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# A Brief Overview of Traffic Sign Detection Methods

**Prof. Abhinav V. Deshpande**
Department of Electronics & Telecommunication Engineering, Prof. Ram Meghe Institute of Technology & Research, Badnera, Amravati-444701
avd.a.deshpande@gmail.com

***Abstract: This paper reviews the popular traffic sign detection methods which are prevalent in the recent literature. The methods are divided into three categories: color-based, shape-based and learning-based. The color-based detection methods from eleven different works are studied and summarized in a table for easy reference. The three shape-based detection methods are presented, and a recent method which is based on Hough Transform is studied in detail. In the section which is based on learning-based detection, we review the Viola-Jones detector and the possibility of applying it to traffic sign detection. We conclude with two case studies which show how the presented methods are used to design complex traffic sign detection systems***
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**Keywords:** Traffic Sign Detection, Color-Based Detection, Shape-Based Detection, Hough Transform, False Alarms, Vienna Convention, HSV

## 1. Introduction:

The recent increase in computing power has brought computer vision to consumer grade applications. As computers offer more and more processing power, the goal of real time traffic sign detection and recognition is becoming feasible. Some new models of high class vehicles already come well equipped with driver assistance systems which offer automated detection and recognition of certain classes of traffic signs. Traffic sign detection and recognition is also becoming interesting in automated road maintenance. Every road has to be periodically checked for any missing or damaged signs; as such signs pose safety threats. The checks are usually done by driving a car down the road of interest and recording any observed problem by hand. The task of manually checking the state of every traffic sign is long, tedious and prone to human error. By using the techniques of computer vision, the task could be automated and therefore carried out more frequently, resulting in greater road safety. To a person who is acquainted with recent advances in computer vision, the problem of traffic sign detection and recognition might seem easy to solve. Traffic signs are fairly simple objects with heavily constrained appearances. By just having a glance at the well-known PASCAL visual object classes challenge for 2009 indicates that researchers are now solving the problem of detection and classification of complex objects with a lot of intra-class variation, such as bicycles, airplanes, chairs or animals. The contemporary detection and classification algorithms will perform really well in detecting and classifying a traffic sign in an image. However, as research comes closer to commercial applications, the constraints of the problem change. In the driver assistance systems or road inventory systems, the problem is no longer how to efficiently detect and recognize a traffic sign in a single image, but how to reliably detect it in hundreds of thousands of video frames without any false alarms, often using low quality cheap sensors which are available in mass production. In order to illustrate the problem of false alarms, consider the following: one hour of video shot at 24 frames per second consists of 86400 frames. If we assume that in the video under consideration traffic signs appear every three minutes and typically span through 40 frames, there are a total of 800 frames which contain traffic signs and 85600 frames which do not contain any signs. These 85600 frames without traffic signs will be presented to our detection system. If our system were to make an error of 1 false positive per 10 images, we would still be left with 8560 false alarms in one hour, or two false alarms every second, rendering the system completely unusable for any serious application. To make the problem even harder, we cannot expect the vehicle on which a commercial traffic sign detection system will be deployed to be equipped with a very high resolution camera or other helpful sensors, as the addition of such sensors increase the production costs. This paper presents an overview of basic traffic sign detection methods. Using the presented methods as commercial stand-alone solutions is impossible, as they fail to provide the required true positive and false positive rates. However, combining the methods has a synergistic effect, so they are commonly used as the building blocks of larger detection systems. In this paper, the traffic sign detection methods are divided into three categories: color-based methods, shape-based methods and the methods which are based on machine learning. After introducing the methods, we present two traffic sign detection systems which use them.

