VISION-BASED TRAFFIC SIGN DETECTION FOR ASSISTED DRIVING OF ROAD VEHICLES

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Abstract: A system for real-time traffic sign detection is described in this paper. The vision-based traffic sign detection module developed in this work is intended for assisted driving of road vehicles by handling color images in RGB (Red, Green and Blue) format. In a first step a preattentive area of interest is determined based on the vertical projection of edge pixels. In a second step, a shape analysis is performed. In a third step, a color analysis is performed, and finally, a template is fitted. Some results obtained on a series of real road images are presented in order to illustrate the robustness of the detection system.

1 INTRODUCTION

Traffic sign detection and recognition have experimented increasing importance in the last times. This is due to the wide range of applications where this kind of systems can be used, specially as driver active aid systems.

There are four types of traffic signs in the traffic code: prohibition, warning, obligation and informative. Depending on the shape and color, the warning signs are equilateral triangles with one vertex at the top. Prohibition signs are circular, having a specific figure in each case over a white or blue background, and a red border. To indicate obligation, signs are circular with a white figure over a blue background. The most important traffic signs are prohibition signs; therefore they have priority to be detected in this work.

One of the greatest inconveniences of using the RGB color space is that it is very sensitive to changes in light (A. de la Escalera,2003). This is the reason why other color spaces are used in computer vision applications, specially the hue, saturation, intensity (HSI) one. This system keeps high immunity to changes in light (R. C. Gonzalez,1993). The problem with HSI is that transformation equations (between RGB and HSI) are nonlinear, making the computational cost prohibitive. Instead, we propose to use the relation between the RGB components for traffic sign detection, as this work is intended for real-time systems and no further processing is needed after digitalization.

To detect a traffic sign in an image, the algorithm follows these steps:

- Candidate image regions are obtained by accumulative vertical and horizontal edge projections.
- Centre and radius of circular prohibition and obligation signs are obtained by a centre determination technique using three points of the contour.
- Candidate image regions are validated based on:
  a. Red image thresholding, for prohibition sign.
  b. Blue image thresholding, for obligation sign.
- Blob shape analysis from red or blue image thresholding.
- Circular ring templates- based correlation method is used to identify potential traffic signs in images (D. M. Gavrila,1999).

2 CANDIDATE IMAGE REGIONS

Candidate regions of interest are computed for preattentive purposes based on vertical and horizontal projections of edge pixels.

2.1 Edge image

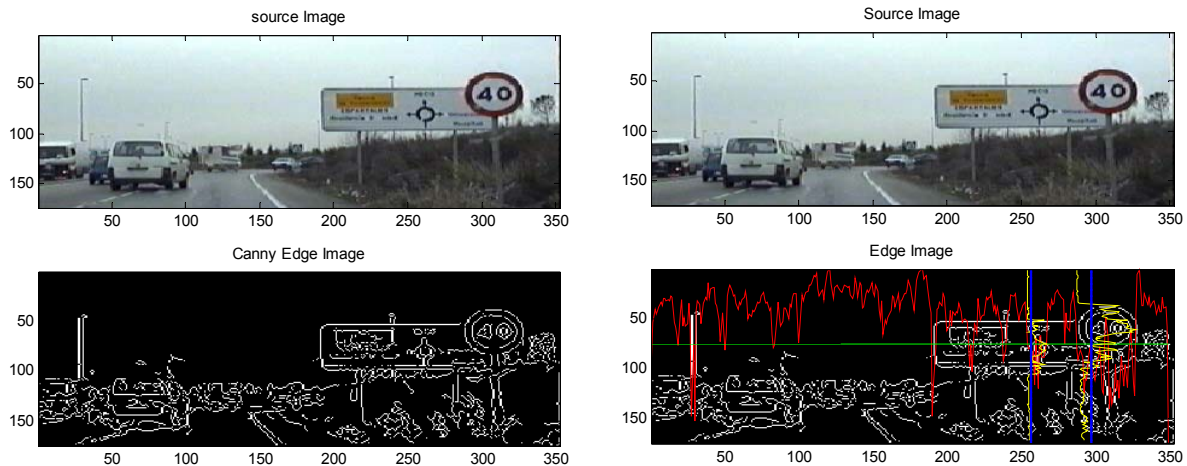The appropriate choice of the color features to use in the process is of crucial importance in order to

