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Driving Supportive System for Warning Traffic Sign Classification

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Abstract: *Traffic signs should be accurately identified in order to prevent vital road accidents and secure lives. The objective of this paper is to detect the warning traffic signs and recognize the message it is designed to convey. This system is based on extracting the warning sign from the traffic scene by Windowed Hough Transform. Next Histogram Oriented Gradient (HOG) is used to collect the feature of the extracted part of triangular object and finally SVM classifier is applied to train the HOG features. To summarize, the system first detects the warning traffic sign in the first place, specifies whether the detected sign is a warning sign, and then determines the meaning of the symbol inside it. The SVM classifier was trained with 200 images which were collected in different light conditions. To check the robustness of this system, it was tested against 327 images which contain 292 warning traffic sign and 35 other types of traffic signs. It was found that the accuracy of recognition was approximately 94% which indicates clearly the high robustness targeted by this system.*
Keywords: *HOG, SVM, Traffic sign; Windowed Hough Transform.*

I. Introduction

One of the major reasons behind the increase rate of road accidents is the failure of the drivers to recognize road signs mainly due to poor light or weather conditions. Researchers have worked for years to find a proper and permanent solution to address this issue but still there is no accurate way out to this problem. An automatic recognition system can greatly reduce such mishap by warning the drivers ahead of time.

Traffic signs are crucial in guiding the road users while being on the road. The drivers need to drive carefully in circumstances where there is a road under construction or school nearby. These types of instructions are displayed by warning traffic signs [1]. Therefore to avoid serious injury and mishaps, it is strongly recommended that the traffic signs are properly interpreted.

Warning traffic signs are the group of signs which warn the drivers about certain hazards ahead of the road such as animals crossing the road, speed breaker etc. Since human visual perception abilities depend on the individual's physical and mental conditions, these abilities can be affected by many factors such as tiredness, and driving tension. Moreover the symbols inside the sign may be misinterpreted by the drivers. Therefore it is very important to have an automated system that can warn the drivers ahead of time no matter what the weather and light conditions are. If properly implemented, these systems can greatly reduce road accidents, and also increase driving efficiency [2-3].

The paper proposes a system that can achieve these tasks with greater robustness than the previous works. The aim of this paper is to detect one valuable group of traffic signs which is warning signs. Proposed system is based on Windowed Hough Transform for the detection of the warning sign. To confirm whether the detected sign is a warning sign, SVM classifier which was trained by the HOG features of the extracted warning sign, is invoked to classify different warning sign and specify the actual warning on the road.

The paper follows the following structure. Section 2 presents the related work as the proposed approach and the drawbacks. Section 3 gives an overview about the format of warning traffic signs. The detailed procedures of how the algorithms are applied are mentioned in section 4. In section 5, the result and analysis is given. Finally the conclusion is mentioned in section 6.

II. Related Work

Rapid advancement of technology in recent times has encouraged researchers to work with object and traffic sign detections mainly due to its vast scope and applications. An automated system is not only more accurate than humans; rather it is faster, efficient and time saving. Although researchers are building these automated systems, the difference lie in terms of cost, speed, memory space, availability and precision.

Hsiu, Chao, Kun and Shang [4] proposed a system that used discrete cosine transform (DCT) and singular value decomposition (SVD) for extracting features. For the preprocessing of data, they used ROI detection, RGB color segmentation and LoG edge detector. The training dataset contained 10000 images whereas test dataset had more 210 new images. But overall precision was 78% compared to the proposed system where the precision is more than 90%, the procedure is very complex and not much reliable for distorted images in poor weather condition.

Vincenzo, Giuseppe and Domenico [5] proposed a system using GIS and Hough Transform to automatically recognize road signs. It is based on the use of the Standard Hough Transform in order to detect the shape, i.e. the macro-class, of road sign (e.g. circular, squared, triangular, etc.). The performances of proposed approach are very encouraging: 97% of used road signs have been correctly recognized.

Another approach was proposed by Bram, Guy, Herbert and Csaba [6] where a learning method was introduced that selected features based on the implicit transmission function of the designer's template to the object's appearance in the image. The system was able to detect 85% of the objects from 12 pixels width and 95% objects from 24 pixels width at a low false alarm rate. The major drawback of this system is its degraded performance in handling the rotatory or poor visibility images.

P. Rybski, D. Huber, D. Morris and R. