Path Following Unit based on Digital Image Processing

Engineering

KEYWORDS: Image Processing; CMOS camera; Path Follower; Histogram Equalization; Morphological operations; Robotics

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ABSTRACT

This paper describes a novel algorithm for tracking a path for a robot (any contrasting colors) with the information related to steering decision obtained from the images of the path by analyzing the images using MATLAB Image Processing Toolbox. A CMOS camera is mounted on the robot which captures the video of the path ahead in real time. The images are captured using MATLAB Image Acquisition Toolbox by triggering frames from a video in real time and applying the algorithm on these frames. Based on this, the steering decision is taken. The sensor based Path followers have certain limitations like choice of sensor selection depending on colors, dependence on the dimensions of path and lighting conditions which this project proposes to overcome. For this proposed system, various preprocessing tools like histogram equalization and morphological operations will be extensively used.

I. INTRODUCTION

There are cases where smarter versions of line followers are used to deliver mail within an office building and deliver medications in a hospital. Line followers usually use IR sensors for sensing a line and maneuvering the robot to stay on course, the problems with these robots are that, if the IR sensors are faulty they are very hard to debug, they have a limited lifetime and they are color dependent i.e. sensor output is dependent on lighting conditions.

In this project the line follower is taken to the advanced level by implementing it using a CMOS camera, processing the images acquired by the image processing toolbox (IPT) in Matlab and based on which robot is made to follow a given path.

A CMOS camera mounted over a robot acquires the images as the robot traverses through a given path. The images are sent to the processor by means of USB connectors, which are then processed in IPT (Matlab). The steering decision is sent to the microcontroller, which steers the robot accordingly.

II. LITERATURE REVIEW

In this section some of the existing tools and technologies developed so far in the field line follower robots are reviewed.

Hymavathi & Vijay Kumar (2011) presented a paper on Design of a double line follower using IR sensors, opamp and 8051 Microcontroller. Arora & Mengi (2011) presented a paper on line follower using IR sensors and S12X Microcontroller.

These techniques have a major drawback that they are colour dependent. The voltages outputted by the sensors depend on the colour sensed. Hence they are not flexible. Also these IR sensors are affected by other IR radiations if present in the same environment. The placement of sensors is also dependent on the dimensions of the path. Also IR sensors have a limited lifetime and it's difficult to debug faults.

III. IMPLEMENTATION

This paper presents the technique of path following based on Image Processing. The images of the path are continuously captured at predefined interval of time. The images (RGB) are therein converted to gray scale, then to 2 tone images (black and white) by thresholding. A proper threshold is to be obtained based on experimental verifications. The black pixels in each row are then to be averaged to find centre points along the path. The equation of the lines is then obtained using these points.

Figure 3 below shows the block diagram for the process.

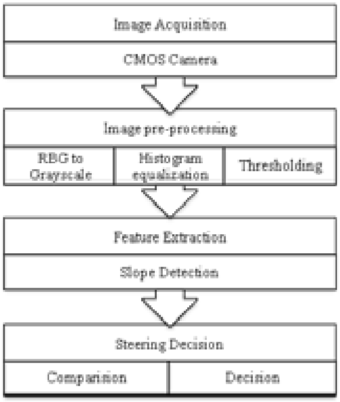

Figure 3 Process Flow for Path follower

i) RGB-Gray Conversion

RGB – Gray conversion can be carried out using variety of techniques -

The lightness method averages the most prominent and least prominent colors (Jayaraman S.Esakkirajan & T Veerakumar, 2011)

$$Y = ((\max(R,G,B) + \min(R,G,B))/2 \qquad -(1)$$

The average method simply averages the values (I.Yung, J. Gerbrands & L.Van Vliet , 2009)

$$Y = ((R + G + B))/3 \qquad -(2)$$

The luminosity method is a more sophisticated version of the average method. It also averages the values, but it forms a weighted average to account for human perception. We're more sensitive to green than other colors, so green is weighted most heavily. The formula for luminosity is

$$Y= 0.333 R + 0.5 G + 0.1666B \qquad — (3)$$

This method will be used for Conversion.(R, G, B are the intensities of Red, Green and Blue in a Pixel)

Histogram Equalization

An image histogram is a type of histogram that acts as a graphical representation of the tonal distribution in a digital image. It plots the number of pixels for each tonal value. Histogram Equalisation is a method in image processing of contrast adjustment using the image's histogram.

