Visibility Estimation of Road Signs Considering Detect-ability Factors for Driver Assistance Systems

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Abstract: - This paper proposes an automated system to estimate the visibility of road signs from the driver's perspective in daytime using in-vehicle camera images. A set of detect-ability parameters such as surrounding simplicity, occlusion, and tilting of road sign were computed to estimate the overall sign visibility. Detect-ability is defined as the ability of the driver to locate road sign object from a scene and thus; it measures sign posting with respect to cluttered or complex environment. The proposed system can be deployed in Driver Assistance Systems (DAS) to control information provided to drivers, since providing too much information could lead to driver distraction. Road signs are classified according to their visibility level and thus; Driver Assistance Systems can use these visibility levels to warn drivers about road signs with less visibility and high importance. The proposed system consists of four stages: 1) road sign detection and shape recognition; 2) segmentation of surrounding regions; 3) detect-ability parameters measurement; and 4) visibility level determination. This paper proposes a visibility estimation system of road signs in the United States and experimental results are used to show its effectiveness. Visibility levels from the proposed system have been compared subjectively with human expert's decisions where a notable agreement between both decisions has been gained.

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

1 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 illumination factors and 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 due to occlusion, similar surrounding color difference, or complex environment.

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.

2 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. In [10], both detectability and discriminability of traffic signals have been measured from in-vehicle images. In [11], five image features were used to estimate the visibility of specific road sign. In [12], visibility estimation in foggy conditions has been proposed using in-vehicle images. Local and global features were extracted in [13] to measure the ability of human driver to detect and recognize a sign object. In [14], a novel technique has been demonstrated that estimates road sign saliency using SVM learning.

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.

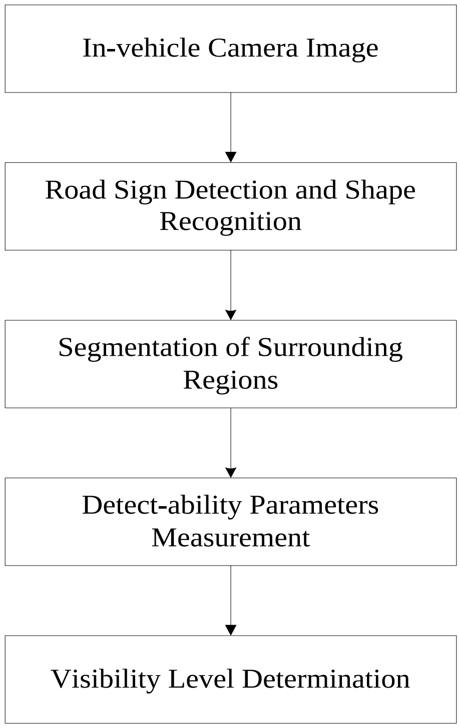

Fig.2. Flow diagram of the proposed system.

3 The Proposed System

The road sign imaging-based visibility estimation system, as shown in Figure 2, follows five 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. Detect-ability parameters measurement: in this stage, four visibility parameters (color difference, surrounding complexity, occlusion, and tilting) that describe road sign detect-ability are established and calculated for each sign.
4. Visibility level determination: in this stage, the level of road sign would be determined and labeled as: low, medium, or high.

3.1 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 (**blobs**). Secondly, a set of geometric detectors have

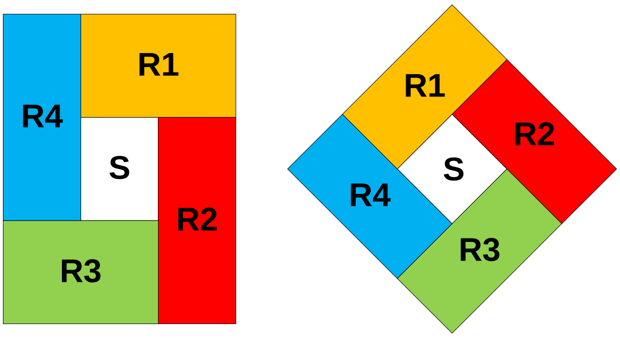

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Fig.3. The road sign region and its four surrounding regions. a) rectangular road sign and surrounding regions. b) diamond road sign and surrounding regions.

