Traffic Sign Recognition for Self Driving Vehicles Using MatLab and Tensorflow

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Abstract

Traffic sign recognition is one of most important aspects of creating a safe and user friendly autonomous/self-driving vehicle. The objective of this work is the development of an algorithm for the automatic recognition of traffic signs. Two major problems exist in the process of detection and recognition of traffic signals. Road signs are frequently occluded partially by other vehicles and many objects are present in traffic scenes which make the sign detection hard and pedestrians, other vehicles, buildings, and billboards may confuse the detection system with patterns similar to that of road signs.

The main objective of this project is to design and construct a computer based system which can automatically detect road signs so as to provide assistance to the users or the machine so that they can take appropriate actions. The proposed approach consists of building a model using convolutional neural network by extracting traffic signs from an image using color information. We have used Convolutional Neural Networks (CNN) to classify the traffic signs and we used color based segmentation to extract/crop signs from images.

Keywords : **Traffic sign recognition, self driving vehicles, Convolutional Neural Networks**

I. INTRODUCTION

Traffic signs are an essential part of our day to day lives. They contain critical information that ensures the safety of all the people around us. Without traffic signs, all the drivers would be clueless about what might be ahead of them and roads can become a mess. The annual global road crash statistics say that over 3,280 people die every day in a road accident. These numbers would be much higher in case there were no traffic signs.

This method detects the location of the sign in the image based on its geometrical characteristics, and recognizes it using color information. Partial occlusion is dealt by the use of the Hough Transform.

Traffic sign recognition (TSR) can be considered part of the bigger problem of autonomous vehicles. An autonomous vehicle system relies on vision-based recognition of surrounding area in order to make driving decisions. This vision-based recognition system may function as the feedback provider for control of steering wheel, accelerator, brake etc. It may recognize road and lane to allow control system follow the course of own vehicle, detect obstacles on the road till control system avoids them, detect the passing vehicles (e.g. by side or back cameras) to notify the control system about probable hazards and detect and interpret traffic signs to provide feedback for safe driving.

Traffic signs provide important information for drivers about road condition and hazards. Their discriminating shape and colors make them easily recognizable by humans.

Road and traffic signs considered in this thesis are those that use a visual/symbolic language about the road(s) ahead that can be interpreted by drivers. The terms

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are used interchangeably in this thesis, and elsewhere might also appear in combination, as "road traffic signs". They provide the driver with pieces of information that make driving safe and convenient. A type of sign that is not considered in this thesis is the direction sign in which the upcoming directions for getting to named towns or on numbered routes are shown not symbolically but essentially by text. Road and traffic signs must be properly installed in the necessary locations and an inventory of them is ideally needed to help ensure adequate updating and maintenance. Meetings with the highway authorities in both Scotland and Sweden revealed the absence of but a need for an inventory of traffic signs. An automatic means of detecting and recognizing traffic signs can make a significant contribution to this goal by providing a fast method of detecting, classifying, and logging signs. This method helps to develop inventory accurately and consistently. Once this is done, the detection of disfigured or obscured signs becomes easier for human operator. Road and traffic sign recognition is the field of study that can be used to aid the development of an inventory system (for which real-time recognition is not required) or aid the development of an in-car advisory system (when real-time recognition is necessary). Both road sign inventory and road sign recognition are concerned with traffic signs, face similar challenges, and use automatic detection and recognition. A road and traffic sign recognition system could in principle be developed as part of an Intelligent Transport Systems (ITS) that continuously monitors the driver, the vehicle, and the road in order, for example, to inform the driver in time about upcoming decision points regarding navigation and potentially risky traffic situations. Fig. 1.1 depicts these relationships among the three fields. ITS focuses on integrating information technology into transport infrastructure and vehicles. These systems can include road sensors, in-vehicle navigation services, electronic message signs, and traffic management and monitoring. The aim of intelligent transport systems is to increase transportation efficiency, road safety, and to reduce the environmental impact with the use of advanced communication technologies [1, 2]. This thesis aims to develop a system to recognize and classify road and traffic signs for the purpose of developing an inventory which could assist the highway authorities to update and maintain traffic signs. It is based on taking images by a camera from a moving vehicle and invoking colour segmentation, shape recognition, and classification to detect the signs. In an ideal condition (off-line indoor detection of signs with direct front view) traffic sign recognition is not very hard in principle as signs have discriminating color and 2-D shape [4]. Some of the main issues involved are a variety of signs with all different colors, shapes, and pictographic symbols, complex, and uncontrolled road environment (lighting, shadow, occlusion, orientation, distance) which all can be categorized as *noise* and real-time recognition. In the following section the methodology for traffic detection and recognition system is described. Results of the proposed system are discussed in section III. Section IV describes the conclusion and future work.

One of the terminating conditions can be the minimum of weight difference achieved for convergence, or if the error is below pre-specified value. Also, if the number of iterations reach a pre-specified value, we cannot run the algorithm indefinitely. Interpretation is one of the drawbacks of neural networks as we cannot understand what the weights do and initial biases depend on and also on number of hidden layers that is basically the network topology. We use sensitivity analysis to interpret the internal understanding of the structure.

II. METHODOLOGY

There are two steps in the proposed method, namely, detection of the location of sign in the image and recognition of the sign, which are discussed in the following sections.

A. Detection of Location of Sign in Image

(i) ROI Segmentation with Image Thresholding : The first step of the algorithm is the region of interest segmentation, using sign color information [3]. A "region of interest" is an area of the image that may contain a traffic sign. A new black and white image is constructed in which all the pixels that satisfy certain thresholds of the sign color are black and the background is white (binary image – an image with only two possible pixel values) as shown in Fig. 1. The color thresholds are measured in test images.

After image thresholding, a thinning algorithm is implemented. The goal of this process is the reduction of the edge thickness in the binary image. As a result, the edges after implementation have a thickness of one

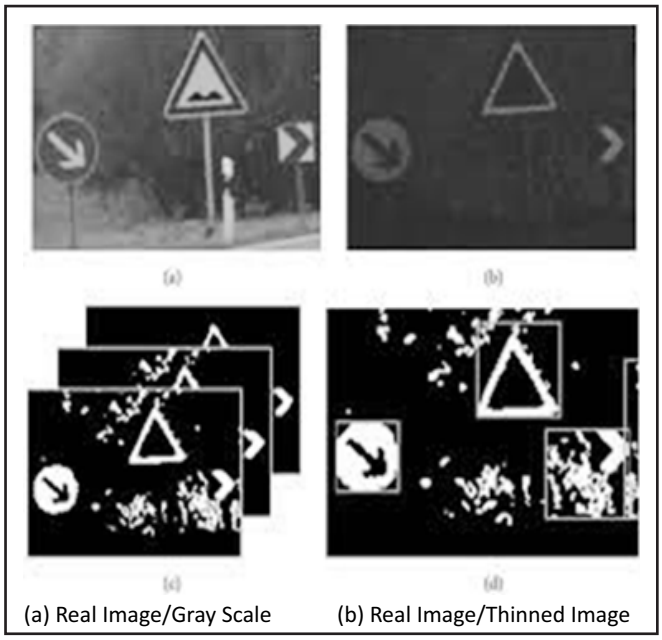

Fig. 1. Thinning and Edge Detection

pixel. This process makes it easier for the algorithm to detect lines in a later step and also increase its speed (less pixels of interest). In the case of blue traffic sings which don't have a clear outline, an edge detection filter is implemented for the removal of their interior pixels. Fig. 2 shows the thinning of the thresholded image.

(ii) Region Identifying and Region Clustering : Region identifying is the calculation of the down left and upper right apex coordinates of the rectangles which include the regions. This way the search is constrained only in the regions of interest. After that, the regions are clustered according to their total number of pixels and their center distances. Furthermore, regions with total number of pixels less than a certain value are eliminated and not examined in later steps.

(iii) Line Detection : In each ROI, line detection is carried out so as to check the kind of shape in the ROI (triangle, rectangle, circle – ellipse). In the case of the triangle and the rectangle, the line detection process also calculates the necessary data for the calculation of the sign's centre of gravity coordinates. The Hough Transform is used for the detection, a unique and effective way for the analysis of shapes and movement in images that include noise, missing or surplus data. It is a curve detection technique that can be applied when the object location is unknown but its shape can be described as a parametric curve.

(iv) Shape Check : The angles between the lines can be now calculated, using the line direction coefficients deprived from the previous check. If there are three angles between [50, 70] or [-70, 50] degrees then the shape is accepted as a triangle. In the other case, the algorithm continues with the ellipse detection step.

