CIRCULAR ROAD SIGN EXTRACTION FROM STREET LEVEL IMAGES USING COLOUR, SHAPE AND TEXTURE DATABASE MAPS

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ABSTRACT

Detection and recognition of road signs can constitute useful tools in driving assistance and autonomous navigation systems. We aim at generating a road sign database that can be used for both georeferencing in autonomous vehicle navigation systems and also in high scale 3D city modelling. This paper proposes a robust algorithm that can detect road signs shape and recognizes their types.

1 INTRODUCTION

Road signs are very important features for providing rules of navigation. Indeed, they are key landmarks when navigating on the roads. Their visual properties are very strong because they have been designed to be remarkable and unmissible objects. Road signs are thus key objects to enrich road model databases to generate roadbooks, shortest paths, etc. The automatic detection and recognition of road signs from images (together with objects such as road marks) is thus a key topic and issue for road model updating but also for tomorrow's applications of these databases, i.e. driving assistance, and accurate localisation functions for autonomous navigation. Most of the previous work in image based road sign extraction deal with three following issues:

- **Color detection :** road signs are often red or blue with some black and white. Many authors used this property to detect them. Often, color base rules are defined in a color space and used for segmentation. (de la Escalera, 1997) use RGB color space and work with relations between the red , green and blue. Other authors works with color spaces that are less sensitive to lighting changes. Although the HSI (Hue, Saturation, Intensity) space is the most common (Piccioli et al., 1996). More complicated color space such as LCH (Lightness, Chroma, Hue) (Shaposhnikov et al., 2002) and CIELAB (Reina et al., 2006) are also used.
- **Shape detection:** road signs forms are often rectangular, triangular or circular. In order to strengthen the detection, some authors propose to detect these geometric forms within ROIs[1] provided by color detection. (Ishizuka and Hirai, 2004) present an algorithm for circular road sign detection. (Habib and Jha, 2007) propose an algorithm for road sign forms detection by line fitting. An interesting measure of ellipticity, rectangularity, and triangularity is proposed by (Rosin, 2003).
- **Type recognition:** It consists in recognising road sign type using its pictorial information. It is often performed by comparing the inside texture of a detected road sign with the textures in a database. For this purpose different kind of algorithms are used in the state of the art. (Priese et al., 1995) propose an algorithm that is based on neural networks. SIFT descriptors are used by (Aly and Alaa, 2004). (de la Escalera et al., 2004) used intensity correlation score as a measure of similarity to compare the detected road sign with a set of standard signs.

2 OUR STRATEGY

We propose an algorithm consisting in three main steps. Diagram of Figure 1 shows the pipeline of our algorithm. First step uses color properties of signs and perform a predetection (Section 3). It provides a set of ROIs in image space. Then, an ellipse detection algorithm is applied to detect circular shape signs within the ROIs (Section 4). The detected shapes are considered as road sign hypotheses. Final step consists in validation or rejection of hypotheses. This is performed by matching detected hypotheses with a set of standard circular signs of the same color (Section 5). Results and evaluations are presented in Section 6.

3 COLOR DETECTION

A large number of road signs are blue or red. It can simplify their detection by looking for red and blue pixels. However their RGB values depend on illumination conditions. We use HSV (Hue, Saturation, Value, see Equation 1) color space because it is robust against variable conditions of luminosity. In order to choose the adapted threshold of saturation and hue, we learn these parameters from a set of road sign sample in different illumination conditions. Figure 2(a) shows our running example image and result of blue color detection is shown in Figure 2(b). In order to provide ROIs, connected pixels are labeled (see Figure 2(c)). Each label defines a window in image space. The following form detection and validation steps are performed within these windows.

