Door detection for mobile robot navigation using fuzzy door classifier

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Abstract— **The proposed scheme focuses on an idea of autonomous interaction of a robot with its environment using visual information only. Doors are frequently encountered in structured man-made environments and function as transitions between different places. The capability to identify doors autonomously with aid of image processing algorithms is the principle objective of this work. This functionality of door detection is essential for visually guided navigation. In this scheme focus is given on the problem of door detection using intensity variation in the captured image(s) and consequent edge detection methodology for detecting the door framework. Then, a fuzzy decision is made on the detected framework by defining the likeliness of various features for a general door. Based on the percentage of trust generated by fuzzy likeliness kernel, the final decision is made about the likeliness of the detected framework to be a genuine door.**

Keywords— **Door detection, morphological Transform, edge detection, fuzzy decision making**

I. Introduction

In this paper we present a new technique for detecting doors using only visual information. Detection of doors is of great importance for various navigation and manipulation tasks. The doors are often places which separate different locations, can be used as landmarks for navigation.

The problem of door detection has been studied numerous times in the past. The existing approaches differ in the type of sensors they use and the variability of the environment they consider. For example in many approaches the information obtained from visual data is processed for geometric figures matching the appropriate dimensions of a door. In other schemes lasers and sonars have also be used for suitable schemes of door detection. In certain works, door detection was achieved using linguistic variables of size, direction and height of the geometric figure and combine the evidence using fuzzy logic.

In this paper the basic approach is to first recognize the vertical lines in the given image that represent the possible geometric shape and appearance of an ordinary rectangular door. For that, first the edges of the image is obtained by ‘Sobel’ edge detection and this edge-framework is pre-processed as per the requirement and then the vertical lines are extracted. After the extraction of the vertical lines, the possible top and bottom corners are extracted. If the extracted four corners satisfy the criterions of a door, then the four corners are assigned as the four corners of the detected door.

II. Sobel Edge Detection and Image Preprocessing

The image needs to be pre-processed. First the original image is converted into its corresponding gray scale image. Then the edge framework from the image is extracted using ‘Sobel’ edge detection technique. Then the edge framework is made prominent using morphological transform on the image. The eroded image is then filtered through a 40 x 3 averaging filter. Since the image is binary, the average value will be either 0 or 1. The averaging filter serves the purpose of strenthening the vertical edges of the image. The vertical edges of the image serve as possible candidates of the long vertical edges of the door in the image. This processed image is then utilized for further processing of the door detection algorithm. Figure 1.a, 1.b, 1.c and 1.d shows the different stages of processing.

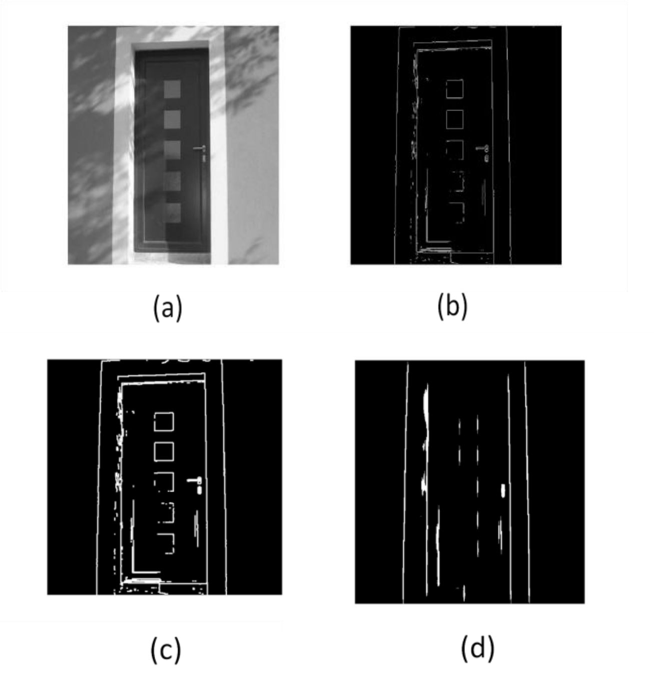


Figure 1 a) Original Gray Scale Image, b) Image after ‘sobel’ edge detection, c) Image after dilation of edges, d) Image with strengthened Vertical Edges