Figure 1: Canny edge image. Accumulated vertical and horizontal projection and their corresponding threshold-levels

achieve proper and fast detection. Accordingly, only the Red component is considered as it provides a high capacity for color discrimination in visual analysis of traffic signs and no further processing is needed after digitalization. In an attempt to carry out a preattentive strategy, a coarse analysis of vertical edges is performed in a first stage based on differential characteristics computed on the Red component of the image using the method of edge detection described by john Canny (Canny, 1986). This method has been extremely influential in many applications. Numerous implementations of edge detectors based on Canny's idea have been developed. Canny described a method of generating edge detector using an optimization approach and showed how to use the technique to generate edges-robust detector. Canny's method preserves contours that are very important for detecting traffic sign using shape information. Figure 1 shows the result of applying the Canny edge detector road image.

2.2 Vertical projection of edge pixels

One of the most common techniques for traffic sign segmentation is to use grey-level images, the red component in our case, and to project accumulative edge pixels onto the axes.

Vertical projections of different types of signs are shown in Figure 1. As it can be observed, a maximum in the projected signal occurs in the area of the image where the sign is placed.

As a first step, an adaptive thresholding is performed aiming at removing the common offset component in the projection profile. For this purpose, a threshold u is computed as expressed in (1).

$$u_v = \mu_v + \mu_v^+ \qquad (1)$$

Where μ_v stands for the average value of the projection profile, while μ_v^+ represents the average of all points in the projection whose value is greater than μ. Finally, the coarse detection stage ends by removing narrow peaks from the projection profile. This yields a set of candidate image regions that highly reduces and constraints the portions of the image where traffic signs are likely to appear.

2.3 Horizontal projection of edge pixels

In order to restrict the area of interest a bit more, a similar method is applied to horizontal projections of edge pixels in the region of interest. In this case the adaptive threshold is obtained as expressed in equation (2)

$$u_h = \mu_h \qquad (2)$$

Where μ_h denotes the standard average value of the horizontal projection. After applying this segmentation process, regions of interest remain more restricted. Nevertheless, not all the regions include a traffic sign inside. Resultant regions of interest are shown in Figure 2.
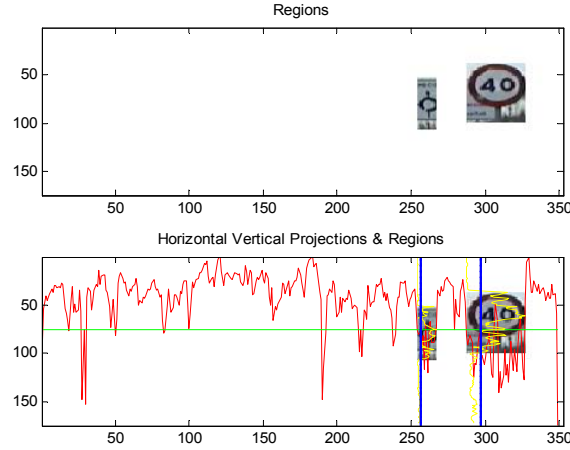
Figure 2: Vertical and horizontal projection to obtaining regions of interest

3 SHAPE ANALYSIS

The shape of traffic sign represents essential information for road-sign detection and further classification. The main signs, prohibition and obligation are circular and their contours are defined by (3):

$$r^2 = (x + x_c)^2 + (y + y_c)^2 \qquad (3)$$

Where 'r' denotes the radius of circumference and (x_c, y_c) indicates the centre of circumference. The centre can be determinate using a graphic method of three points of the circular contour, as it is shown in Figure 3, following these steps:

1. The three points are grouped in pairs; (x_1, y_1), (x_2, y_2) and (x_3, y_3).
2. Centre points of the segments determined by every pairs of point are obtained by (4).

