Volume 2, 2022 ISSN: 2769-2477

Image-based Visibility Estimation of Road Signs in Cluttered Environment

Jafar J. Abukhait
Communications, Electronics and Computer Engineering Department
Tafila Technical University
Tafila, 66110, Jordan
jafar@ttu.edu.jo

Abstract: - This paper proposes an imaging-based system to estimate road sign visibility in a cluttered environment from the driver's perspective in daytime using in-vehicle camera images. The proposed system can be deployed in both Driver Assistance Systems (DAS) and Driver Safety Support Systems (DSSS) as a choosing criterion of what information to provide to drivers. Driver Assistance Systems can only provide drivers with warnings about road signs with less visibility and high importance. The proposed system estimates the visibility by measuring the detect-ability of road signs. The detect-ability parameter measures the ability of the driver to locate road object from a scene and thus; it measures sign postage with respect to cluttered or complex environment. Road signs posted in complex environment are harder to be recognized by drivers and thus have low value for the detect-ability parameter. This paper proposes a visibility estimation system of road signs in the United States and experimental results are used to show its effectiveness.

Key-Words: - Road Sign Detection, Color Segmentation, Edge Detector, Driver Assistance System, Driver Safety Support Systems, Detect-ability, Visibility Estimation.

I. INTRODUCTION

Recently, the usage of Driver Assistance Systems (DAS) and Driver Safety Support Systems (DSSS) has been increased due to the expansion of complicated road networks. These systems are used and deployed in vehicles to ease the driving task and to improve driver safety. Road signs are one significant source of information for drivers and for both DASs and DSSSs, but their visibility decreases in many situations and under different circumstances. Circumstances that affect road signs visibility are either temporal because of bad weather conditions or permanent because of vandalism and bad postage of signs. Fig.1 shows some road signs with low visibility.

Low visibility of road signs decreases the chances of information transfer between drivers and road signs and thus; DASs could be used to inform drivers of warnings in such situations. In fact, good DAS and DSSS should not provide drivers with a lot of information over roadways since a lot of information could lead to driver distraction problem [1].

Fig.1. Examples of low visible road signs in cluttered environments.

Computer vision techniques can be deployed in both DASs and DSSSs to estimate the visibility of road signs and accordingly inform drivers with the most important warnings of low visible signs. Using these techniques will increase the driver safety.

II. BACKGROUND AND SIGNIFICANCE

Road sign visibility estimation systems benefit from Road Sign Detection (RSD) techniques. The goal of RSD is locating the road sign object in a scene or from an in-vehicle image. Road sign detection techniques are categorized mainly into color based and shape based. Color thresholding in RGB space has been used to segment road sign images in [2, 3] while Hue Saturation Intensity (HSI) space has been suggested to segment road signs in [4].

Shape based methods were also suggested by different researchers. In [2], four vectors of distances from border to bounding box were trained with SVM to recognize road sign shape. In [5], distance to border (DtB) vector was deployed to recognize the shape of road signs. Boosted detector cascade was trained with dissociated dipoles to detect ROI while Hough transform and radial symmetry were used to recognize triangular or circular shape road signs [6]. Genetic algorithm was used in [7] while Haar-like features were used in [4] to detect road sign shape. A set of cascaded geometric detectors was used to in [8] to detect and recognize road sign shapes benefiting from their symmetric property.

Road sign visibility estimation from digital images has been proposed by several researchers. In [9], a novel technique has been suggested to measure road sign retroreflectivity from two images with different illumination. Support Vector Machine (SVM) has been used to classify road signs based on their deterioration levels [10]. In [11], both detectability and discriminability of traffic signals have been measured from in-vehicle images. In [12], five image features were used to estimate the visibility of specific road sign. In [13], visibility estimation in foggy conditions has been proposed using in-vehicle images.