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[1]Region of Interest

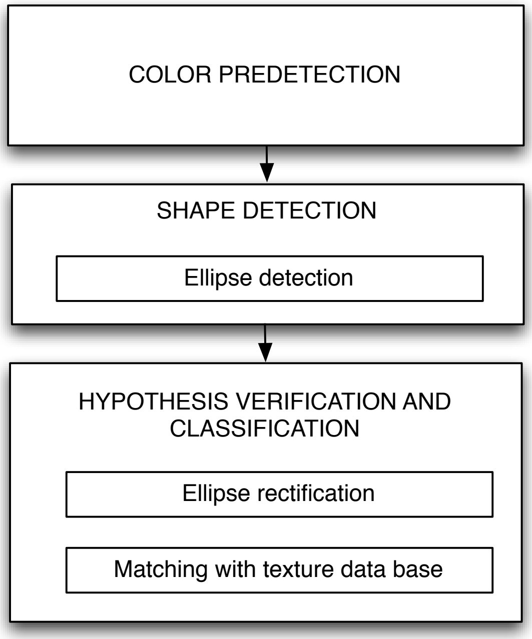
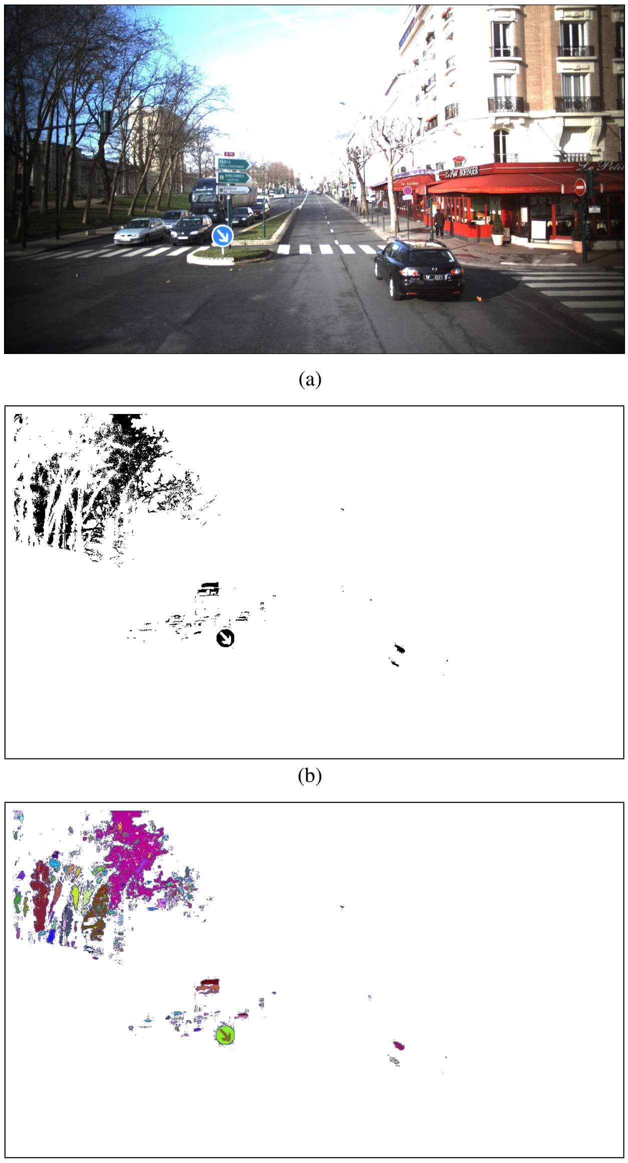


Figure 1: Our 3 steps strategy.

$$
\begin{aligned}
&H = \begin{cases} (0 + \frac{G-B}{MAX-MIN}) \times 60 & \text{if } R = MAX, \\ (2 + \frac{B-R}{MAX-MIN}) \times 60 & \text{if } G = MAX, \\ (4 + \frac{R-G}{MAX-MIN}) \times 60 & \text{if } B = MAX, \end{cases} \\
&S = \frac{MAX - MIN}{MAX}, \\
&V = MAX, \\
&\textbf{where:} \\
&MAX = max(R, G, B) \\
&MIN = min(R, G, B)
\end{aligned} \tag{1}
$$



(a) (b) (c)

Figure 2: Color detection results. a) our running example RGB image, b) blue color mask, c) labeling independent connected pixels.

4 CIRCULAR SIGN DETECTION

The shape detection have to detect all the types of road signs (the rectangular, triangular and circular road signs). In this first version of work we choose to focus on the circular road signs because they are the most common. Theorically, a circle appears as an ellipse in perspective images. The quantity of perspective deformation depends on the angle between image and the circle plane. Often, road signs belong to a traffic lane and supposed to provide information to drivers in the same lane. In this case perspective deformation is negligible. This is the reason why most of the Driver Assistance Systems (ADAS) ignore perspective deformation.