$$\left.\begin{array}{ll} x_{m12} = (x_1 + x_2)/2 & y_{m12} = (y_1 + y_2)/2 \\ x_{m23} = (x_2 + x_3)/2 & y_{m12} = (y_2 + y_3)/2 \end{array}\right\} \ (4)$$

3. Orthogonal lines, r_{12} and r_{23}, to segments obtained in previous step, are traced through respective central points already obtained as well by (5).

$$\left.\begin{array}{ll} r_{12} & y = (x - x_{m12})\dfrac{x_2 - x_1}{y_1 - y_2} + y_{m12} \\ \\ r_{23} & y = (x - x_{m23})\dfrac{x_3 - x_2}{y_2 - y_3} + y_{m23} \end{array}\right\} \quad (5)$$

4. Centre of circumference (x_c, y_c) from intersection between orthogonal lines r_{12} and r_{23} is obtained by solving equation (5).

These steps are repeated using three different points of the contour every time and along the contour that might include a large enough number of pixels.
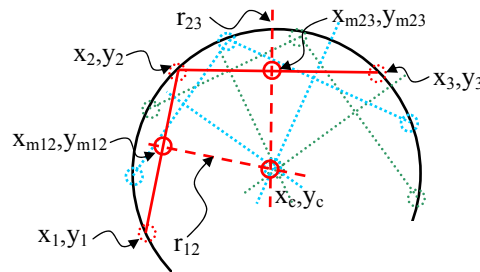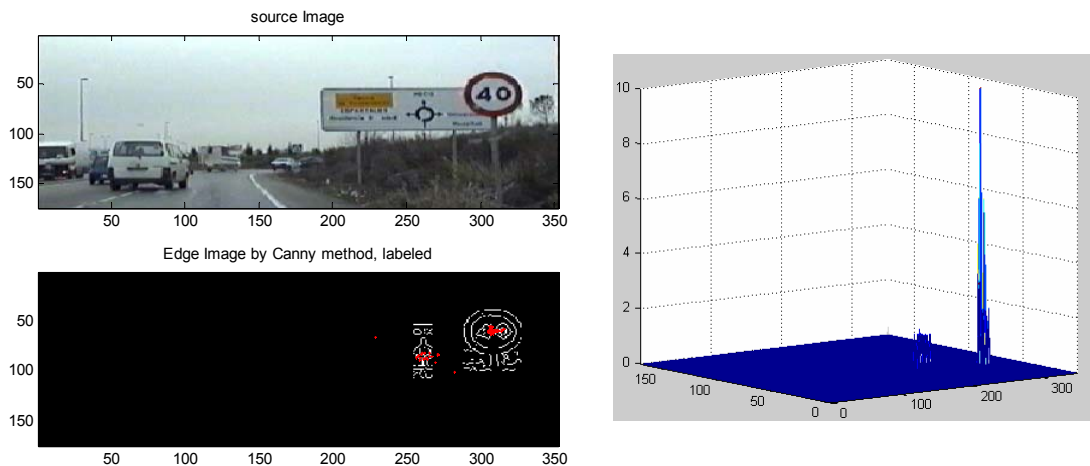

Figure 3: method of calculus of centre

Figure 4: two-dimensional distribution of points, and maximums in the distribution.

With this method a two-dimensional distribution of possible points of centre is obtained, as it is shown in Figure 4. A maximum in the distribution occurs in the area of the image where the sign is placed, see Figure 4 right.

4 COLOR ANALYSIS

Color is a very important parameter to be taken into account for road-sign detection and further classification. Some authors choose color-spaces that exhibit high immunity to changes in light, HSI (Hue, saturation Intensity) (T. Hibi, 1996) (G. Piccioli, 1996), so that color regions can be segmented by means of a look-up table (LUT).(A. de la Escalera, 1997). Computation time needed to obtain red-component image in HSI space is ten times bigger than in RGB space.