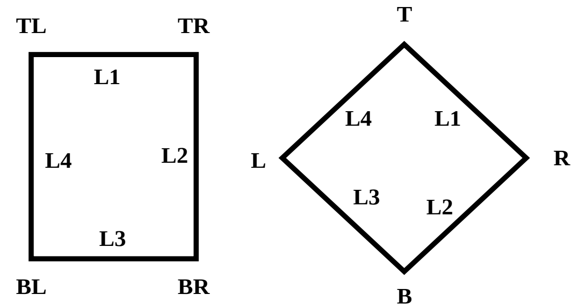

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Fig.4. The four vertices of each sign shape along with its dimensions. a) rectangular sign shape. b) diamond sign shape.

been applied on each **blob** to keep only the ones that are possible road sign regions. These geometric detectors are: area, solidity (the ratio between number of **blob** background pixels and the total number of **blob** pixels), and dimensions ratios detector which keeps only symmetric shapes. 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.

3.2 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.

3.3 Detect-ability Parameters Measurement

Different features of road sign region and surrounding regions are used to establish detect-ability parameters which would be used along with readability parameter to determine the visibility level of road sign. Road sign that is partially occluded, tilted, or has surrounding regions with complex and similar background color is difficult to be detected and thus; has a low detect-ability value.

Four detect-ability parameters are proposed to describe the visibility of road signs: 1) color difference between sign region and the four surrounding regions; 2) shape complexity of surrounding regions; 3) occlusion of road sign region (blob); and 4) tilting of road sign shape.

- 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 chances. This means that the highly color difference between the sign region (blob) and its surrounding regions, is the better of road sign visibility.

- Surrounding Simplicity

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 in the surrounding regions and the total number of pixels in these regions is used to determine the shape complexity (C) of road sign surroundings. The simplicity parameter (S) is calculated using the complexity ratio as follow:

$$S = 1 - \frac{N_E}{N_T} \quad (5)$$

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 high value for the simplicity parameter and thus; will increase the visibility level. The overall simplicity level of sign surrounding regions would be either high or low depending on the simplicity parameter value.

- Occlusion

This parameter measures the percentage of road sign area occluded partially by trees, leaves, or other objects. Partial occlusion on both top and right side of road sign region is considered while occlusion on both left and bottom side is neglected. The occlusion parameter (O) is defined as:

$$O = 1 - \frac{A_O}{A_T} \quad (6)$$

where A_O is the real filled area (with occlusion) of road sign region (blob) calculated as the number of pixels and A_T is the estimated area of road sign region (blob) without occlusion. Both left and bottom dimensions are used to calculate A_T as shown in Fig.5. The estimated area of road sign (A_T) is calculated using L_3 and L_4 as follow:

$$A_T = L_3 * L_4 \quad (7)$$

Occlusion level can be either low or high depending on the occlusion parameter value. High occlusion of sign region would decrease the detect-ability and visibility of road sign.

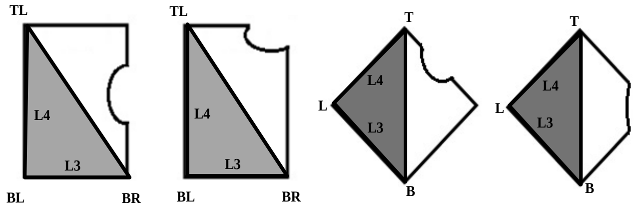

Fig.5. Partially occluded rectangular and diamond sign shapes.