We aim at extracting all visible road signs within an image what ever their orientation is. This is interesting in both database generation and the use of road signs as visual landmarks for positioning purposes. Thus, an ellipse detection algorithm is investigated (Section 4.1).

4.1 Ellipse Detection

Input of this step is a set of image windows provided by the color detection step. We use edge points for ellipse detection. In each image window, edges are extracted using Canny-Deriche edge detector (Deriche, 1987).

An ellipse is defined with five parameters (2 for the center, 2 for the axes length and one for orientation). Equation 2 express equation of ellipse. In this Equation p and q stand for ellipse center. Orientation and axes length depend on a, b and c.

$$a(x-p)^2 + 2b(x-p)(y-q) + c(y-q)^2 = 1 \tag{2}$$

This equation is not linear. We make use the Pascal's theorem to find the center (p, q) of the ellipse using only 3 points by estimation of tangents at each point. It allows a linear estimation of ellipse using only 3 points.

4.1.1 Ellipse from three points

Given 3 points P_1, P_2, P_3 on an ellipse (see Figure 3) the center is computed as follows:

- Tangents at these 3 points (t_1, t_2, t_3) are found.
- Intersections of t_1 with t_2 (I_1) and t_2 with t_3 (I_2) are computed.
- Midpoints of the segments $[P_1P_2]$ and $[P_2P_3]$ (M_1 and M_2) are found.
- The intersection of the segments $[I_1M_1]$ and $[I_2M_2]$ gives the ellipse center (C).

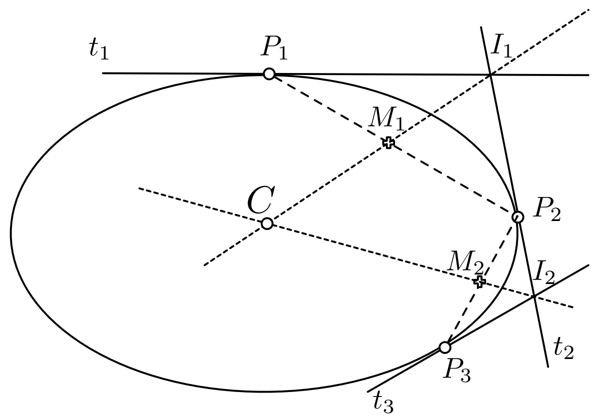


Figure 3: Use of Pascal's theorem for estimating ellipse center with 3 points.

When the center coordinates (p, q) are obtained the coordinate system is shifted such as (p, q) become origin. Then, the Equation 3 can be applied to estimate the ellipse equation using 3 points.

$$ax^2 + 2bxy + cy^2 = 1 \tag{3}$$

4.1.2 Ellipse estimation with RANSAC

In the previous section the ellipse estimation method was explained when we have three points on the ellipse. The problem is to obtain three points belonging to the ellipse within the noise (see Figure 4(a)). We used a RANSAC algorithm (Fischler and Bolles, 1981). It is composed of six steps:

1. Pick randomly three points within the edges points.
2. Estimate the ellipse parameters (see Section 4.1.1).
3. Search how many edge points fit on the ellipse model (number of support points).
4. If the number of support point is sufficiently great, we accept the model and exit the loop with success. We assume that the number of support point is sufficient when it is higher than a percentage of the estimated theoretical ellipse circumference.
5. Repeat the steps 1 to 4, n times.
6. If we arrive to this step, we declare a failure and there is no ellipse found.

Suppose that the density ratio of inlier is 50% and the probability that the algorithm exit without finding a good fit is chosen 5%, then, the number of needed iterations (n) is 25.

In ellipse estimation, in order to compute the needed tangent on each edge point, a line is fitted to its neighbours on the linked edges. A neighborhood of 2 pixels is chosen. Due to discretisation, it does not provide a good tangent estimation when using pixel accuracy. This problem is shown in Figures 4(b) and 4(c). It causes more frequent failure and less accurate result. In order to cope with this problem, the edge points are delocalised to provide a subpixel accuracy using the method developed in (Devernay, 1995).

Figure 5 shows an example of result obtained by this algorithm.

