Real-time color segmentation of road signs

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Abstract

This subject is part of a more challenging research project aimed at developing a computer vision system, embedded in a car, and capable of identifying and locating road signs. Several constraints limit the possible solutions are first identified. For instance in such an application, we definitely need a real-time system; in addition, we wish to limit our choice to a single camera methodology to keep the hardware as simple as possible and finally our approach must work efficiently on low cost hardware. For this purpose we first rely on a color segmentation strategy to recognize the road signs. We have studied the behavior of the RGB components of several road signs from sunrise to sunset. From these results we have shown that the simple comparison of the RGB components taken two by two is sufficient to segment road signs in real-time. From this segmentation it should be much easier to identify the shape (and meaning) of a particular sign.

1. Introduction

Among the several manners that exit and could be used in order to improve safety and efficiency on the road, a computer vision system, embedded in a car, and capable of identifying and locating in real time road signs is certainly one of the most challenging one [1-5]. The importance of such project was confirmed by large research projects on intelligent vehicle such as the Intelligent Vehicle and Highway Systems (IVHS) and the PROgraM for an European Traffic with Highest Efficiency and Unprecedented Safety (PROMETHEUS). Such road sign computer vision system could be divided into three main modules: detection, identification and location. The detection module can rely on color or shape to extract the signs from the image. The identification step also uses color and shape but also the content (pictograms or characters) of the sign to perform its task. Finally, the running vehicle relative position with respect to the road sign can be estimated from the know dimensions of the recognized sign and the camera parameters with an appropriate pose assessment algorithm for polygonal object with monocular vision [6-7].

In this paper we focus on the first detection or segmentation step. We impose several constraints that limit the possible choice of solutions. For instance in such an application, we definitely need a real-time system; in addition, we wish to limit our choice to a single camera methodology to keep the hardware as simple as possible and finally our approach must work efficiently on low cost hardware. Many laboratories has developed numerous algorithms for road sign detection based on more or less sophisticated statistical or neuronal pattern recognition. But in all cases they do not fulfill one (or more) of these constraints.

2. Road sign segmentation

Detection of road signs from shape suffers from several drawbacks with respect to the required constraints stated above. First it necessitates a robust edge detection and/or matching algorithm to detect the relevant shapes. This is particularly difficult when the road sign appears relatively small in the image, a situation that is going to occur often in particular with low-end (low resolution) cameras. Moreover even if a shape of interest is identified, it can be confused with several other shapes of man-made objects such as commercial signs and building windows.

Color [8] represents an interesting alternative and is definitely an important attribute for road signs to facilitate and improve driving conditions. Moreover the colors used are regulated by each country and are often nearly simple primary colors (red, green or blue) with the exception of

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yellow, a secondary color. The main inconvenient of color segmentation is that the outdoor illumination affects the color seen by the camera. For this reason, in the next section we study the behavior of road sign colors from sunrise to sunset.

3. Road sign color variability under different outdoor illuminations

Since most colors used for road signs are nearly primary colors (red, green or blue) except for yellow, a secondary color (red + green), and because one of our constraints is real-time segmentation, it sounds normal to use the RGB color space to represent the data because this information is directly supplied by the camera without any transformation.

In figure 1, the RGB profile of a line (identified with the white arrows) drawn across a STOP sign shows the "nearly" primary nature of the sign color with the red component being much higher than the two other ones. Similar results are obtained with blue and green road signs. A yellow road sign will show as expected a much lower blue component with respect to the other two.

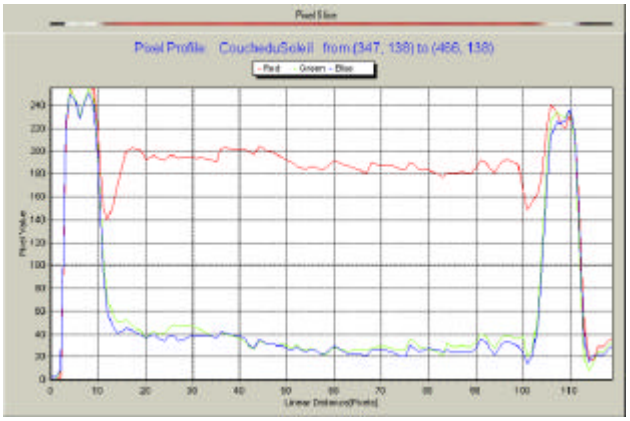

Figure 1. RGB profile through a red STOP sign

This result is important and confirms that the choice of the RGB color space seems a good one. However does this behavior remain stable under different illumination conditions?

