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Road and Traffic Sign Color Detection and Segmentation - A Fuzzy Approach

Hasan Fleyeh
Department of Computer Engineering, Dalarna University, Borlänge, Sweden
Transport Research Institute, Napier University, Edinburgh, Scotland
hfl@du.se

Abstract

This paper presents a new algorithm for color detection and segmentation of road signs based on fuzzy sets. The images were taken by a digital camera mounted in a car. The RGB image was converted into HSV color space, and segmented by using a set of fuzzy rules depending on the hue and saturation values of each pixel in the HSV color space. The fuzzy rules are used to extract the colors of the road signs. The method was tested on outdoor images in different light conditions, and it was tested on color images from different European countries and it showed high robustness. This project is part of the research conducted by Dalarna University-Sweden and Napier University Edinburgh-Scotland in the field of the Intelligent Transport Systems (ITS).

1 Introduction

Road and traffic sign recognition is one of the biggest fields in the Intelligent Transport System (ITS). This is due to the importance of road signs and traffic signals in daily life. They define a visual language which can be interpreted by the drivers. They illustrate the current traffic situation on the road, indicate dangers and difficulties drivers may encounter, give warnings to them, and help them with their navigation by providing useful information which makes driving safe and convenient [1, 2].

The field of road sign recognition is not very old; the first paper appeared in Japan in 1984. The aim was to test various computer vision methods for the detection of objects in outdoor scenes. Since that time many research groups and companies have been interested and have conducted research in the field, and an enormous amount of work has been done. Different techniques have been used, and great improvements have been achieved during the last decade.

Human visual perception abilities depend on the individual's physical and mental conditions. In certain circumstances, these abilities can be affected by many factors such as tiredness and driving tension. Hence, it is very important to have an automatic road sign recognition system which can be a supplementary means to the driver [3, 4]. Giving this information in good time to drivers can prevent accidents, save lives, increase driving performance, and reduce pollution caused by vehicles [5-7].

The identification of road signs is achieved by two main stages: detection and recognition. In the detection phase, the image is preprocessed, enhanced, and segmented according to the sign properties such as color or shape. The output is a segmented image containing potential regions which could be recognized as possible road signs. The efficiency and speed of detection are important factors which play a strong role in the whole process, because it reduces the search space and indicates only potential regions. In the recognition stage, each of the candidates is tested against a certain set of features to decide whether it is in the group of road signs or not, and then according to these features they are classified into different groups. These features are chosen in order to emphasize the differences among the classes.

Colors represent the basic cue for road sign detection; however shapes are used by some research groups to detect road signs. Shadeed et al. [8] proposed an algorithm in which color segmentation was achieved by converting the RGB image into HSV and YUV color spaces, and then applying proper threshold to H and UV values. Then the two results were combined by an AND operation. Bénallal and Meunier [9] developed a computer vision system which was embedded in a car and capable of identifying road signs. Segmentation was achieved by the RGB color space. de la Escalera et al. [10] built a color classifier based on two look-up tables derived from hue and saturation of an HSI color space. Fang et al. [2] developed a road sign detection and tracking system in which the color images from a video camera were converted into the HSI system. Color features were extracted from the hue using a two-layer neural network.

The layout of the paper is as follows. Section 2 shows the difficulties when working in outdoor scenes, and the effect of different factors on the perceived images. Section 3 describes how the color varies in the outdoor images and the parameters affecting this. The new detection and segmentation algorithm is introduced in Section 4, and Section 5 shows the experimental result and proposes future research.

2 Traffic Signs: Potential Difficulties

Due to the complex environment of roads and the scenes around them, the detection and recognition of road and traffic signs may be problematic. The color of the sign fades with time as a result of long exposure to sunlight, and the reaction of the paint with the air [1, 7]. Visibility is affected by weather conditions such as fog, rain, clouds and snow [1]. The color information is very sensitive to the variations of the light conditions such as shadows, clouds, and the sun. [1, 7, 11]. It can be affected by the illuminant color (daylight), illumination geometry, and viewing geometry [12]. The presence of objects similar in color to the road signs in the scene under consideration, such as buildings or vehicles. Signs may be found disoriented, damaged or occulted. If the image is acquired from a moving car, then it is often suffers from motion blur and car vibration.

3 Color Variations in Outdoor Images

One of the most difficult problems when using colors in outdoor images is the chromatic variation of daylight. As a result of this chromatic variation, the apparent color of the object varies as daylight changes. The irradiance of any object in a color image depends on three parameters:

The color of the incident light: Daylight's color varies along the CIE curve. Given by:

$y = 2.87x - 3.0x^2 - 0.275 \qquad for\ 0.25 \le x \le 0.38$.

The variation of daylight's color is a single variable which is independent of the intensity.