In this paper, we propose an imaging based system to estimate the visibility of road signs in the United States in terms of their detect-ability. Detect-ability is defined as the ability of the driver to locate and recognize the existence of specific road sign in a complex or cluttered environment. This proposed system can be deployed in DSSSs to reduce the amount of information provided to drivers. In addition, transportation agencies could benefit of such system to evaluate their sign postage over road networks.

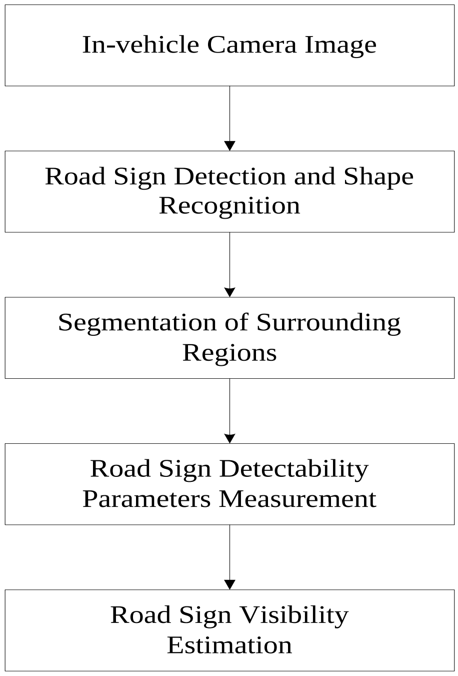

Fig.2. Flow diagram of the proposed system.

III. THE PROPOSED SYSTEM

The road sign imaging-based visibility estimation system, as shown in Figure 2, follows four stages.

1. Road sign detection and shape recognition: in this stage, color thresholding and a set of geometric detectors are applied on the in-vehicle images to extract and recognize road sign objects.
2. Segmentation of surrounding regions: this stage segments geometrically the four neighboring regions of road sign object.
3. Road sign detect-ability parameters measurement: in this stage, two visibility parameters (color difference and surrounding complexity) that describe road sign detect-ability are established.
4. Road sign visibility estimation: in this stage, the values of detect-ability parameters are used to classify the road sign visibility as: low, medium, or high.

A. Detection and Shape Recognition

Extracting the road sign region from the input image is necessary to estimate its visibility. In [8], we have proposed a method to detect and recognize road sign shapes, in which color thresholding is applied firstly to extract possible speed or warning signs regions

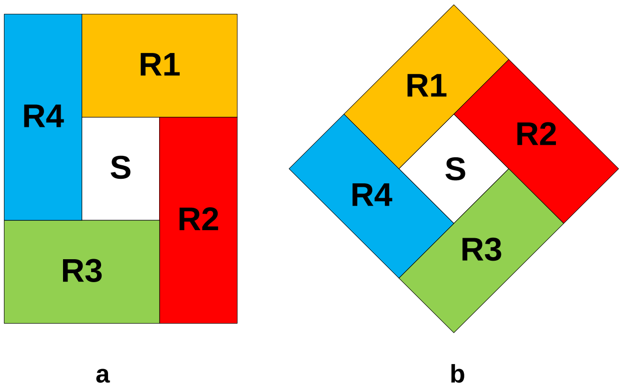

Fig.3. The road sign region and its four surrounding regions. a) rectangular road sign and surrounding regions. b) diamond road sign and surrounding regions.

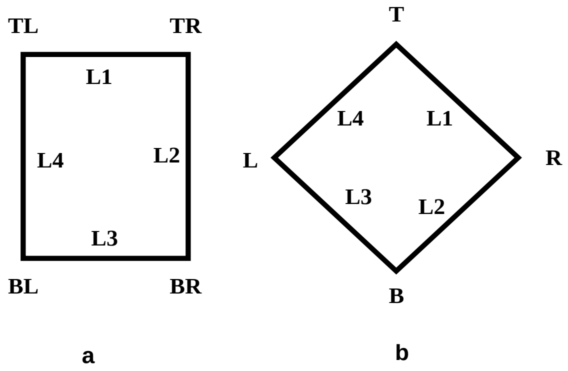

Fig.4. The four vertices of each sign shape along with its dimensions. a) rectangular sign shape. b) diamond sign shape.

(**blobs**). Secondly, a set of geometric detectors have been applied on each blob to keep only the ones that are possible road sign regions. These geometric detectors are: area, solidity, and dimensions ratios. Finally, the relative positions of the object's vertices are used to determine the shape whether it is rectangular or diamond or other symmetric shape.

B. Segmentation of Surrounding Regions

Visibility of road sign in this proposed work is defined as the ability of the driver to detect its region from background regions in an actual scene. Different background features could distract the driver from detecting the road sign region. Measuring the visibility is done by comparing road sign region against its background regions. Four neighbouring regions have been extracted from the input image for both rectangular and diamond sign shapes as shown in Fig.3.

Segmentation of road sign regions has been achieved by finding the four vertices of each sign shape as shown in Fig.4. The four vertices of rectangular sign shape are: top-left (TL), top-right (TR), bottom-right (BR), and bottom-left (BL) while the four vertices of diamond sign shape are: top (T), right (R), bottom (B), and left (L). These vertices are used to calculate the four dimensions of each symmetric shape.

The four regions are cropped from the input image such that each region has a symmetric shape and a double area of the sign region. The four surrounding regions are labelled as: **R1**, **R2**, **R3**, and **R4** while the sign region is labelled as **S** as shown previously in Fig.3.

C. Detect-ability Parameters Measurement

Color and shape features of surrounding regions are used to establish detect-ability parameters which would be used to determine the visibility level of road sign. Road sign that has surrounding regions with complex background with similar background color is difficult to be detected and thus; has a low visibility value. On contrast, road sign that has a simple background of surrounding regions with different background color is easier to detect and thus; has a high visibility value.

Two detect-ability parameters are proposed to describe the visibility of road signs: 1) color difference between sign region and the four surrounding regions and 2) shape complexity of surrounding regions.

- Color Difference

The average color of the RGB values is calculated for the sign region and the surrounding regions. The color difference between sign region and each one of the four surrounding region is defined as:

$$D1 = \sqrt{(\bar{R}_S - \bar{R}_{R1})^2 + (\bar{G}_S - \bar{G}_{R1})^2 + (\bar{B}_S - \bar{B}_{R1})^2} \quad (1)$$

$$D2 = \sqrt{(\bar{R}_S - \bar{R}_{R2})^2 + (\bar{G}_S - \bar{G}_{R2})^2 + (\bar{B}_S - \bar{B}_{R2})^2} \quad (2)$$

$$D3 = \sqrt{(\bar{R}_S - \bar{R}_{R3})^2 + (\bar{G}_S - \bar{G}_{R3})^2 + (\bar{B}_S - \bar{B}_{R3})^2} \quad (3)$$

$$D4 = \sqrt{(\bar{R}_S - \bar{R}_{R4})^2 + (\bar{G}_S - \bar{G}_{R4})^2 + (\bar{B}_S - \bar{B}_{R4})^2} \quad (4)$$

where ($\bar{R}_S, \bar{G}_S, \bar{B}_S$) are the average RGB colors in the sign region and ($\bar{R}_{Ri}, \bar{G}_{Ri}, \bar{B}_{Ri}$) are the average RGB colors in the surrounding region R_i.

The four difference values can then be averaged to calculate the color difference value D. Low color difference decreases the chances of road sign detection by a driver while high color difference increases the detection results. This means that the highly color difference is the better of road sign visibility.

- Shape Complexity

This Parameter measures the amount of details on the surrounding regions. The edges of all surrounding regions are extracted and the number of pixels of these edges is calculated. The ratio between the number of edges pixels and the total number of pixels in the surrounding regions is used to determine the shape complexity of road sign surroundings as follow:

$$C = \frac{N_E}{N_T} \tag{5}$$

where N_E is the number of pixels of all edges in the surrounding regions and N_T is the total number of pixels in the surrounding regions.

