Traffic sign recognition based color model

Majid Dherar Younus, Emad A. Al-Sabawi
Computer and Information Engineering Department, College of Electronics Engineering, Ninevah University, Mosul, Iraq

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ABSTRACT

The main problems that encounter the traffic light detection algorithm have become a handicap to the performance of the algorithms. Problems associated with the change of sign color due to bad weather and illumination changes of sunlight make the detection hard task. In the current work, we discuss these problems and propose a new idea of an efficient real time color sign recognition that relies only on color information. The proposed approach is based on building a red-model in hypothetical red, green, blue (RGB) cube using a large database of traffic signs. The segmentation has been implemented on the traffic signs that hold red color only as an example to illustrate the proposed approach. Results showed that the proposed algorithm is accurate as well as the computational cost is reduced.

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Corresponding Author:

Emad A. Al-Sabawi
Computer and Information Engineering Department, College of Electronics Engineering
Ninevah University
Al Majmoaa Street, Mosul, Iraq
Email: emad.khalaf@uoninevah.edu.iq

1. INTRODUCTION

The identification of traffic signs is a fundamental task of a driver assistance system (DAS) [1]–[7]. Traffic signs improve traffic safety by notifying drivers of speed limits and alerting them to potential hazards such as upcoming roadwork, pedestrian crossings, and slick roads. They are easily comprehensible and perceivable due to their simplified pictograms and bright colors [8]–[12]. Detection and recognition are the two main stages of fully road sign recognition system. Using either color or shape information, the task of the first stage is to detect prospective road signs in the image, i.e. the regions which contain road sign features. The potential regions are further examined in the second stage in order to find the proper sign and it's meaning [13].

A substantial amount of study has been implemented in order to develop a feasible solution of road sign detection system. Because of the importance of color, color based segmentation of a region of interest presumed to comprise road signs is the first step in computerized road sign identification and recognition [14]–[16]. Due to changes in the surroundings and the speed of cars, traffic sign identification presents numerous challenges. When traffic signs, for example are exposed to the sun for an extended period of time they normally fade.

Furthermore, their colors can be changed due to different lighting effects caused by weather conditions like snow, fog, or cloud. It is influenced not only by the brightness of daylight but also by the dim nightlight [12], [17], [18]. To recognize traffic signs, a variety of color spaces were used to accomplish color segmentation. The threshold selection problem in any color space. However, is a significant challenge due to color variation. Despite the fact that there has been a large number of studies in the area of road sign recognition, very few of the published work has regarded the use of the available color representation models in color based segmentation or intended to do a comparison study of how different color spaces operate under various environmental conditions and illumination changes [14]. In current work, the focus will be on segmentation part of detection stage. The proposed algorithm will avoid the confusion in color space selection and will solve the signs color variation problematic.

The color model can be defined as a digital representation of potentially contained colors; another explanation is that it is the method by which we can recognize color, in which humans can interpret color using attributes such as brightness and hue [19]. The red, green, blue (RGB) color model is shown in Figure 1. The name of RGB color model is taken from the three main primary colors (red, green, and blue), which are mixed as one color in a light spectrum to generate a new spectrum colors as shown in Figure 1(a). The RGB color model can be visualized as a cube of RGB normalized color values in the interval [0,1]. The main diagonal represents the gray colors, the black is (0,0,0) whereas (1,1,1) is the white on the opposite corner as illustrated in Figure 1(b). Because the acquired image does not require any further conversion to be displayed on the screen, it is considered the fundamental color model for several image applications [20].

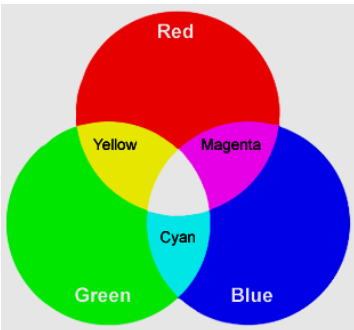
In hue, saturation, value (HSV) color model, the color scheme is inspired by the human visual system. In this approach, H stands for hue, which indicates color purity, S stands for saturation (the amount of white color incorporated in a certain color), and V stands for value. HSV color model is used in computer vision and image analysis for segmentation as illustrated in Figure 2 [21].

The European TV signal is widely used YCbCr color model for digital television. It was defined in the ITU-R BT.601 standards (International Telecommunication Union). The YCbCr color model has three components. The luma is represented by Y, whereas Cr and Cb chroma components represent the blue and red differences, respectively [5]. Figure 3 shows RGB color cube in YCbCr color space.

