Machine Vision Based Traffic Sign Detection Methods: Review

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Abstract - *According to statistics, most road accidents take place due to lack of response time to instant traffic events. With the self-driving cars, this problem can be addressed by implementing automated systems to detect these traffic events. To design such recognition system in self-driving automated cars, it is important to monitor and maneuver through real-time traffic events. Traffic signs recognition (TSR) is an important part of some advanced driver-assistance systems (ADASs) and auto driving systems (ADSs). Traffic sign recognition contains two technologies, namely, traffic sign classification (TSC) and traffic sign detection (TSD). As the first key step of TSR, traffic sign detection (TSD) is a challenging problem because of different types, small sizes and complex driving scenes. In today's world there are many technologies for Traffic sign recognition (TSR).Here is an attempt of understanding and reviewing the different technologies and methods of designing the TSR system.*

Key Words: **ADAS systems, TSD, Lidars, RGB Color space, Region of Interest (ROI) and Neural Network (NN)**

1. INTRODUCTION

Machine vision and pattern recognition are the two main technologies that are used not only in the ADAS systems but also used for other applications like biological and biomedical imaging and interpretation of temporal patterns in seismic array recordings. For any image recognition or detection system the first thing that has to be considered is sensing the image which is done by cameras and LIDARS for an autonomous car. Fig-1 shows the basic block diagram of image detection. In the review process the detection techniques can be classified under three main categories namely color based detection techniques, shape based detection techniques and machine learning based detection techniques. Through the advantages and disadvantages the different techniques have led to new efficient algorithms. Regarding color based detection, there are two approaches, either working on the standard RGB color space [1], or performing a deeper analysis of color information. Shape detection methods are popular methods which are used to obtain the position of the traffic signal and to detect shapes like circle, triangle and octagon. With the development of machine learning methods especially deep learning methodologies, the machine learning based detection methods have gradually become the main stream algorithms. Based on the deep learning methodologies there are three main structures: AdaBoost based detection, Support Vector Machine (SVM) based detection, and Neural Networks (NN) based detection.

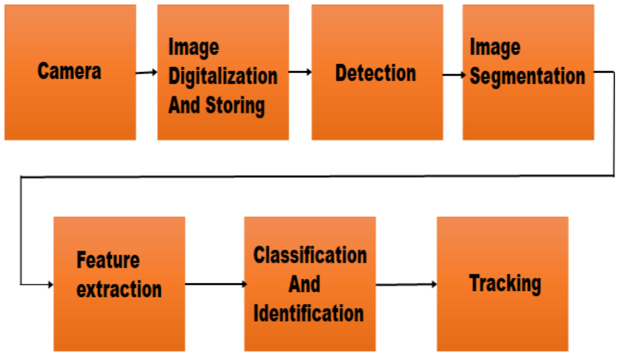

Fig -1: Basic block diagram of Image Detection

2. Detection Methodologies

2.1 Color based detection

Traffic signs are designed in such a way that the colors for particular signal are different which will be easier for the driver to immediately recognize it. This concept is used in the color based detection technique where distinct color characteristics are main attributes for the system. Table-1 shows the color based detection techniques.

The RGB space is the most basic color space for images and videos captured by cameras. Though RGB can be used with no transformation, but are sensitive to illumination changes because the R, G and B channels have high correlation. It is difficult to robustly segment a special color with some fixed thresholds in RGB space [1]. This was eliminated by using normalized version of RGB (NRGB) with respect to R+G+B. In the NRGB space, different illuminations have little effect on the pixel values; and two channels are enough to perform classification because the rest channel can be obtained with these two channels. RGB space is highly sensitive to lightning which is the main drawback of the RGB based thresholding [1].

The hue and saturation channels can be calculated using RGB, which increases with the increase in time[1].The RGB-HSV conversion formulae are non-linear and that's the reason the computation is difficult [3].However, this problem can be easily avoided by pre-computing the color space conversion and storing it in a look-up table[4].

Thresholding on other spaces are the methods that are designed on some other color spaces, which are Ohta, L*a*b and XYZ. Ohta space is used in extracting red, blue and yellow colors [1]. In [5] L*a*b space used K means clustering method to detect the blue, yellow and green colors.

All the methods used above were finding color pixel value whereas the chromatic/achromatic decomposition method finds pixels with no color information. A detail description of the categories of this method is given in [1] can be divided into five main categories: chromatic/achromatic index method, RGB difference method, NRGB method, saturation and intensity based method and Ohta components based method. In [5] to detect white color the author combined L*a*b space, HIS space and RGB space.

SVM classification method is used to classify the color from background pixels in [1]. Based on the neural network concept the input pixel values are used to train the network for color pixel classification [6].

Table -1: Color based detection techniques

Category	Method	Detected colors	Reference paper
RGB based thresholding	Normalized RGB Thresholding	Red, blue, yellow	[1]
	Color Enhancement	Red, blue, yellow	[2]
	Color Enhancement	Red, blue, yellow	[3]
Hue and saturation Thresholding	Hue and Saturation Thresholding	Red, blue, yellow	[1]
	LUT's based Thresholding	Red, blue, yellow	[4]
Thresholding on other Spaces	Ohtra Thresholding	Red, blue, yellow	[1]
	Lab Thresholding	Red, blue, yellow	[5]
Chromatic/Achromatic decomposition	RGB,HIS,Ohta decomposition	white	[1]
	RGB based Achromatic Segment	white	[5]
Pixel Classification	SVM classification	Red, blue, yellow	[1]
	Neural network	Red, blue, yellow	[6]

2.2 Shape Based Detection

Shape based detection techniques are classified as shown in the Table-2. With respect to the shape based techniques some common standard shapes in the traffic sign like circles, triangles, rectangle and octagon can be detected.

The standard shape of traffic sign are usually detected using shape detection. The special shapes are detected using several shape based detection techniques like Hough Detection [7] but whenever there are large number of images Hough based methods don't give much efficiency. To overcome this Barnes *et al.* [8] designed speed shape based detection technique called fast radial symmetry which utilizes radial symmetry voting to detect symmetry shapes. Even the polygon shapes can be detected using this technique [14].

The signs with significant edges can be detected by the analysis and matching of various shapes. Fang et al. [9] designed various complex shapes which were not easy to be detected by the previously stated techniques, hence decomposition method [10] was designed which was supported by maximal supported convex arcs to detect various complex traffic signs.

In 2011 the traffic signs were represented in the form of Fourier transformation to make it easy for detection [15], which became very helpful in detecting signs by combining various measures. In [12] Fourier transformation method which adopted fast Fourier transforms with triangular normalization and reorientation algorithm to locate sign position [11].

Key points detection detects singularities or angular edges of the traffic signs. Scale–invariant and rotation invariant are very well known Feature Transforms [17]. The corners of the signs were detected using Harris corner [16] by selecting the ROI according to the shapes in the corresponding neighborhood. Khan *et al.* [13] introduced Gabor filter which extracted stable local features of the detected ROI.

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Table -2: Color based detection

Category	Method	Detected shapes	Reference paper
Shape Detection	Hough	Circle And Triangle	[7]
	Radial Symmetry Transform	Circle	[8]
	Radial Symmetry Transform	Polygons	[14]
Shape Analysis And Matching	Complex Shape Models	Circle, Polygons	[9]
	Shape Decomposition	Circle, Square , Triangle	[10]
Fourier Transform	Fourier Descriptors	Circle, Square , Triangle	[15]
	Fast Fourier Transform	Circle, Square , Triangle	[11]
Key Points Detection	Sift	Circle, Square , Triangle, Octagon	[12]
	Harris Corner	Circle, Square , Triangle	[16]
	Interest Point Clustering	Circle, Square , Triangle	[13]