- Tilting

This parameter computes the tilting angle (θ) geometrically using the tangent between the left and bottom points of road sign shape. In [15], we have proposed a framework for tilting angle computation of different sign shapes as shown in Fig.6. The tilting parameter (T) for rectangular signs is defined as:

$$T = \frac{180}{\pi} * \tan^{-1}\left(\frac{|X_B - X_L|}{|Y_B - Y_L|}\right) \quad (8)$$

and for diamond shapes is defined as:

$$T = \frac{180}{\pi} * \tan^{-1}\left(\frac{|X_B - X_L|}{|Y_B - Y_L|}\right) - 45 \quad (9)$$

where X_B and X_L are the x-axis coordinates of both the bottom and left points and Y_B and Y_L are the y-axis coordinates of both the bottom and left points.

Tilting level can be either low or high depending on the tilting angle value. High tilting of road sign would decrease its detect-ability and thus; its visibility level.

3.4 Visibility Level Determination

Road signs are classified subjectively in terms of visibility levels to: low, medium, or high. The four detect-ability parameters: color difference (D), surrounding simplicity (S), occlusion (O), and tilting (T) calculated in the previous stage are used together to decide the visibility level as shown in Table 1.

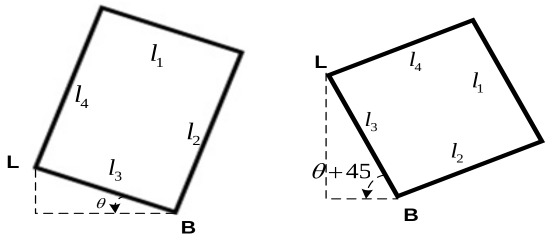

Fig.6. Rectangular and diamond road sign tilt angle.

Table 1: Visibility estimation using detect-ability parameters.

Color Difference (D)	Simplicity (S)	Occlusion (O)	Tilting (T)	Visibility Level (VL)
x	x	high	x	low
low	low	x	x	low
low	high	low	high	medium
high	low	low	high	medium
low	high	low	low	high
high	low	low	low	high
high	high	low	x	high

The four parameters participate in the final decision of road sign visibility level but with different weights. Occlusion parameter is given the greatest weight while tilting has the smallest weight in the decision. Both color difference and surrounding simplicity are equally weighted less than occlusion and higher than tilting.

4 Experimental Results

The proposed visibility estimation system has been applied on road signs in-vehicle images from the United States. These in-vehicle images have been captured using SAMSUNG ST65 camera in addition to images from VISAT™ Mobile Mapping System. Images were scaled to 864x648 pixels and 802x617 pixels by numeric fraction to overcome the impact of objects' distortion. The proposed visibility estimation system has been implemented in MATLAB software running on 2.4-GHz i3 CPU.

A sample of 32 in-vehicle images has been used in the training phase to determine the threshold value of each detect-ability parameter. Another sample of 118 in-vehicle images divided as: 62 rectangular regulatory signs and 56 diamond warning signs has been chosen to verify the effectiveness of the proposed system. Both the training and the testing sample contain a variety of road signs under different visibility situations.

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 four detect-ability parameters as shown previously. Some detect-ability parameters have been computed between the sign region and its four surrounding regions. Fig.7 shows an example of segmenting the four regions of a warning sign.

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Fig.7. An example of the segmentation process of the four surrounding regions of a warning sign.

The relation between the four detect-ability parameter values and their levels has been decided using different threshold values as is shown in Table 2. These threshold values have been chosen based on a set of 32 in-vehicle images (training set) divided as: 16 rectangular signs and 16 diamond signs. The decisions of a human expert have been used in this training phase to determine suitable threshold values for the four detect-ability parameters.

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

	High	Low
Color difference	≥ 120	< 120
Surrounding simplicity	≥ .95	< .95
Occlusion	≥ .15	< .15
Tilting	≥ 15	< 15

The proposed visibility estimation system has been tested on 118 in-vehicle images (62 rectangular signs and 56 diamond signs). The decision of the proposed system has been compared with the human expert decision on each sign separately. Table 3 shows the decisions of the proposed system against the human expert decisions. The comparison shows an agreement of both decisions on 105 road signs with an accuracy of 89% while 13 road signs have been decided differently. These 13 road signs have not decided extremely different between the proposed system and the expert. The difference between the proposed system and the expert decisions was only one visibility level.