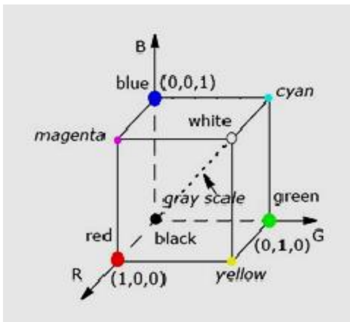
Detection algorithms utilize two main features to perform detection, sign shape (circle, triangle, rectangle, and octagon) and sign color (red and blue). To assist drivers in recognizing road signs easily and rapidly, they are designed specifically to have a distinct color from the surrounding area [13]. Therefore, this feature was adopted in this paper to build segmentation algorithm based on color information.

The goal of some researches discussed in this section is sign detection and recognition others just aim to perform detection. However, we will focus on segmentation part of detection stage of these researches. Color space segmentation has many techniques, segmentation based on thresholding, segmentation based on learning technique, and segmentation based on color distance.

Zaklouta and Stanciulescu [22] propose to threshold image pixels in RGB model based on simple equation. Khanal *at al*. [13] threshold pixels using log color space after founding the appropriate values for threshold. Zakir *et al*. [14] perform threshold on multiple color spaces for each image, then AND operation is done between results from each one. Fleyeh [23] propose three methods. First one, threshold pixel based on euclidian distance that calculated between H an S, if it's less than or equal threshold calculated from luminance image it's consider as object otherwise the pixel is considered as a back ground. Second method, divided into three steps: first threshold hue and saturation planes based on previous knowledge about the color range in each. Second, applying filter 16*16 pixels to adjust results in first step then at the end perform AND operation between two images resulted. Third, method threshold hue and saturation planes based on minimum and maximum saturation values that have been chosen, then AND is performed between two binary images resulted. Dean and Jabir [24] after performing image enhancement on the image it converted to YCbCr color space then threshold the Cr plane to detect the red color. Le *et al*. [17] applying K-Means method on large data collected in various states. Qin *et al*. [25] use color distance method in RGB color cube with threshold based on value selected from statistical work.



(a)



(b)

Figure 1. RGB color model (a) primary color representation and (b) primary color cube

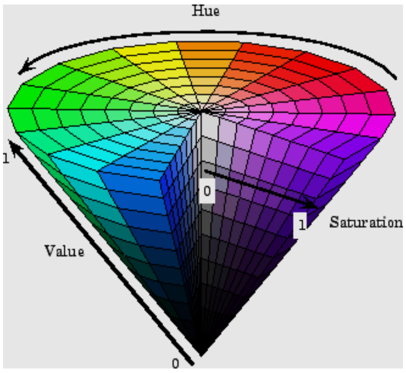


Figure 2. HSV color model single hex cone

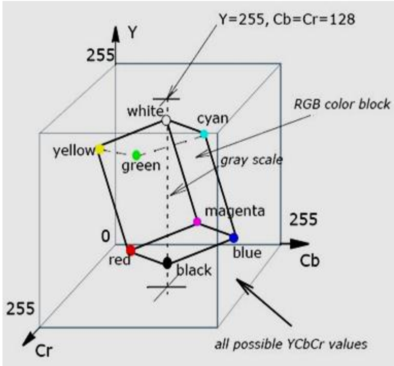


Figure 3. RGB color cube in YCbCr color space

2. METHOD

The majority of cameras capture images in the RGB color space. Working with a color space that isn't the same as the images is a problem. Any color space conversion is based on an approximated equation. Yet the transformation process spends a significant amount of time in addition to the processing time for doing floating point calculations, which results in low efficiency [25]. As a result, we concentrate our efforts on working with the RGB color space that cameras give. Relying on equations to solve color variation problem in order to segment signs won't produce the desired results regardless of equations' accuracy. Our efforts to encounter any possible difference in the signs colors' came out with building red-model in RGB cube depending on a large database of red signs in different situation of daylight and weather.

This article developed a red-model based on "The German traffic sign recognition benchmark". It has approximately 2,730 red color signs divided into 13 classes, each of which contains 7 photos with distinct weather conditions and luminance in 30 captures made at various distances [26]. We chose roughly 2,730 photographs from the database; each one is distinct from the others in terms of the sign's brightness, daytime, and weather effect. The colors are then saved in a paint file with only the red color extracted from the signs. "Reference colors" is the name of the file. Figure 4 illustrates an example of these stored images.

An algorithm that reads each pixel in the "reference colors image" used to create a red-model in a hypothetical RGB cube. This is accomplished by assigning a value of "1" to each red pixel in the hypothetical RGB cube, while assigning a value of "0" to the remaining pixels. Our red model represents 56,000 points out of the 16 million points in the RGB cube. Figure 5 shows the based red- model in the RGB cube. Furthermore, in 16M RGB points, the predicted size of the red color (almost 1M) is only 56,000 points. This issue may be overcomed by increasing the number of images in the data base from a large number to an unlimited number in order to account for all traffic sign image conditions.

