sequences is widely used in machine vision, intelligent monitoring systems and video tracking system in recent years.

It mainly functions in three parts: frame-difference, background subtraction and optical flow. The unwanted background subtraction of image is done firstly and gets the difference image the current image and background image, then extracts target by the threshold segmentation technology. Moving target has more complete edge information and can well meet the system requirements for real-time. The characteristics of the required object is obtained from each frame of the video attained. But the grey scale images the important information is lost while converting the image from color to grey scale and resizing the imaging. Using the advanced computational verb theory, the edge detection can be further improved. In CV image processing, the evolving function of a spatial verb denotes the changes of gray-values along spatial coordinates. [16] Conventional interpolation algorithms are: nearest neighbor interpolation, bilinear interpolation, bicubic interpolation and so on[17]. For a non-edge point, we choose the nearest neighbor interpolation as the fastest implementation, because the gray values in its neighborhood do not change sharply. To reduce the computational complexity, we can make a look-up table. And a high degree of parallel processing can greatly improve the efficiency of our algorithm. [16] RGB(Red, Green, Blue) color space using a point in 3-Dimensional space to represent one color. Each point has three components, representing the Red, Green, Blue brightness values of the point. By clustering in RGB space, the similar color clustered together, so we can distinguish the different color parts, thus to extracting the same color regions.[18] Active Contour method has been shown very effective in detecting the contour of region(s)-of-interest(ROI) and is widely used in image processing and computer vision.[19] Pattern recognition is another method to improve the detection and getting object required. the Invariant pattern recognition is a useful tool in automatic inspection. The use of geometric moments for the two-dimensional image characterization was introduced by Hu, who defined a class of moment invariants derived from the geometric moments, moments have linear characteristics which are invariant to translational shifts, changes of scale or rotations of the image. [20]

III. IMPLEMENTATION

The robot is controlled using the Ros master which the program running in the laptop with webcam and the points are generated from the contour which is comes from the OpenCv part these points are then reached using goal fashioned way.

Fig 1. Ptolemy (Amigobt)

Publisher is said to be the talker and subscriber is listener. Publisher and subscriber are used to send and receive the data from different topics or the sensors.

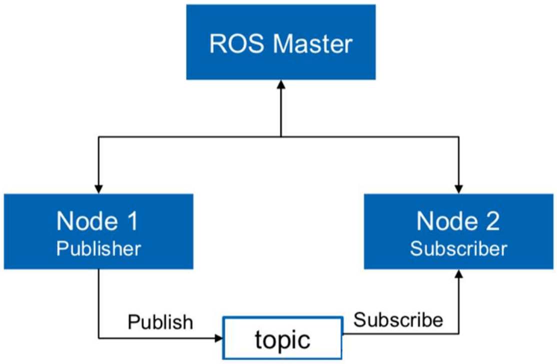


Fig 2. ROS communication

In the image processing step, the ROS node captures an image of the path using a webcam. Using a PixyCam with a Raspberry-Pi and Arduino was considered, however OpenCV cannot directly control the PixyCam this way and a webcam as the same functionality. To detect what the shape is the image is first converted to grayscale. This is done because the find Contours method works better on grayscale images. Then the find Contours method is used to detect all the contours in the image. This method returns the x, y points of every contour in the image. These points are the pixel locations in the image, so the values will often be in the hundreds, so they have to be scaled for use on the robot. The script assumes that the largest contour is the paper that the shape is drawn on and the second largest contour. The approxPolyDp method was considered for smoothing the shape. However, because the shapes could be straight or curved a large sample size of images would be needed to determine a value of epsilon that only removes points that are truly redundant.