(v) Hough Transform for Ellipse Detection : For the ellipse detection the algorithm uses a different approach of the Hough Transform, the RHT (Randomized Hough Transform) [8]. The general idea of the transform is the same. Pixels of interest in the current ROI are being tested in random groups of three. After the detection of an ellipse, the algorithm runs a check whether this ellipse is acceptable or not, based on its eccentricity and the number of points that belong to the ellipse. In the case of an accepted ellipse, detection of the location of the sign is complete because during the ellipse detection process, the center coordinates have been calculated. From this point on, the ellipse is considered a circle with a radius equal to the large half-axis. If there isn't an accepted ellipse, the algorithm loops back to the line detection step and examines the next ROI [9].

(vi) Calculation of the Apexes and the Center of Gravity (Triangle and Rectangle Sign) : From the line equations, the coordinates of the center of gravity and of the apexes are calculated. The coordinates of the apexes are needed in the later step of the template transformation. At this point the detection of the sign location is complete. We know that traffic signs usually occur in different closed shaped like rectangles, triangles, diamonds etc. We can use this property to extract closed shaped from each of the three binary masks. This can be done by using 'Topological Structural Analysis of Digitized Binary Images by Border' [5]. We used the OpenCV implementation of this algorithm [6].

The extracted contours from the binary masks are as follows :

(1) As we can see from these images, we have narrowed down the areas of interest from the entire image. These areas of interest are further refined based on the size of the contour to reduce the areas of interest. Once we have refined the set of areas of interest, we use the convolutional neural network which we are going to build

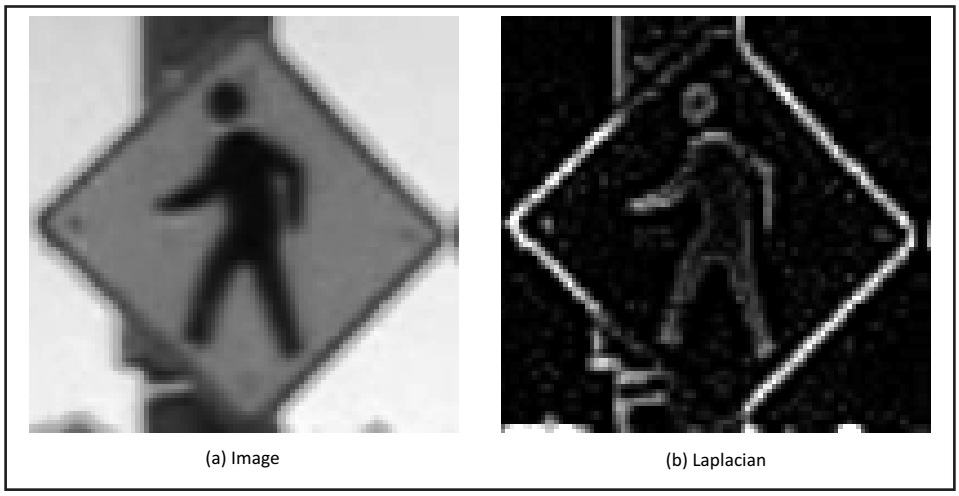

Fig. 2. Traffic Sign and Its Laplacian

in the next step to predict the type of this sign (or if it is not a sign).

(2) Predicting the type of Extracted traffic sign. From the extracted areas of interests in the previous step we want to determine if it is a sign or not and if it is a sign we wish to know what type of sign it actually is.

For this purpose, we can train a convolutional neural network. The data used to train and test the CNN was obtained from http://cvrr.ucsd.edu/LISA/lisa-traffic-signdataset.html. It had about 6000 frames and 49 different types of traffic signs. For each frame, the coordinate positions for the traffic sign in the image was given. From these positions the traffic signs were cropped out to use for training.

B. Convolutional Neural Networks (CNN)

A CNN is basically inspired by the connections between neurons in the visual cortex of animals [7]. Since traffic signs have unique shapes inside them like arrows, words, circles etc., it is useful to convert the traffic sign into a more useful form by using a Laplacian operation on the traffic sign. We can apply the Laplacian operation by convolving the following kernel on the input image :

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Consider the following traffic sign and its Laplacian :

The Laplacian is now fed into the CNN whose architecture in shown in Fig. 3.