In figure 2, one of the many experiments carried out with several road signs is illustrated. Here one red sign pixel is studied during the whole day. Notice that the x axis is numbered in half hour units. During daylight conditions (from sunrise to sunset, about x=13 to x=42, that is 6h30 to 21h00) one can easily see that the differences Δ_{RG} and Δ_{RB} between the red and respectively the green and blue components remain high and could easily be used with an appropriate (not too sensitive) threshold for segmentation.

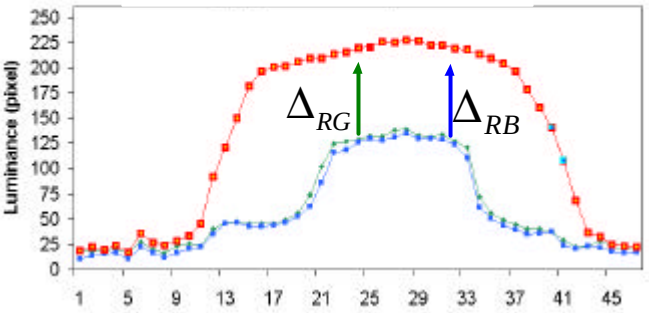

Figure 2. RGB value as a function of the time of the (sunny) day for a red STOP sign pixel. The x axis is numbered in half hour units.

Therefore, the main inconvenient of color segmentation, that is outdoor illumination variations does not affect significantly the RGB component differences for the typical road sign colors. Moreover, this means that working in this 3D space for segmentation is not necessary. In the next section we present an algorithm that take advantage of these observations for road sign segmentation.

4. Segmentation algorithm

The previous section study leads to a very simple algorithm for image segmentation that can run easily real-time on any low-end computer vision system. Using three thresholds Δ_{RG}, Δ_{RB} and Δ_{GB} that need not be selected very precisely we can propose the algorithm described in figure 3 to perform the segmentation of road signs that are painted with approximately primary colors red, green or blue. Segmentation of other signs painted with yellow or any other secondary colors can also be easily added to this algorithm by following the same principles.

FOR all pixels *i* in image
{
  IF $Ri > Gi \ \& \ Ri - Gi \geq \Delta_{RG} \ ; \ Ri - Bi \geq \Delta_{RB}$
    THEN pixel *i* is RED
  ELSE IF $Gi > Ri \ \& \ Gi - Ri \geq \Delta_{GR} ; Gi - Bi \geq \Delta_{GB}$
    THEN pixel *i* is GREEN
  ELSE IF $Bi > Gi \ \& \ Bi - Gi \geq \Delta_{BG} \ ; \ Bi - Ri \geq \Delta_{BR}$
    THEN pixel *i* is BLUE
  ELSE pixel *i* is WHITE (or BLACK)
  ENDIF
}
ENDFOR

Figure 3 : Real time road sigh color segmentation algorithm for red, blue and green signs.

Figure 4 illustrates a real scene application of the algorithm. As expected the red sign is easily extracted from the scene.

Figure 4 : Road scene segmentation

Figure 5 shows the use of the same algorithm real-time to segment a “Forbidden Access - Private Property” red sign which is moved by hand in front of the camera.

These results demonstrate that the simple comparison of the RGB components taken two by two is sufficient to segment road signs in real-time.

6. Conclusion

Although it is well known that spectral composition of day light varies as a function of the time of the day, seasons, weather (sunny or cloudy conditions) etc. we have shown in this research that simple differences between RGB components of the road sign colors can be used reliably for segmentation purposes. This is mainly due to the characteristics of the colors used for painting road signs. Indeed, in most cases these colors are nearly primary or

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secondary colors and remain easy to segment with a simple threshold allowing real-time detection.

Remember that this segmentation constitutes only the first step toward the development of a vehicle with a single camera system capable of identifying and locating road signs. However, from the proposed segmentation step it will be much easier to restrict the search and to identify the shape (and meaning) of a particular sign. Moreover, in some cases where man-made objects of the same or similar color interfere, shape analysis and/or the recognition module will help resolve the problem.

Figure 5 : Real-time road sign color segmentation

7. References

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