Simple road sign surrounding environment will yield in a low value for the complexity parameter and thus; will increase the visibility level.

D. Visibility Estimation

Road signs are classified in terms of visibility levels to: low, medium, or high. Both the color difference value (D) and the shape complexity value (C) calculated in the previous stage are used together to decide the visibility level as shown in Table 1.

Table 1: Visibility estimation using detect-ability parameters.

Color Difference	Complexity	Visibility Level
low	high	low
low	low	medium
high	high	medium
high	low	high

Color difference and shape complexity parameters are weighted equally in the decision of road sign visibility level.

a b

Fig.5. An example of the segmentation process of the four surrounding regions of a warning sign.

IV. EXPERIMENTAL RESULTS

The proposed visibility estimation system has been tested on road signs from the United States. A sample of in-vehicle images of 28 rectangular regulatory signs and 34 warning signs has been chosen to verify the effectiveness of the proposed system. These in-vehicle images have been captured using SAMSUNG ST65 camera in addition to images from VISAT^{TM} Mobile Mapping System. Moreover, the proposed visibility estimation system has been implemented in MATLAB software running on 2.4-GHz i3 CPU.

In our proposed system, each road sign should be classified as high, medium, or low in terms of visibility level. The decision of visibility level has been taken according to the values of both color difference and complexity parameters between road sign region and the four surrounding regions. Fig.5 shows an example of segmenting the four regions of a warning sign. The relation between visibility parameter values and visibility levels is shown in Table 2. These parameter threshold values have been chosen based on a set of road sign images (training set). Color difference threshold values are different between white and yellow signs because illumination affects white color (achromatic color) sharply.

Table 2: Relation between visibility parameter values and visibility levels.

	Color difference with white signs	Color difference with yellow signs	Complexity
High	>100	>120	> 5%
Low	<100	<120	< 5%

a

b

Fig.6. Two in-vehicle images of road signs with visibility estimation decision. a) speed sign with visibility level low by the proposed system and medium by the expert. b) warning sign with visibility level low by both the proposed system and the expert.

The visibility results have been compared with decisions from human expert. Table 3 shows the results of the proposed system against the human expert results. The comparison shows an agreement of both decisions on 52 road signs with an accuracy of 84% while 10 road signs have been decided differently. These 10 road signs have not decided extremely different between the proposed system and the expert.

Table 3: Comparison between the numbers of road signs decided similarly and differently by the proposed system and the expert.

	Total number	**Number of signs decided similarly**	**Number of signs decided differently**
Rectangular road signs (white color)	28	21	7
Warning signs (yellow color)	34	31	3

Table 3 shows that the proposed system has worked better with yellow road signs than white ones. This difference happens because of illumination factor which is affect white color (achromatic color) sharply and thus; the color difference visibility parameter may not describe the situation accurately.

Finally, it is worth to say that even for cases of disagreement, the decision between the proposed system and the expert does not differ extremely. In eight disagreement cases between the expert and our system, the visibility decision has one level difference. Fig.6 shows examples of visibility estimation of both cases where agreement and disagreement happens between the expert and the proposed system.

V. CONCLUSION

In this paper, we have proposed an imaging-based technique to estimate the visibility of road signs in the United States. We have concentrated on the detect-ability of road signs by drivers on roadways. The proposed system can be deployed in Driver Assistance Systems (DAS) as a choosing criterion of what to display to drivers. The proposed system has measured two visibility parameters; color difference and shape complexity between road sign and its background, to classify road signs with three visibility levels: high, medium, and low.

We are working on improvements such as: 1) measuring other visibility parameters to estimate the content readability of road signs and to estimate the effect of partial occlusion on road signs visibility; 2) deploying the proposed system on larger and varied set of road signs; 3) comparing the results of the proposed system with more number of human expert decisions; and 4) estimating the visibility of road sign content.