## 2. Traffic Sign Classes: The Vienna Convention

Before investigating the common traffic sign detection methods, it is useful to briefly review the data on which these methods operate, i.e. the classes of traffic signs. In 1968, an international treaty aiming to standardize traffic a sign across different countries, the so-called Vienna Convention on Road Signs and Signals was signed [2]. To date, there are 52 countries which have signed the treaty, among which 31 are in Europe. The Vienna Convention classifies Road Signs into seven categories, which are designated with letters A-H, danger warning signs (A), priority signs (B), prohibitory or restrictive signs (C), mandatory signs (D), information, facilities or service signs (F), direction, position or indication signs (G) and additional panels (H). The examples of Croatian traffic signs for each of the categories are shown in the figures below:

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**Figure 1 A Danger Warning Sign**

**Figure 2 A Prohibitory Sign**

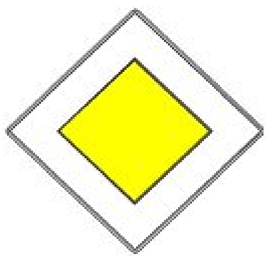

**Figure 3 A Priority Sign**

In spite of appearances of traffic signs being strictly prescribed by the Vienna Convention, there still exist variations between countries which have signed the treaty. The variations are seemingly irrelevant for a human, but might pose significant challenges for a computer vision algorithm. For example, one can refer the Table 1 where variations of two traffic signs across six different European countries are shown. Therefore, the contemporary traffic sign detection systems are still country-specific.

**2.1. Evaluating Traffic Sign Detection Methods:**

The research work containing traffic sign detection is often hard to compare, as different research scholars approach the same problem with different application areas and constraints in mind. The traffic sign detection methods are inherently dependant on the nature data for which they were developed. Some of the factors in which the methods differ are given as follows:

1. Input type: Videos or static images?

2. Scope of the Method: Is the method applicable for a single traffic sign class or for multiple classes?

3. Filming Conditions: Is the data shot in broad daylight, in nighttime or both? Are there adverse weather conditions such as rain, snow or fog?

4. Sensor Type: High resolution or low resolution camera, grayscale or color? Multiple cameras? Other sensors?

5. Processing Requirements: Should the lines be detected in real time or is offline processing acceptable?

6. Acceptable true positive and false positive rates: Determined by the nature of the problem

The nature of the problem, the availability of the sensors and the target application determine which method to be used. For example, color-based detection is pointless if we are working with a grayscale camera. On the other hand, it might be very useful if we are trying to detect traffic signs in high resolution color images which are taken in a broad daylight with a high quality camera. Shape-based detection might not work if we are using a camera with interlacing. The learning-based approaches might be a perfect solution if we have a lot of labeled data, but if no labeled data is available then we cannot use them.

**2.2. Color-Based Detection Methods:**

The prevalent approach in detecting traffic signs based on color is very obvious- one finds the areas of the image which contain the color of interest by using simple thresholding or more advanced image segmentation methods. The resulting areas are then either immediately designated as traffic signs, or passed on to subsequent stages as traffic sign location hypotheses (i.e. regions of interest). The main weakness of such an approach lies in the fact that the color tends to be unreliable-depending on the time of the day, weather conditions, shadows etc. the illumination of the scene can vary considerably. The RGB color space is considered to be very sensitive to illumination, so many research scholars choose to carry out the color-based segmentation in other color spaces such as HIS or L*a*b.

**3. Color Spaces: A Short Review**

In order to understand why some color spaces are considered to be very illumination sensitive and some not, we briefly review the theory of color spaces. A color space is defined by using a color model. In general, a color model is an abstract mathematical model which defines how the colors can be represented as tuples of numbers. All the valid tuples constitute a color space. Common dimensionality of tuples is three to four. There is a myriad of color spaces which differ in the basic color used. Some of the most popular are RGB (red-green-blue) color space, HIS (Hue-Saturation-Intensity) color space, L*a*b (Lightness-color component dimensions), CMYK (Cyan-Magenta-Yellow-Black) color space, CIECAM 97 color space. In the RGB color model, the colors are specified as mixtures of red, green and blue components. The figure shown below illustrates how two different shades of orange can be obtained by mixing red, green and blue. The differences between RGB components for the first and the second color are -31, +24 and +59. The RGB color model is unintuitive from a human standpoint-a human might expect to vary just one parameter namely illumination to obtain the second color from the first. It would be hard for a human to guess the changes in R, G and B which are necessary for the required change in color. Similarly, it is hard for a computer to learn that these two colors are similar based purely on the distances between the numerical values of their R, G and B. Several color models were designed to address this problem. In the mid 1970's, the research scholars working in the field of computer graphics developed the HSL and HSV color models, which rearrange the RGB color space in cylindrical co-ordinates so that the resulting representation is closer to human visual perception. A very similar model is HIS which is most commonly used in computer vision. HSL, HSV and HIS differ only in the definition of the third component-L stands for lightness, V for value and I for intensity. The first two components are hue and saturation. In the HS* cylinder, the angle around the central vertical axis corresponds to hue, the radius to saturation and the height to lightness or value or intensity. In the HS* representation, the components of two similar colors are numerically much closer, which is why it is said to be less sensitive to illumination.