III. VERTICAL LINE DETECTION OF DOOR BASED ON INTENSITY DISTRIBUTION OF VERTICAL EDGES

After the extraction of the vertical edges of the image, the next objective is to find the absiccas of the two pixel co-ordinates where the intensity distribution of the vertical edges is maximum. This is done considering a r x 21 window, where *r* is the number of rows in the image pixel array. This window is translated horizontally through the image and the corresponding pixels lying within this translating window is examined. As seen from figure 1.d, it is a binary image with pixel value 1 for white and 0 for black. Using this property, the two vertical edges with maximum white pixels in the window is considered as potential candidates for the two vertical lines of the door.

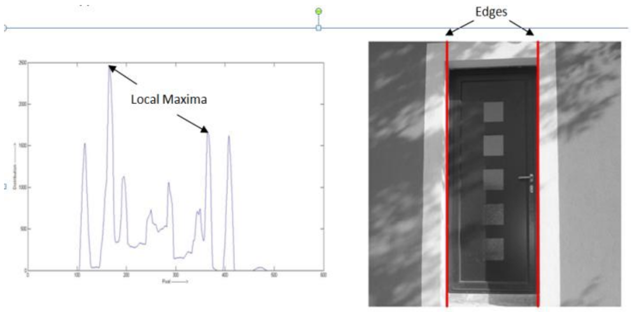
After extraction of these two maxima ($x1$, $x2$), the pixel absiccas are then passed through if-else logic which matches the pixel geometric orientation with the probable geometric orientation of the vertical lines of an ordinary door. For example, the door vertical lines separation should be within a particular threshold range.

$$Lower\ Threshold < N < Upper\ Threshold$$

where, N= normalized separation of door edges
if $x1$,$x2$ are the two abcissas of the pixels with maximum intensities.

Then, $N = {|x1 - x2|}/{Image\ width(in\ pixels)}$

In this case the upper threshold is selected to be 80% and a lower threshold of 25%



(a) **(b)**

Figure 2 a) Intensity Distribution of white pixel in a 21 x r translating window, b) Detected vertical edges of the door

As seen from figure 2.a the local maxima are first extracted and if they satisfy the door criterion stated above then they are treated as the vertical edges of the door.

In the above case, the normalized door edges separation is found to be 37%, which lies within the acceptable range and hence is declared as the possible door edges.

IV. CORNER DETECTION OF THE DOOR

Once the rectangular edges of the door are detected, the four corners of the door are then found out by traversing a 21 X 21 square window vertically along the detected vertical edges. Every time the window is translated vertically the number of white pixels in the square window is calculated and a distribution is obtained. Starting from the middle, distribution is traversed either ways. The points of either side where there is a drastic change in the distribution of white pixel is treated as a possible corner. This method is based on the assumption that the four corners of the door are located on either side of the horizontal middle line bisecting the image vertically. As seen from the Figure 3.a, the corners of the image are those points where vertical white lines end. This forms the basis of extraction of the corners from the door edges.

Sliding the 21 x 21 window along the two columns of maximum white pixel intensity and finding a sudden drop in the white pixel count we ascertain the possible corners of the door.

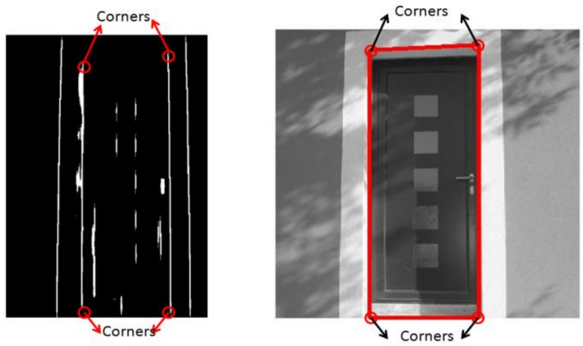


Figure 3.a) Horizontal lines showing probable corners, 3.b) Detected Corners in the original Image