REFERENCES

[1] Doman, K.; Deguchi, D.; Takahashi, T.; Mekada, Y.; Ide, I.; Murase, H.; Tamatsu, Y., "Estimation of traffic sign visibility toward smart driver assistance," in *Intelligent Vehicles Symposium (IV), 2010 IEEE* , vol., no., pp.45-50, 21-24 June 2010 doi: 10.1109/IVS.2010.5548137.

[2] S. Maldonado-Bascón, S. Lafuente-Arroyo, P. Gil-Jiménez, H. Gómez-Moreno, and F. López-Ferreras, “Road-sign detection and recognition based on support vector machines,” IEEE Trans. Intell. Transp. Syst.,vol. 8, no. 2, pp. 264–278, Jun. 2007.

[3] A. de la Escalera, L.E. Moreno, M.A. Salichs, J.M. Armingol, “Road traffic sign detection and classification,” Industrial Electronics, IEEE Transactions on , vol.44, no.6, pp.848-859, Dec 1997.

[4] A. de la Escalera*, J.MaArmingol, M. Mata, “Traffic sign recognition and analysis for intelligent vehicles,” Image and Vision Computing 21 (2003) 247–258.

[5] J.F. Khan, S.M.A. Bhuiyan, R.R. Adhami, “Image Segmentation and Shape Analysis for Road-Sign Detection,” Intelligent Transportation Systems, IEEE Transactions on , vol.12, no.1, pp.83-96, March 2011.

[6] X. Baro, S. Escalera, J. Vitria, O. Pujol and P. Radeva, “Traffic Sign Recognition Using Evolutionary Adaboost Detection and Forest-ECOC Classification,” Intelligent Transportation Systems, IEEE Transactions on, vol. 10, pp. 113-126, 2009.

[7] Jialin Jiao, Zhong Zheng, Jungme Park, Y.L. Murphey, Yun Luo, “A robust multi-class traffic sign detection and classification system using asymmetric and symmetric features,” Systems, Man and Cybernetics, 2009. SMC 2009. IEEE International Conference on , vol., no., pp.3421-3427, 11-14 Oct. 2009.

[8] Abukhait, J.; Abdel-Qader, I.; Jun-Seok Oh; Abudayyeh, O., "Road sign detection and shape recognition invariant to sign defects," Electro/Information Technology (EIT), 2012 IEEE International Conference on , vol., no., pp.1,6, 6-8 May 2012.

[9] Balali, V., Sadeghi, M.A., and Golparvar-Fard, M. (2015). "Image-based Retro-Reflectivity Measurement of Traffic Signs in Day Time." Elsevier Journal of Advanced Engineering Informatics, 29(4), 1028-1040.

[10] P. Siegmann, S. Lafuente-Arroyo, S. Maldonado-Basc´on, P. Gil-Jim´enez, and H. G´omez-Moreno, “Automatic evaluation of traffic sign visibility using SVM recognition methods,” in Proc. 5th WSEAS Int.Conf. on Signal Processing, Computational Geometry & ArtificialVision, pp. 170–175, September 2005.

[11] Kimura, F.; Takahashi, T.; Mekada, Y.; Ide, I.; Murase, H.; Miyahara, T.; Tamatsu, Y., "Measurement of Visibility Conditions toward Smart Driver Assistance for Traffic Signals," in Intelligent Vehicles Symposium, 2007 IEEE , vol., no., pp.636-641, 13-15 June 2007.

[12] Doman, K.; Deguchi, D.; Takahashi, T.; Mekada, Y.; Ide, I.; Murase, H.; Tamatsu, Y., "Estimation of traffic sign visibility considering temporal environmental changes for smart driver assistance," in Intelligent Vehicles Symposium (IV), 2011 IEEE , vol., no., pp.667-672, 5-9 June 2011.

[13] K. Mori, T. Kato, T. Takahashi, I. Ide, H. Murase, T. Miyahara and Y. Tamatsu, “Visibility Estimation in Foggy Conditions by In-vehicle Camera and Radar,” Proc. International Conference on Innovative Computing, Information and Control, Vol. 2, pp. 548-551, Aug. 2006.