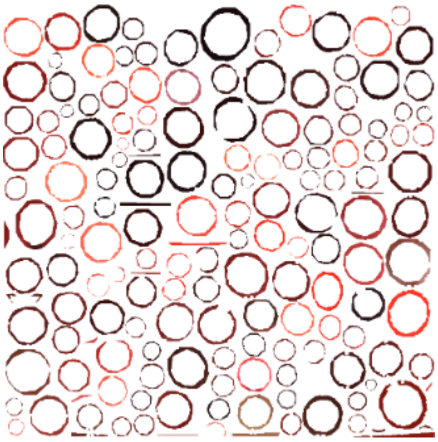


Figure 4. Reference colors image example

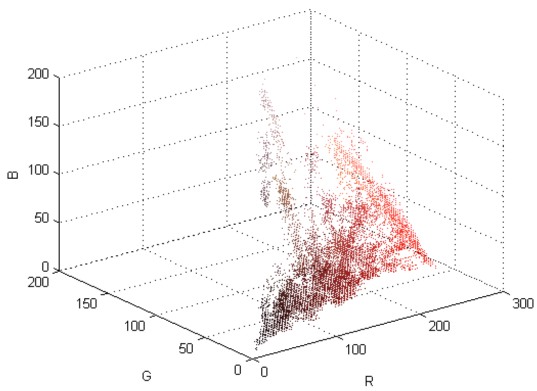


Figure 5. Color model based red-model in RGB cube

The proposed approach solves this problem in a simple and easy algorithm. There are two steps in this method. The first is to minimize the number of reference red points in the based red-model from 56,000 to about 11,000 by ignoring locations separated by 4 units. The second, start filling in the gaps between the reduced locations mentioned previously. This is accomplished by connecting each of the 11,000 points to every other point. Then, adding all of the points within the links to the basic red-model. The red model has reached the 1M. The created red-model is illustrated in Figure 6.

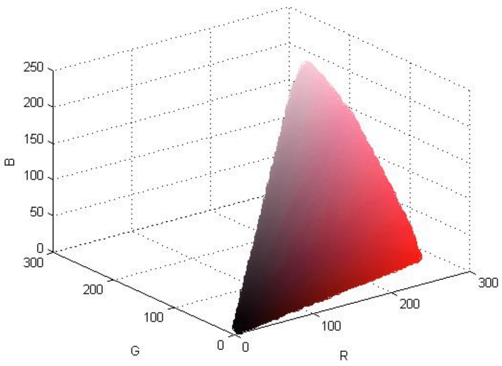


Figure 6. Red model in RGB cube

3. RESULTS AND DISCUSSION

Before we review the segmentation results of our model, let's compare it first with other models. For each pixel (W) in the image where W={W_R, W_G, W_B}, [1] enhance the red color according to: f_R (x)=max (0, min (W_R-W_G,W_R-W_B)/D) where D=W_R +W_G +W_B. The resulted model from this algorithm is shown in Figure 7.

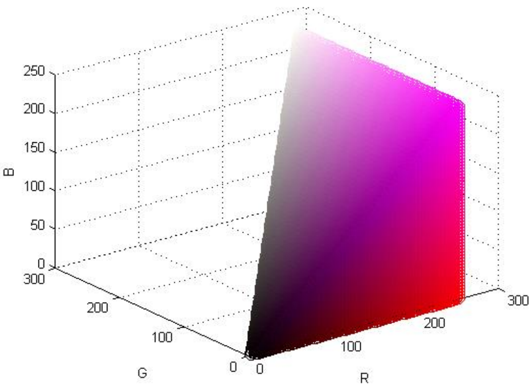


Figure 7. Red-model in RGB cube as [22] algorithm

The log chromaticity color space approach is used in [12]. It designates it as red, if a pixel's LCCS projection meets the following criteria as (1).

$$a_4 >= \log(B/G) >= a_3 \text{ and } a_2 >= \log(R/G) >= a_1 \quad (1)$$

Where (a_1, a_2, a_3, a_4) are threshold values and are equal to (0.50, 2.10, -0.90, 0.80) respectively. Figure 8 illustrates the red model created using this algorithm. According to color distance method in [26] the color distance between standard red (255, 0, 0) and a pixel can be written as (2).

$$CDred = \sqrt{(B-0)^2 + (G-0)^2 + (R-255)^2} \quad (2)$$

Figure 9 shows the red model created using this algorithm. Indeed, none of the three models could detect the entire red color model. Additionally, they incorporate other colors that are in the neighbourhood of the red-model. As a result, a missed or incorrect detection will be occurred.