Pn = (number of pixels with intensity n)/(total number of pixels) -(4)

Where n = 0,1…… L-1

$T(k)= floor((L-1)\sum_{(n=0)}^{k} Pn$- (5)

iii) Thresholding

Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images(Gonzalez, Rafael C. & Woods Richard, 2002). During the thresholding process, individual pixels in an image are marked as «object» pixels if their value is greater than some threshold value (assuming an object to be brighter than the background) and as "background" pixels otherwise. This convention is known as threshold above. Variants include threshold below, which is opposite of threshold above; threshold inside, where a pixel is labeled "object" if its value is between two thresholds; and threshold outside, which is the opposite of threshold inside.

In the analysis a threshold value of 0.50 was used

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Threshold = 0.50
if pixel(x,y) < (MaxActualValue - MinActualValue)*Threshold + MinActualValue then
pixel(x,y) = black
else
pixel(x,y) = white
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The threshold value is to be chosen by experimental verifications.If threshold value is selected too low then much of the area will be white, if threshold value is too high much of the area will be black.

iv) Slope Detection

To find the slope of the line to be followed we first find the center points along the path. To do this the black pixels in each row are averaged. The line passing through these points is to be followed.

The slope of line is then calculated using the formula below

$Slope(m)= (n\sum xy-(\sum x)(\sum y))/(n\sum x^2-(\sum x)^2)$ -(6)

m is slope of line

Where n is the number of points (x,y) is pair of each coordinates. Equation of line is given by

$y=mx+b$ -(7)

b is the y intercept

IV. RESULTS AND ANALYSIS

Table 1: Path Measurements

	Actual Distance	Measured Distance	Relative Error
A-A'	4.3cm	4.2cm	2.31%
B-B'	4.5cm	3.9cm	13.33%
C-C'	6.0cm	4.9cm	18.33%

Table 1 above shows the Path Measurements and the Relative error.

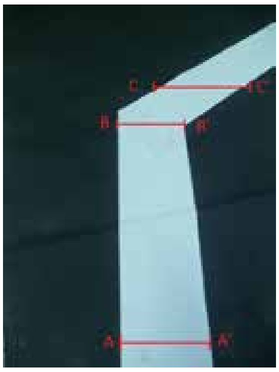

Figure 7 Path Measurements

Figure 7 above shows the Path Measurements at different locations.

CONCLUSION

Path dimensions calculated from the captured images show parallax error.

A difficulty was faced while averaging the black pixels on cross paths. The possible solution is to take a larger number of points on the line. Since the slope of vertical lines is not defined the problem was faced at perfectly straight paths. This can be overcome by using a separate checking condition for a perfectly straight line.

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REFERENCE

Acharya, T. & Ray, A.K. (2006). Image Processing - Principles and Applications. Wiley InterScience. Arora, G & Mengi, S An Ethnic Design of Line Follower Robot (Copy Right © INDIACom-2011 ISSN 0973-7529 ISBN 978-93-80544-00-7) Burger W. & Burge, M.J. (2007). Digital Image Processing: An Algorithmic Approach Using Java. Springer. CMOS Camera https://www.sparkfun.com/products/8667? (Last accessed on 09 Sep 2012) Esakkirajan, J.S. & Veerakumar, T. Digital Image Processing. Tata Mcgraw Publications 2011. Fisher, R., Dawson-Howe, Fitzgibbon, A., Robertson, C. & Trucco, E. (2005). Dictionary of Computer Vision and Image Processing. John Wiley Gonzalez, R. C. & Woods, R. E. (2002). Digital Image Processing. Pearson Education. ISBN 81-7808-629-8 Hymavathi, H. & Vijay Kumar, G. Design and Implementation of Double Line Follower Robot. (ISSN: 0975-5462 Vol. 3 No. 6 June 2011) Stanciu, S.D. Digital Image Processing Starck, J., Murtagh, F.D. & Bijaoui, A. Image Processing and data analysis; Multiscale approach. Published by Cambridge University press. Sutton, E. Histograms and the Zone System Illustrated Photography Yung, I., Gerbrands, J. & Vliet. L.V. Fundamentals of Image Processing. Published by Delft University Technology 2009 http://www.mobilerobotics.com/TowingMed.mov (Last accessed on 25 August 2012) http://kevin.org/frc/2004/TSOP34840.pdf (Last accessed on 08 September 2012) http://math.uci.edu/icamp/courses/math77c/demos/hist_eq.pdf (Last accessed on 01 September 2012)