The learning rate used to train the CNN was 0.001 and the momentum used was 0.9**.** The CNN was trained for 200 iterations (magic numbers). Once the CNN has been trained, it is used to predict the sign of the contours obtained in step 1.

Each of these contours are assigned the sign with the maximum probability which is the output of the CNN.

We can also use the trained CNN to get the Accuracy, Precision, Recall, and F1 score metrics on the test set.

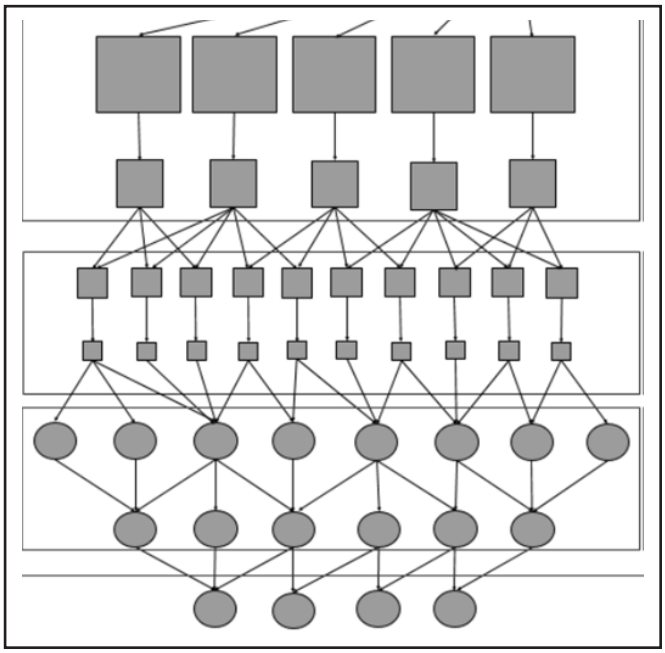

Fig. 3. CNN Reference Diagram to Display the Working Principle

Fig. 4. Street With Traffic Sign

C. MATLAB

Matlab 7 was used for the implementation of the work [7]. The algorithm working is shown with some of the figures. Fig. 5 (a) shows original image, which is filtered depending on color information as shown in Fig. 5(b). We convert the resultant image to gray scale shown in Fig. 5(c). In the next step we apply an edge detection technique which is shown in Fig. 5(d). Further thinning, line detection, shape detection, and cross correlation matching takes place. Depending on the cross correlation matching result we will be able to identify the sign.

Some more results based on the proposed algorithm are shown in Fig. 6. It can be noticed from the results that the proposed algorithm successfully detected and