2.3 Neural Networks Based Detection

Feature extraction is the main method in the most of the Support vector machine and AdaBoost methods. In table-3 the various NN methods have been listed. Neural network based methods are the ones which are different from the other detection technologies. Mainly convolutional NN use a classifier to classify the objects from the backgrounds and need R0Is extraction methods to get the image [18][19]. Later along with the CNN AdaBoost classifier extraction came into existence [26]. Zhu *et al.* [20] proposed text based method along with the two NN (ROI extraction network and fast detection network), the accuracy of these methods depends on the designed ROI's extraction method. Yang *at el* [24] proposed a two stage strategy, first stage is Attention Network (AN) and second stage is Fine Region Proposal Network (FRPN). In [21] a new method was proposed fully convolutional network and deep CNN for classification which have their own ROI extraction network. Most of the CNNs are slow to detect the traffic signs. This defect in CNN led to the new concept called You Only Look Once (YOLO) [22] which had YOLOv2 to design the network.

Table -3: Neural Network based detection

Reference paper	Method
[18]	SVM+CNN
[19]	RGB thresholding +RCNN
[23]	CNN
[21]	FCN + deep neural network
[24]	AN and Faster RCNN
[25]	CNN
[20]	Cascaded Segmentation Detection Network
[26]	Cascaded CNN
[22]	YOLOv2

3. CONCLUSION

In this review basically we have divided detection methodologies into three main categories: color based detection, shape based detection and neural network based detection methods. Based on the performance of all the detection methods mentioned above it can be concluded that the performance of the neural network based methods is good as far as the best method to detect the traffic signs is considered. Extreme weather has a great impact on the quality of the images captured by cameras. Extreme weather conditions such as heavy fog, heavy rain and heavy snow were also not considered in previous methods. In future, new methods and new datasets that can handle night and extreme weather conditions are needed to improve the ability of camera based TSD methods to deal with these conditions.

REFERENCES

[1] H. Gómez-Moreno, S. Maldonado-Bascón, P. Gil-Jiménez, and S. Lafuente Arroyo, *"Goal evaluation of segmentation algorithms for traffic sign recognition,"* IEEE Trans. Intell. Transp. Syst., vol. 11, no. 4, pp. 917–930, Dec. 2010.

[2] A. Ruta, Y. Li, and X. Liu, "Real-time traffic sign recognition from video by class-specific discriminative features," *Pattern Recognit.*, vol. 43, no. 1, pp. 416-430, 2010.

[3] S. Salti, A. Petrelli, F. Tombari, N. Fioraio, and L. D. Stefano, "Traffic sign detection via interest region extraction," *Pattern Recognit.*, vol. 48, no. 4, pp. 1039-1049, Apr. 2015.

[4] A. de la Escalera, J. M. Armingol, J. M. Pastor, and F. J. Rodríguez, "Visual sign information extraction and identification by deformable models for intelligent vehicles," *IEEE Trans. Intell. Transp. Syst.*, vol. 5, no. 2,pp. 57-68, Jun. 2004.

[5] J. M. Lillo-Castellano, I. Mora-Jiménez, C. Figuera-Pozuelo, J. L. Rojo-Álvarez, "Traffic sign segmentation and classification using statistical learning methods," *Neurocomputing*, vol. 153, pp. 286-299, Apr. 2015.

[6] K. Zhang, Y. Sheng, and J. Li, "Automatic detection of road traffic signs from natural scene images based on pixel vector and central projected shape feature," *IET Intell. Transp. Syst.*, vol. 6, no. 3, pp. 282-291, Sep. 2012.

[7] P. Yakimov, "Traffic signs detection using tracking with prediction," in *Proc. Conf. E-Bus Telecommunication* Colmar, France, 2015, pp. 454-467.

[8] N. Barnes, A. Zelinsky, and L. S. Fletcher,"Real-time speed sign detection using the radial symmetry detector," IEEE *Trans. Intell. Transp. Syst.*, vol. 9, no. 2, pp. 322-332, Jul. 2008.

[9] C.-Y. Fang, S.-W. Chen, and C.-S. Fuh, "Road-sign detection and tracking," *IEEE Trans. Veh. Technol.*, vol. 52, no. 5, pp. 1329-1341, Sep. 2003.

[10] S. Xu, "Robust traffic sign shape recognition using geometric matching," *IET Intell. Transp. Syst.*, vol. 3, no. 1, pp. 10-18, Mar. 2009.