In this work, the RGB color space has been chosen, so that relations between components are used to highlight red-colored and blue-colored regions in the image and reduce the light-dependency of the RGB space in the perception of the color, as is described by (6).

$$r = \min \left(\begin{cases} f_r - f_g & if \quad f_r - f_g > 0 \\ 0 & if \quad f_r - f_g \leq 0 \\ f_r - f_b & if \quad f_r - f_b > 0 \\ 0 & if \quad f_r - f_b \leq 0 \end{cases} \right) \quad (6)$$
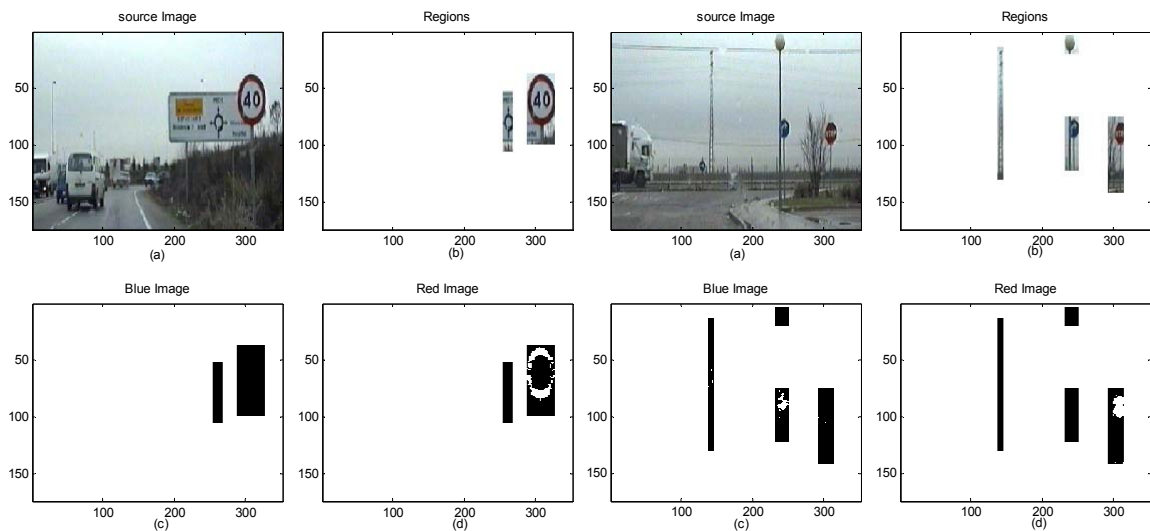

Figure 5: source images, regions of interest, blobs in the red image and blobs in the blue image

Where f_r, f_g, and f_b are, respectively, the functions that give the red, green, and blue levels of each point of the image, and r is the highlight red-colored region. Similar method to obtain the highlight blue-colored regions is used.

The most important reason why RGB is used is that it allows to speed up the detection process while preserving the detection robustness at the same time.

4.1 Blob-based analysis

The red and blue components of the regions of interest already obtained are calculated and thresholded, yielding the blobs that can be seen in Figure 5. These blobs, corresponding to road signs, must fulfill the size and aspect constraints described by (8) and (9):

$$A_i \geq A_{min} \qquad (8)$$

$$r_{min} \geq \frac{|h_i - l_i|}{\max(h_i, l_i)} \geq r_{max} \qquad (9)$$

Where A_i is the minimum area that a blob must have and h_i and l_i are the blob's width and height respectively. Resultant blobs are useful to place a road sign-searching template on the image.

5 TEMPLATE MATCHING

A ring-shaped template T is placed in the edge image I, in the centre of the blob obtained, for prohibition and obligation signs, which are circular. The matching-measurements matrix $D(T; I)$ (D. M. Gavrila,1999) is determined by the pixel values of I which lie under the high level pixels of the T. These pixel values form a distribution of distances from the template points to the nearest contour in the image. The lower these distances are, the better the match between image and template at this location.