5 HYPOTHESIS VERIFICATION AND TEXTURE PATTERN RECOGNITION

5.1 Ellipse Rectification

Validation and recognition of road sign is performed by comparing the detected circular road sign with a set of reference ones (See Figure 7) . The inside texture of sign is used to measure the its similarity with all reference signs. Correlation coefficient seems to be particularly interesting for this purpose. However the detected signs are deformed to ellipse while the reference ones are circular. It make the correlation process difficult. In order to resolve the problem, we propose to rectify the texture of the detected sign to match the geometry of reference ones. The needed transformation must transform an ellipse to a circle of a given radius. This is performed using an 8 parameters projective transformation. We suppose that the images are approximately horizontal or the orientation of the images are known so the transformation is unique. Figure 6 shows some examples of resampled road signs.

5.2 Matching with texture DB

After rectification, in order to match only the pixel inside the road sign, we generate a circular mask and we apply the ZMNCC (Zero Mean Normalized Cross Correlation) function to compute the similarity of detected and reference object (See Equation 4).

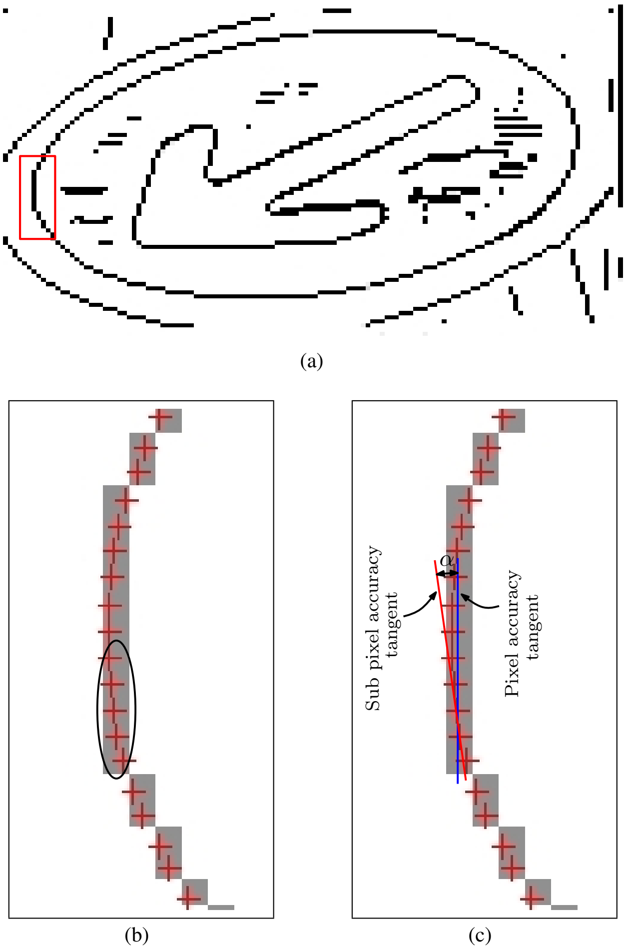


Figure 4: Edge extraction: red crosses represent subpixel accuracy edge position. : a) extracted edges, b) a zoom on edges of (a), 5 points are chosen for tangent estimation, c) Difference between pixel accuracy tangent and sub pixel one.

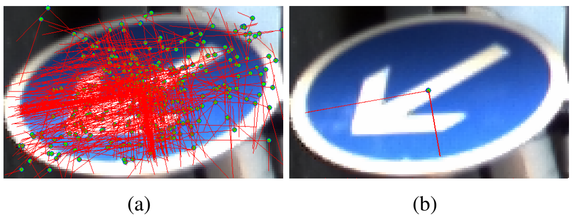


Figure 5: (a) Example of all the centers and axes explored by RANSAC algorithm (b) the estimated solution.

Figure 8 shows some result of correlation. We match detected red signs only with the red reference signs and blue ones with blue references. However in Figure 8, correlation coefficient with all signs are shown to demonstrate the discrimination power of correlation function. In most of the cases, the maximum of correlation coefficient corresponds to the good sign. We accept the maximum of correlation if it is higher than 60%. Hypotheses with lower correlation coefficients are rejected. This threshold is chosen relatively low. The reason is that the texture of signs in images suffer from both radiometric calibration problem and illumination changes within one sign. Better radiometric calibration can partially reduce this effect. So higher correlation coefficient thresholds can be set in the algorithm and improve the reliability of recognition.

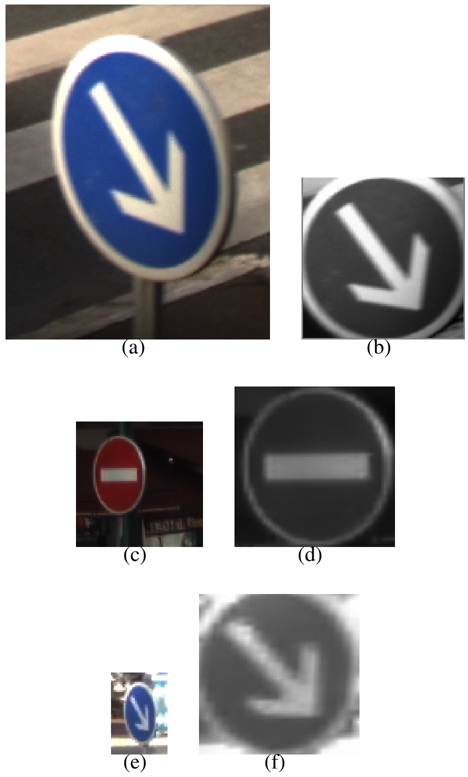


Figure 6: (a), (c) and (e) are the original image windows and (b), (d) and (f) are respectively their resampled images.

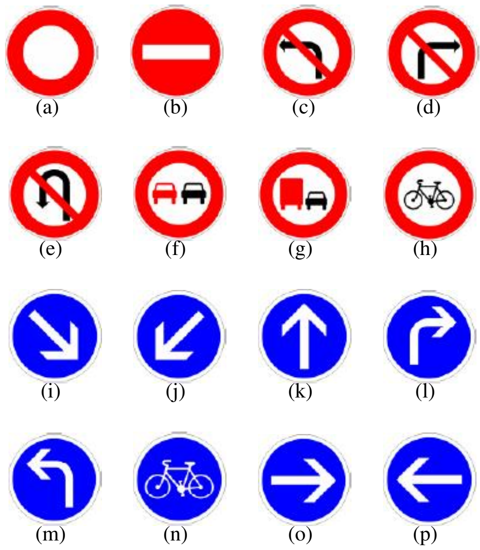


Figure 7: Circular road signs reference database.

$$Score_{corr}(A,B) = \frac{\sum_{x=1}^{n}\sum_{y=1}^{m}[A(x,y)-\overline{A}][B(x,y)-\overline{B}]}{\sqrt{\sum_{x=1}^{n}\sum_{y=1}^{m}[A(x,y)-\overline{A}]^2 \sum_{x=1}^{n}\sum_{y=1}^{m}[B(x,y)-\overline{B}]^2}} \quad (4)$$

6 RESULTS AND PERFORMANCE EVALUATION

The proposed algorithm is evaluated on a set of 1370 images acquired in dense urban area with real traffic conditions. Figures 9-13 show some obtained results. In each image the number of correct detection, false detection, and true road signs are counted manually. We assume that if a road sign is smaller than 10 pixels, we can not detect it.

We observed that there is 67% of good detection and 33% of road signs are not detected. This is due to our camera radiometric calibration problems that causes color detection failure. As color detection is at the beginning of our pipeline the shape detection and recognition processes are not performed on the lost road signs.

The shape detection and recognition steps works well. We mean that, in most of the cases they reject correctly the false hypotheses and in the case of validation the type of road signs are correctly distinguished. However, there is 5% of false detection. They are in most of the cases due to the red lights behind the cars or the tricolor lights that are very similar to wrong-way (see Figure 7(b)) traffic sign (see Figure 9) .

7 CONCLUSION AND TRENDS

In this paper we proposed a pipeline for road sign detection in RGB image. Thanks to ellipse detection and rectification processes, the algorithm is not sensitive to road sign orientation. The matching step provides a reliable recognition of road sign type.

Evaluations revealed that, the detection rate is about 70%. This is always due to failure in color detection step. Better radiometric calibration of the camera and test of other color spaces are the work in progress for improving color detection. In contrast to color detection step our shape detection and recognitions steps provide satisfactory and reliable results.

The proposed algorithm can be easily extended to handle the rectangular and triangular road signs. For this purpose, it is enough to adapt the shape detection step and both other steps remain unchanged.

In Figure 13 we can see a particular case which represent two small road signs on a bigger road sign. These cases can be handled using a stereo system allowing 3D position and size estimation.

In real time applications such as driver assistance systems, it is often interesting to track objects in video sequences. Actually, our algorithm does not work in real time and can not be applied on video sequences. The edge detection is the most time consuming step. In order to reduce the processing time, other edge detectors such as Sobel or Prewitt filters can be applied and evaluated. The search area can also be limited to remove the sky and so speed up the global processing time.

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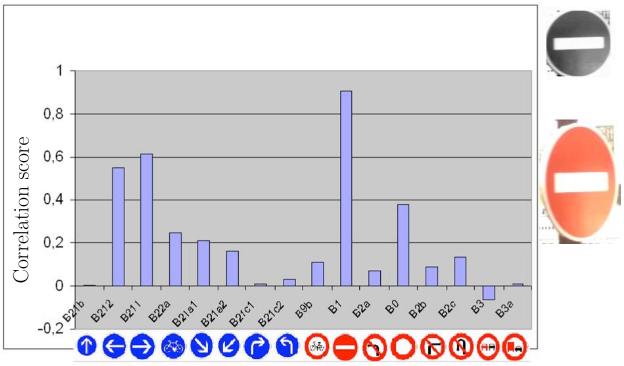
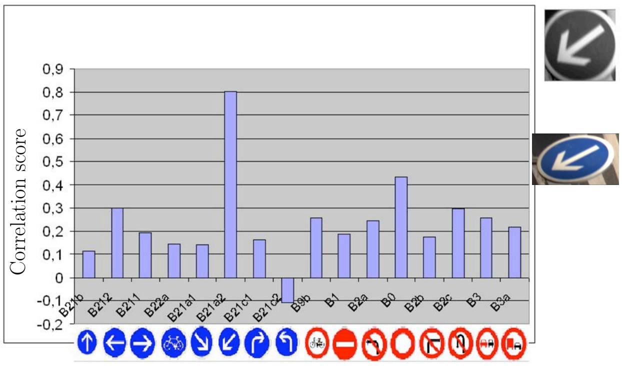
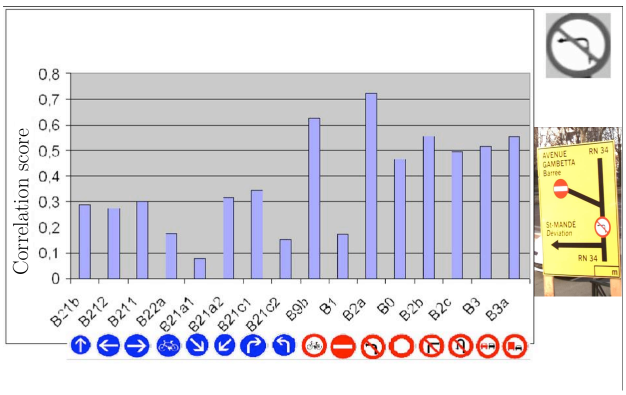


(a)



(b)



(c)

Figure 8: Correlation score of the hypotheses with road sign DB.

Figure 9: A false detection example. Red light of tri color light is detected as wrong way traffic sign.

Figure 10: Detection of road signs.

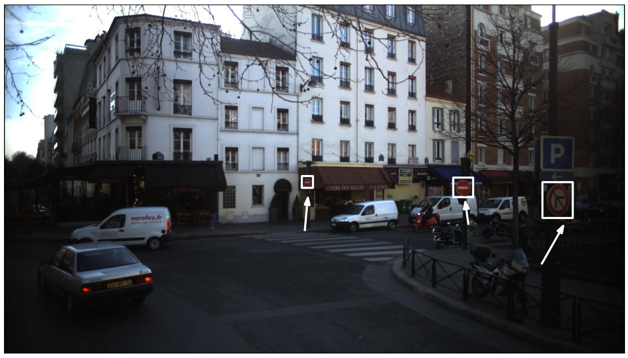


Figure 11: Detection of red road signs.

Figure 12: Detection of blue road signs.

Figure 13: Detection of particulars road signs.