The reflectance properties of the object: The reflectance of an object $s(\lambda)$ is a function of the wavelength λ of the incident light. It is given by: $s(\lambda) = e(\lambda)\phi(\lambda)$. Where $e(\lambda)$ is the intensity of the light at wavelength λ, and $\phi(\lambda)$ the object's albedo at each wavelength.

The camera properties: The observed intensities depend on the lens diameter d, its focal length f, and the image position of the object measured as angle a off the optical axis. Given by: $E(\lambda) = L(\lambda).(\pi/4)(d/f)^2\cos(4a)$. According to this equation, the radiance $L(\lambda)$ is multiplied by a constant which will not affect the object's observed color. By cancelling the camera's lens chromatic aberration, only the density of the observed light will be affected.

As a result, the color of the light reflected by an object located outdoors is a function of the temperature of the daylight and the object's albedo, and the observed irradiance is the reflected light surface scaled by the irradiance equation [12, 13].

4 The Color Segmentation Algorithm

The color segmentation algorithm is carried out by taking RGB images using a digital camera mounted on a moving car. The images are converted to HSV color space. The HSV color space is chosen because Hue is invariant to the variations in light conditions as it is multiplicative/scale invariant, additive/shift invariant, and it is invariant under saturation changes. Practically this means that it is still possible to recover the tint of the object when it is lit with intensity varying illumination space. Perez and Koach [14] showed that the hue is unaffected by shadows and highlights on the object when the illumination is white.

The Swedish National Road Administration defined the colors used for the signs [15] in CMYK color space. These values are converted into Normalized Hue and Normalized Saturation as shown in Table 1.

Table 1. Normalized Hue and Saturation.

Color	Normalized Hue [0,255]	Normalized Saturation [0,255]
Red	250	207
Yellow	37	230
Green	123	255
Light Blue	157	255
Dark Blue	160	230

Normalized Hue and Saturation are used as a priori knowledge to the fuzzy inference system to specify the range of each color in this system. To detect and segment any color mentioned in Table 1, seven fuzzy rules are applied. These rules are as follows:

1. If (Hue is Red1) and (Saturation is Red) then (result is Red)
2. If (Hue is Red2) and (Saturation is Red) then (result is Red)
3. If (Hue is Yellow) and (Saturation is Yellow) then (result is Yellow)
4. If (Hue is Green) and (Saturation is Green) then (result is Green)
5. If (Hue is Blue) and (Saturation is Blue) then (result is Blue)
6. If (Hue is Noise1) then (result is Black)
7. If (Hue is Noise2) then (result is Black)

The membership functions of the Hue and Saturation are shown in figures 1 and 2 respectively. Since the range of the Hue of the red color is around zero value, two fuzzy variables are defined for this Hue. They are called Red1 to represent color values above zero, and Red2 to represent color values below or equal 255. There are two regions of Hues values which are not used for road signs are defined as Noise1 and Noise2. If any of these colors are faced by the fuzzy inference system, it responds by initiating a black pixel.

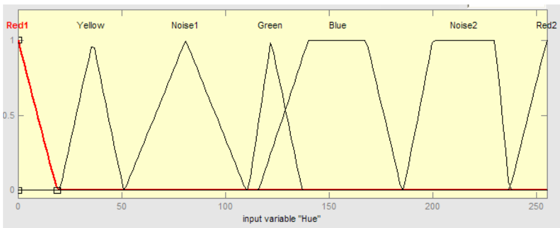

Figure 1. Hue Membership Functions.

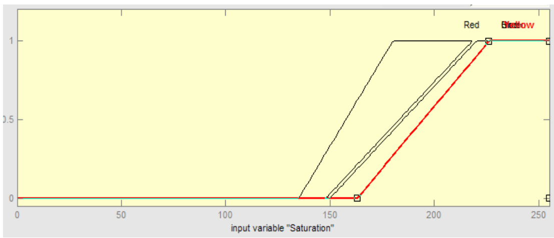

Figure 2. Saturation Membership Functions.

The membership functions of the Saturation show that almost all of the values of colors used in road signs are located on the right sides and they are similar to each other with small differences in their ranges.

Figure 3 shows the "result" output variable. There are five member functions, one for each color. They represents a certain range of gray levels in the output image which correspond to the colors used in road signs. The fuzzy surface is shown in figure 4, and it shows the relation among Hue, Saturation, and result variables.

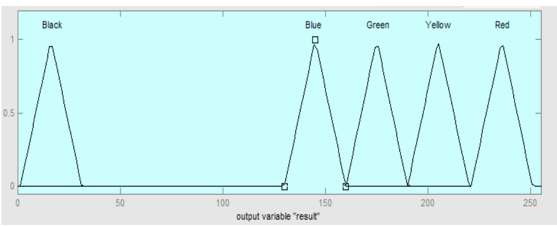

Figure 3. The Output Functions.

Gray level slicing is used to separate different gray levels generated by the fuzzy inference system, which represent different colors. The output of this gray level slicing is a binary image containing the desired color. A median filter is subsequently used after that to remove noise and small unwanted objects.

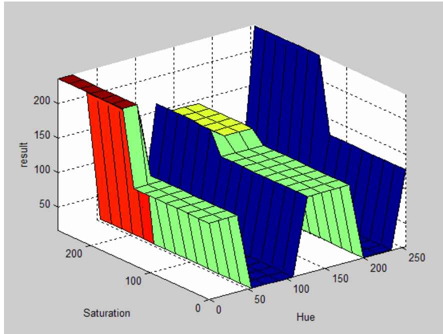

Figure 4. The Fuzzy System Surface.

4 Experimental Results

This paper shows a new method for color detection and segmentation used for traffic signs. The method is based on invoking the HSV color space, and uses hue and saturation to generate a binary image containing the road sign of a certain color. The system described in the previous section uses a fuzzy inference system to achieve color detection and segmentation. It is tested on more than one hundred images taken in different light conditions. The system is very robust, and it could detect all the colors described in the aforementioned section, some of the sample images are shown in figure 5.

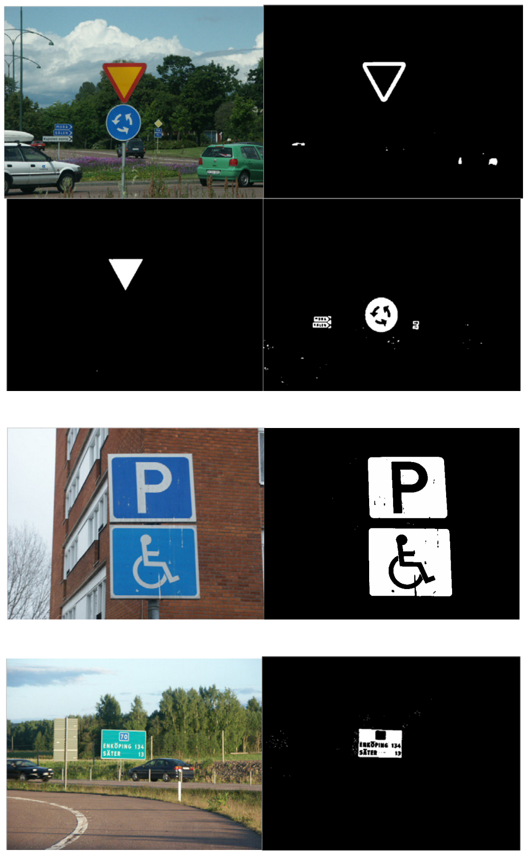

Figure 5. Detection Results.

Furthermore, it was tested on color images from other European countries [16], and it could detect all the test signs. Figure 6 shows the "Children" sign collected from different European countries and the result of the detection is shown in the second row of this figure.

To design a good color detector and segmentation system, it is very important to consider all the difficulties mentioned in section 2. Objects which have similar colors could be available in the scene under consideration as shown in figure 5. The system needs a further stage to delete these objects and keep the road signs. This can be achieved by shape analysis. Light variations and shadows generated by other objects are major problems faced by color detectors. This is a key point for further research in the future. The other key points for further study are the effect of reflections on the stability of the hue in outdoor images.

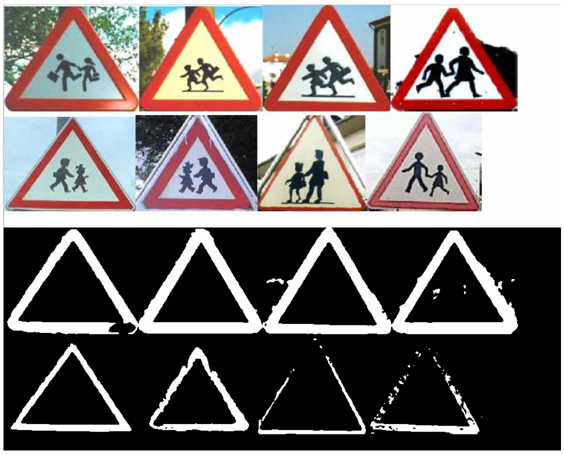

Figure 6. Children Signs from Different European Countries.

Combining these results with shape recognition of the road signs, and pictogram recognition, which are parts of the future work, will provide a good means to build a complete system which supplies drivers with information about the signs in real time as part of the intelligent vehicle. This paper is part of the sign recognition project conducted by Dalarna University, Sweden jointly with the Transport Research Institute, Napier University-Edinburgh, Scotland to invoke digital image processing and computer vision in the ITS field.

Dedication

To my wife Jinan and my children Sadeem and Riam. Thank you for your support.

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