### 3.1. Color-Based Segmentation:

The color of a traffic sign should be easily distinguishable from the colors of the environment. After all, the traffic signs are specifically designed with this requirement in mind. In order to find the sign of a target color, one segments the image based on that color. Image segmentation is a process which assigns a label to each pixel of an image so that the pixels with the same labels share similar visual characteristics. The simplest method of image segmentation is thresholding every pixel with a value above a certain threshold is marked with an appropriate label. Various authors have experimented with color thresholding, especially in the 1990's. High detection rates were reported, but the experiments were usually done on small testing sets. For example, simple thresholding formulas are used by Varun et. al. [5] and Kuo and Lin [8]. The external factors such as illumination changes, shadows, adverse weather conditions can greatly impact the success of color-based detection techniques. This significantly reduces the potential of color thresholding as a standalone solution for detection. In recent research work, color thresholding commonly finds its purpose as a preprocessing step to extract the regions of interest [14][15]. The influences of daily illumination changes are recognized by Benallal and Meunier [3]. They present an interesting experiment in which they observe the color of a red STOP through 24 hours. They show that the red color component is dominant between approximately 6.30 a.m. and 9.00 a.m. During that time, the differences $\delta_{RG}$ and $\delta_{RB}$ between the red color component and the green and blue components remain high, the red color having a value of approximately 85 above the green and the blue components. Based on this experiment, they propose formulas for color segmentation intended to correctly segment the red, green and the blue signs. Estevez and Kehtarnavaz [4] present an algorithm for detecting and recognizing a small subset of traffic signs which contain the red components. The first stage of their algorithm is color segmentation, used to localize the red edge areas. The formula for the segmentation relies on a tunable parameter $\alpha$ which can be tuned to varying sensitivities which is based on the intensity levels, in order to avoid illumination intensity. The average intensity values are obtained by sparsely sampling the top line of the image, usually corresponding to the sky. From these values one can speculate about the weather conditions and choose the proper value of $\alpha$ . The exact values of $\alpha$ chosen are not given in the research paper. Broggi et. al. [6] propose a way of overcoming the color dependency of the light source. The default way to determine the light source color is to find a white object in the scene and compute the difference between the image white and theoretical white (RGB values are 255, 255 and 255). In road sequences, one cannot count on having a white reference point, but the road is usually gray. Broggi et. al. therefore find a piece of road (it is unclear whether this is an automated procedure or it needs to be done by hand) and estimate the light source color by assuming that the road should be gray. They then perform the process of chromatic equalization which is similar to gama correction but with the linearization of gamma function. Ruta et. al. [7] used color-based segmentation as a starting stage in the process of traffic sign recognition. They first segment the image based on fixed thresholds and then enhance the obtained colors by using the formulas which are given in the research paper.

## 4. Conclusion:

In this paper, we have presented traffic sign detection methods which are often used as building blocks of complex detection systems. The methods were divided into color-based, shape-based and learning-based. We have shown how the outlined methods are used in two state-of-the-art traffic sign detection systems. We think that the complexity of traffic sign detection systems will diminish in the future, as the technology advances. With the advancement of technology, high quality sensors will become cheaper and more available in mass production. If in the future, every car is equipped with a high resolution color camera, a GPS receiver and an odometer, an infrared camera and other sensors, the problem of traffic sign detection will be infinitely simpler than it is now. However, the advancement will probably proceed slowly, because of the persistent need to minimize the production costs.

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