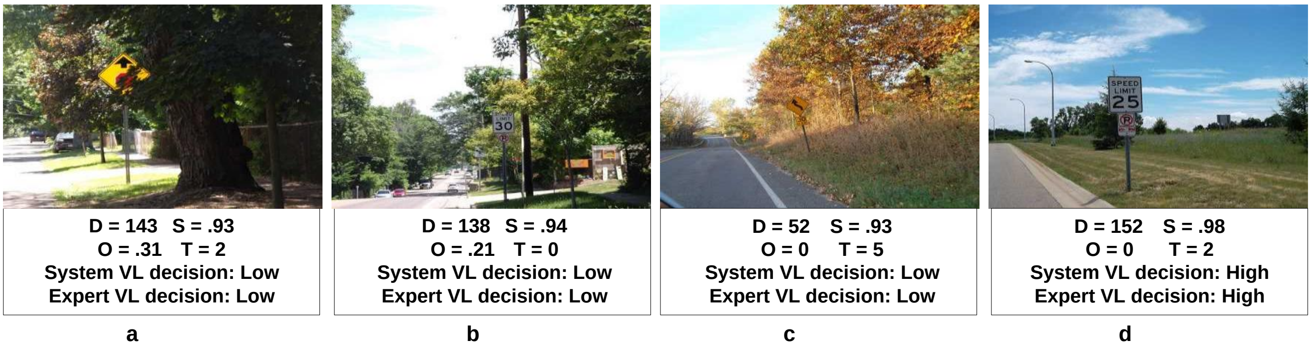

Fig.8. Four in-vehicle images of road signs with detect-ability parameters values, proposed system visibility decision, and expert visibility decision. a) partially occluded warning sign with low visibility level by both the proposed system and the expert. b) partially occluded speed sign with low visibility level by both the proposed system and the expert. c) warning sign in cluttered environment with low visibility level by both the proposed system and the expert. d) speed sign with high visibility level by both the proposed system and the expert.

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 affects white color (achromatic color) sharply and thus; the color difference detect-ability 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 ten disagreement cases between the expert and our system, the visibility decision has one level difference. Fig.8 shows examples of visibility estimation of both cases where agreement and disagreement happens between the expert and the proposed system.

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**
Regulatory road signs (Rectangular)	62	53	9
Warning road signs (Diamond)	56	52	4

5 Conclusion

In this paper, we have proposed an imaging-based system to estimate the visibility of road signs in the United States. Visibility has been defined as the ability of drivers to detect road signs on roadways (detect-ability). 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 four detect-ability parameters; color difference, surrounding simplicity, occlusion, and tilting to classify road signs with three visibility levels: high, medium, and low.

We are working on improvements such as: 1) applying the proposed system on other sign classes; 2) deploying other visibility parameters that describe the readability of road sign contents; 3) adding temporal weather changes that affect road sign visibility; and 4) considering the effect of the illumination factor on the visibility decision.

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] 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.
[11] 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.
[12] 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.
[13] K. Doman et al., "Estimation of traffic sign visibility considering local and global features in a driving environment," Intelligent Vehicles Symposium Proceedings, 2014 IEEE, Dearborn, MI, 2014, pp. 202-207.
[14] L. Simon, J.-P. Tarel, and R. Br´emond, “Alerting the drivers about road signs with poor visual saliency,” in Proc. 2009 IEEE Intelligent Vehicles Symposium, June 2009, pp. 48–53.
[15] J. Abukhait, I. Abdel-Qader, J. S. Oh and O. Abudayyeh, "Occlusion-invariant tilt angle computation for automated road sign condition assessment," *Electro/Information Technology (EIT), 2012 IEEE International Conference on*, Indianapolis, IN, 2012, pp. 1-6.