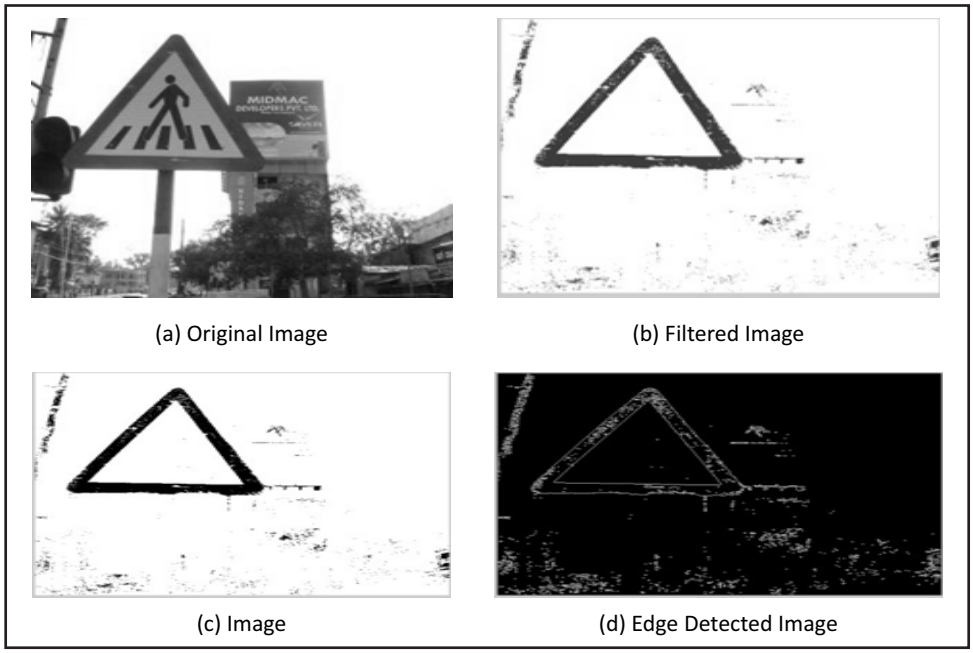

Fig. 5. Signal identification Using Proposed Method

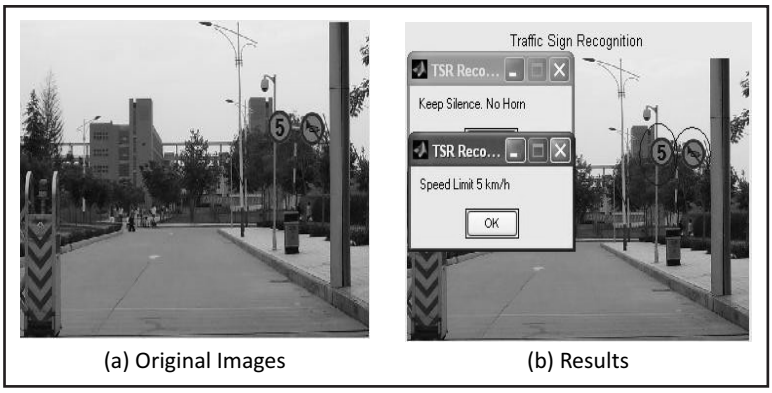

Fig. 6. Results of Automatic Signal Sign Detection Algorithm

identified the sign. In the next case we tested for the same picture from a distance. The algorithm can also identify more than one signs in the same region of interest.

III. CONCLUSION

From the following results we can see that the CNN is doing a good job in classifying different types of traffic signs when the extracted signs are cropped perfectly from the image. Our approach fails to give good results when the extracted signs from test images are cropped incorrectly. Another drawback of our approach is that when the color of the traffic signs varies, which may be due to bad weather conditions and poor camera quality, the image masks obtained are not perfect and hence, the signs are not detected properly. Future improvements can be made for extracting signs from test images by using advanced segmentation methods.

Hough Transform, the GHT can detect shapes in an image, which doesn't necessarily have to be described by an analytical mathematical equation such as the triangle or the circle. Secondly, increase of the speed of the algorithm by improving the source code and again, by possible changes in its structure.

REFERENCES

[1] J. Vavřík, J., P. Barták, and R. Čermák, "Traffic signs detection in image data," *Advanced Eng.*, vol. *4*, no. *2*, 2010.

[2] J. Carlson and S. S. Onge, "Traffic sign recognition functional description and complete system block diagram," Project Rep., Nov. 2007.

[3] M. A. García-Garrido, M. Ocaña, D. F. Llorca, M. A. Sotelo, E. Arroyo, and A. Llamazares, "Robust traffic signs detection by means of vision and V2I communications," *2011 14th Int. IEEE Conf. on Intelligent Transportation Syst. (ITSC)*, Washington, DC, 2011, pp. 1003–1008. Doi: 10.1109/ITSC.2011.6082844

[4] Y. Li, S. Pankanti, and W. Guan, "Real-Time Traffic Sign Detection: An Evaluation Study," *2010 20th Int. Conf. on Pattern Recognition*, Istanbul, 2010, pp. 3033–3036, doi: 10.1109/ICPR.2010.743

[5] A. Ruta, F. Porikli, Y. Li, S. Watanabe, H. Kage, and K. Sumi, "A new approach for in-vehicle camera traffic sign detection and recognition," IAPR Conf. on Mach. Vision Appl. (MVA), Session 15: Mach. Vision for Transportation, 2009. [Online]. Available: https://bura.brunel.ac.uk/bitstream/2438/14130/1/FullText.pdf

[6] M. Mathias, R. Timofte, R. Benenson, and L. V. Gool, "Traffic sign recognition - how far are we from the solution?," P*roceedings of IEEE Int. Joint Conf. on Neural Networks*, 2013, pp. 1–8. Doi: 10.1109/IJCNN.2013.6707049

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