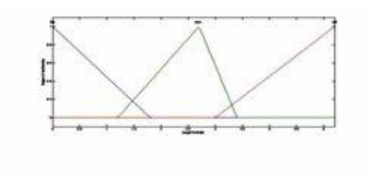
V. MEMBERSHIP FUNCTIONS

After the extraction of the corners they were tested to satisfy the criterion of a normal rectangular door. The classification was done based on a fuzzy rule based classifier which takes two inputs which are:

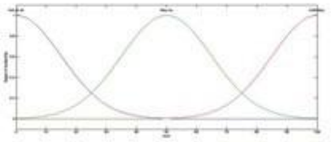
(i) 'Height : width' ratio of the door
R = Door height: Door width ratio
$R = |y2 - y1| / |x1 - x2|$

(ii) Normalized width
$NW = W/N_{col}$

where ,
W=width of the image in pixels.
N_{col} = number of columns in the image.
($x1$,$y1$) = Top Left Corner,
($x1$,$y2$) = Bottom Left Corner,
($x2$,$y3$) = Top Right Corner,
($x2$,$y4$) = Bottom Right Corner
The membership functions are shown in figure 4.



(a)



(b)

Figure 4: Membership functions (a) Height to width ratio (b) Normalized width

VI. FUZZY INFERENCING THE OUTPUT

The fuzzy inferencing system takes two inputs namely height: width ratio of the door(R) and the normalized Width(N_w). The input R can take values {'flat', 'door', 'tall'} and input N_w takes values {narrow, okay, wide}. These value are related with appropriate numerical values of R and N_w.

TABLE 1
The Fuzzy rule base

N_w / R	Narrow	Okay	Wide
Flat	Not at all	May be	Not at all
Door	May be	Definitely	May be
Tall	Not at all	May be	May be

The output is inferenced from the two inputs by aid of the fuzzy rule base shown in table 1. The output of this fuzzy system is the percentage of trust associated with the detected structure. If the percentage of trust is greater than a certain threshold value, then the detected structure is declared as a door otherwise the detected structure is not a door.

VII. EXPERIMENTAL RESULTS

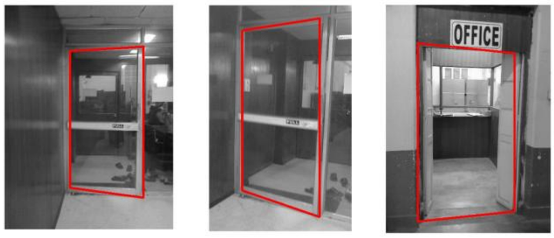
The algorithm was tested in different type of door and for doors at different angles. The algorithm works best for rectangular doors with height: width Ratio around 2.3.

TABLE 2
Results after testing 20 images of varied sites.

Total No. of Doors	True identification	False Positives	Success Rate
20	17	3	85 %

The algorithm was tested for 20 images and the results were as shown in table 2. The angle at which the image is taken is the main deciding criterion for success of the detection. At about 0-45^o angle, the algorithm can detect doors successfully at an average of 9 per 10 doors (The reader can verify this by actually testing the algorithm). At an angle above 45^O the algorithm fails about 50% of the cases. This angle constraint is the main drawback of the proposed algorithm.

The Matlab code for this algorithm can be obtained by e-mailing the author for the same. The figure 5 presents the result in three cases at different angles of photography.



(a) (b) (c)

Figure 5. Illustrating the detection of door at various angles of camera

VIII. CONCLUSIONS

This paper mainly focused on the aspect of detecting door like structure from an unknown environment using visual information only. The percentage of trust associated with the detected structure ascertains whether the detected structure is truly a door. Although the algorithm works well for most cases the inherent drawback of the system lies in the fact that the detection is heavily influenced by the angle of image acquisition.

This method certainly needs modifications in order for it to be completely robust. The possible solution can be a three input one output system where the skewness of the door can be the extra input to the fuzzy inferencing system.

IX. ACKNOWLEDGMENT

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X. REFERENCES

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