The sequence to fit the template is as follows:

- The template is moved over the edge-image I, along the eight directions indicated in Figure 6 (Ritter and Wilson, 2001), while the sum of all the points remaining inside the ring at the shifted position is bigger than the sum of all the points inside the ring in the previous position.
- Radius R and r of the ring are set following the same criteria as in the ring-centre adjustment.
- The first two steps are repeated at each shift step.
- For a candidate object (region) to be considered as a road sign the sum of the points in the ring must be greater than a certain threshold value (10).

$$\sum t(x,y) \geq U_{threshold} \qquad (10)$$

Figure 7 shows the results obtained by using the described method. The image on the right, two signs have been detected, an obligatory-direction blue one and a Stop-one which is not circular but can be fitted using the circular based assumption, the detecting method provides color information, blue for obligation signs and red for prohibition and stop ones. A smaller obligatory-direction road sign has not been detected, because it is still too far from the ego-vehicle. In the image on the left, a speed-limit sign has been detected, and an informative sign as well, but the template has only been fitted to the first one because the informative sign has been rejected.
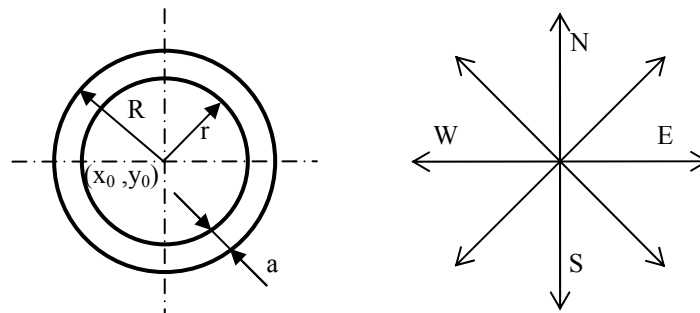
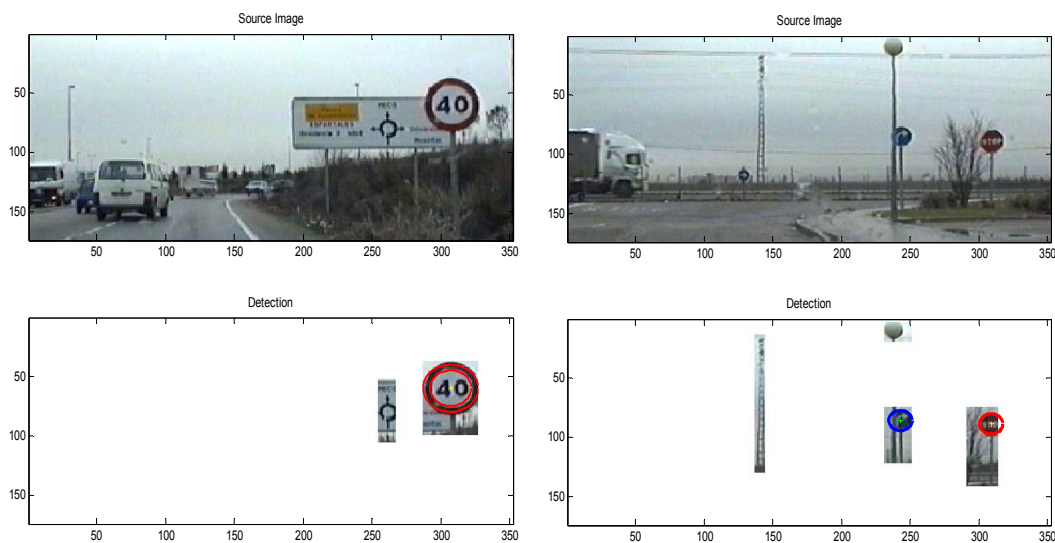Figure 6: Circular ring template, and searching directions.

Figure 7: examples of traffic sign detection.

6 CONCLUSIONS AND FUTURE WORK

An algorithm for real-time detection of traffic signs is carried out based on vertical projections of edge pixels, shape analysis and template-based detection. The algorithm has been empirically tested on real road images, and aims at assisting human drivers in automatic recognition of traffic signs in order to ensure traffic rules fulfilment. Our future work involves robust detection of road signs under adverse weather conditions, as well as the use of a neural network for fine grane classification and validation of the detected road signs.

ACKNOWLEDGEMENTS

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