[11] P. Gil-Jiménez, S. Maldonado-Bascón, H. Gómez-Moreno, S. Lafuente-Arroyo, and F. López-

Ferreras, "Traffic sign shape classification and localization based on the normalized FFT of the signature of blobs and 2D homographies," *Signal Process.*, vol. 88, no. 12, pp. 2943-2955, 2008.

[12] F. Larsson, M. Felsberg, and P. E. Forssen, "Correlating Fourier descriptors of local patches for road sign recognition," *IET Comput. Vis.*, vol. 5, no. 4, pp. 244-254, Jul. 2011.

[13] J. Khan, S. Bhuiyan, and R. Adhami, "Hierarchical clustering of EMD based interest points for road sign detection," *Opt. Laser Technol.*, vol. 57, no. 4, pp. 271-283, Apr. 2014.

[14] N. Barnes and G. Loy, "Real-time regular polygonal sign detection," in *Proc. Conf. Field Service Robot.*, 2006, pp. 55-66.

[15] F. Larsson and M. Felsberg, "Using Fourier descriptors and spatial models for traffic sign recognition," in *Image Analysis* (Lecture Notes in Computer Science), vol. 6688. Berlin, Germany: Springer, May 2011, pp. 238-249.

[16] M. Boumediene, J.-P. Lauffenburger, J. Daniel, C. Cudel, and A. Ouamri, "Multi-ROI association and tracking with belief functions: Application to traffic sign recognition," *IEEE Trans. Intell. Transp. Syst.*, vol. 15, no. 6, pp. 2470-2479, Dec. 2014.

[17] D. G. Lowe, "Object recognition from local scale-invariant features," in *Proc. CVPR*, Kerkyra, Greece, Sep. 1999, pp. 1150-1157.

[18] Y. Wu, Y. Liu, J. Li, H. Liu, and X. Hu, "Traffic sign detection based on convolutional neural networks," in *Proc. Int. Joint Conf. Neural Netw.*, Dallas, TX, USA, Aug. 2013, pp. 1-7.

[19] R. Qian, B. Zhang, Y. Yue, Z. Wang, and F. Coenen, "Robust Chinese traffic sign detection and recognition with deep convolutional neural network," in *Proc. Int. Conf. Natural Comput.*, Zhangjiajie, China, Aug. 2015,pp. 791-796.

[20] Y. Zhu, M. Liao,W. Liu, and M. Yang, "Cascaded segmentation-detection networks for text-based traffic sign detection," *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 1, pp. 209-219, Jan. 2018.

[21] Y. Zhu, C. Zhang, D. Zhou, X. Wang, X. Bai, and W. Liu, "Traffic sign detection and recognition using fully convolutional network guided proposals," *Neurocomputing*, vol. 214, pp. 758-766, Nov. 2016.

[22] J. Zhang, M. Huang, X. Li, and X. Jin, `` A real-time Chinese traffic sign detection algorithm based on modified YOLOv2,'' *Algorithms*, vol. 10, no. 4, p. 127, Nov. 2017.

[23] H. S. Lee and K. Kim, "Simultaneous traffic sign detection and boundary estimation using convolutional neural network," *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 5, pp. 1652-1663, May 2018.

[24] T. Yang, X. Long, A. K. Sangaiah, Z. Zheng, and C. Tong, "Deep detection network for real-life traffic sign in vehicular networks," *Comput. Netw.*, vol. 136, no. 8, pp. 95-104, May 2018.

[25] Z. Zhu, D. Liang, S. Zhang, X. Huang, B. Li, and S. Hu, "Traffic-sign detection and classification in the wild," in *Proc. CVPR*, Las Vegas, NV, USA, Jun. 2016, pp. 2110-2118.

[26] D. Zang, J. Zhang, M. Bao, J. Cheng, K. Tang, and D. Zhang, "Traffic sign detection based on cascaded convolutional neural networks," in *Proc. IEEE/ACIS Int. Conf. Softw. Eng., Artif. Intell., Netw. Parallel/Distrib. Comput.*, Shanghai, China, May/Jun. 2016, pp. 201-206.