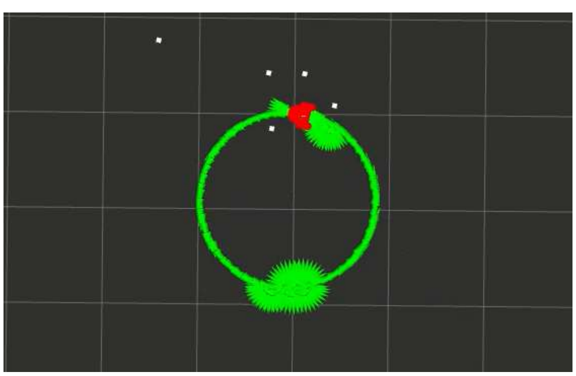


Fig 3. Ptolemy doing a circle

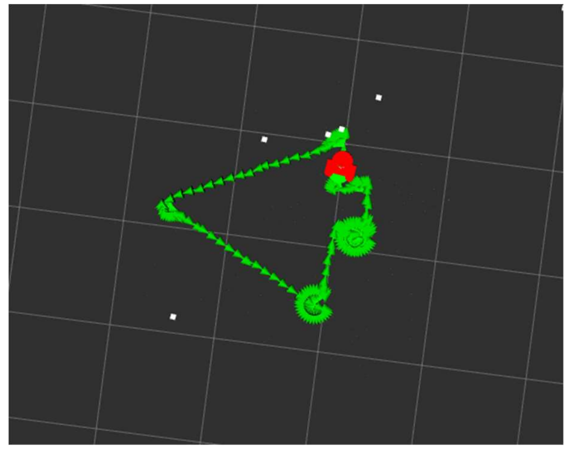
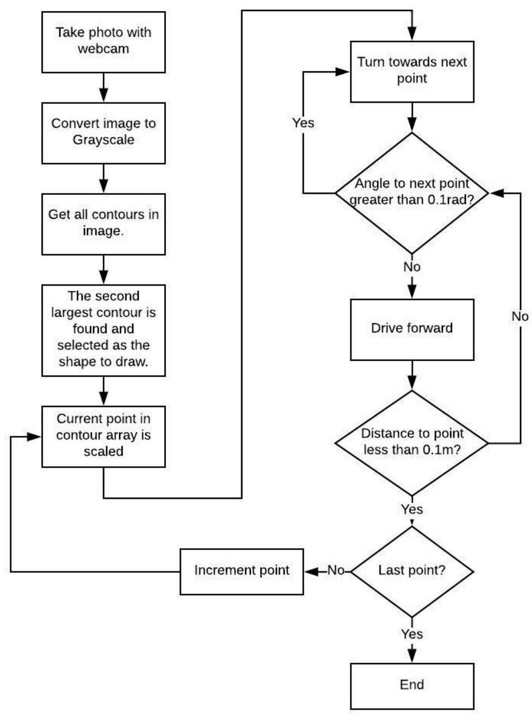


Fig 4. Ptolemy doing a tree

The script moves the robot buy publishing to Twist. The code assumes the robot starts on the first point of the contour array. The robot first changes its angle to face the next point then drives straight to reach it. Atan2 was used to calculate the angle to the next point. The speed decreases as the distance to the goal angle or the point decreases to avoid going over the goal. The encoder information from Odom is used as feedback to make sure the robot drives the correct distance

Fi 5. Flowchart of Robot's Operation



IV. Results

The robot successfully was able to move in the shape shown by the camera regardless of shape complexity. However, some improvements could be made to the program. While taking the image, before starting the program we would have to make sure that the shape was in the picture by using a program on the computer. Instead this functionality could be included in the ROS node. Additionally, when the robot was moving sometimes it would turn greater than 180 degrees. This issue could be addressed by adding a smoothing algorithm to the shape. This could remove points that are incorrectly detected as being part of the shape. Also, it was difficult to tell if the robot had successfully moved in the correct shape if the shape was complicated. To address this the robot would have to mark the points of the shape. To do this the AmigoBot would have to be modified. Lastly, it would be useful to add object detection an avoidance to the algorithm. Once this was implemented, the robot could scale the shape, so it would only drive in the space available. This will make sure the robot doesn't hit walls or other objects while drawing the shape.

V. Future Works

Additional work that could be done to the robot includes better vision where we can directly show the image to the bot and it detects and moves accordingly. Improved and dynamic scaling for better locomotion and better visualization of shape for the naked eye. Additional effort to eradicate the errors of the odometry and use better ways of navigation can the shape look perfect in each and every detail.

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