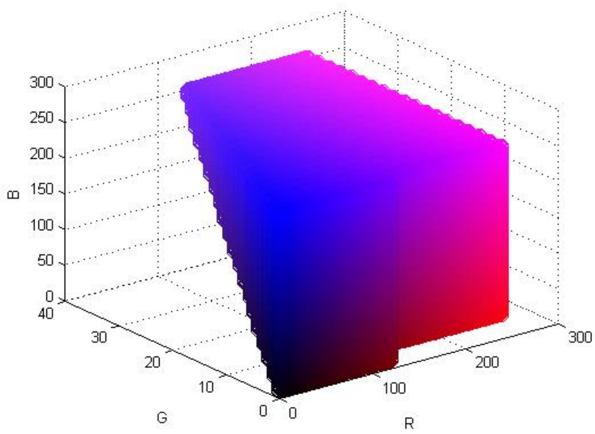


Figure 8. Red-model in RGB cube as [13] algorithm

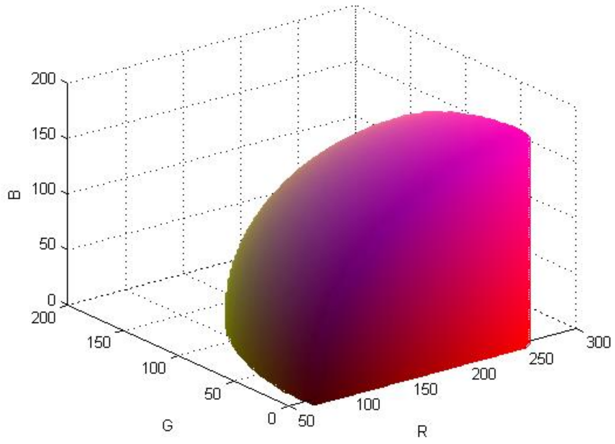


Figure 9. Red-model in RGB cube as [26] algorithm

Practically, we used these segmentation algorithms on a total of 2,130 images all of which contain red signs. Each one differs from the others in terms of the time of day, the weather, and the sign's brightness effect. The results of segmentation for each method are shown in Table 1.

The results were poor, as expected from the created models, especially for [13], [22], which had success rates of 5.96% and 16.62% respectively. In comparison, a 72.96% in [25] is outstanding. Our model has a success rate of 99.39 percent which is a remarkable result. Furthermore, our algorithm's computational cost stands out among the competition.

The results of segmentation in [13], [22] and even in [26] will not rule the overall detection result. Each of the three researchers implements a complete detection algorithm that achieves well detection outcomes. But, what disgraces these detection algorithms is the segmentation part that came out with bad results shown in Table 1. Our segmentation method results in a more convenient outcome, reducing the complexity and execution time of detection stage. Figure 10 shows an example of traffic red sign segmentation with multiple color variations using our red-model.

Table 1. Algorithms segmentation results

Method	Failed segmented image	Execution time msec/frame	Success rate
[22]	2003	11.9	5.96%
[13]	1776	14.5	16.62%
[25]	576	11.3	72.96%
Proposed method	13	10.3	99.39%

Figure 10. Segmentation results based on red-model we built

4. CONCLUSION

An effective road sign segmentation algorithm based on color information has been presented. What distinguishes the proposed method apart from others is that it ensures that the model encounters every color range that the sign could be in for various brightness and weather situations. Furthermore, no faulty segmentation is expected because the model does not include any colors other than the sign colors. A high level of accuracy is maintained by eliminating any color space transformations. The suggested segmentation approach has the merit of efficient real-time implementation because each pixel is mapped on an offline model, and the mapping procedure is simply a comparison operation, resulting in a low-complexity system realization. Because choosing a color model to develop an application is a challenging. The red-model is implemented in a hypothetical RGB cube to prevent confusion about the chosen color space and how it operates with various illumination.

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BIOGRAPHIES OF AUTHORS

Dr. Majid Dherar Younus received his BSc (1992) from MEC, MSc (2000) from University of Mosul, and PhD (2007) from University of Mosul. He is, currently with Computer and Information Engineering Department, College of Electronics Engineering, University of Ninevah. His interests are image processing, intelligent system and digital signal processing. He can be contacted at email: majid.younus@uoninevah.edu.iq.

Dr. Emad A. Al-Sabawi received his BSc (1992) from MEC, MSc (1996) from University of Mosul, and PhD (2004) from University of Technology-Baghdad. He is, currently with Computer and Information Engineering Department, College of Electronics Engineering, University of Ninevah. His interests are intelligent system, image processing, and real time systems. He can be contacted at email: emad.khalaf@uoninevah.edu.iq.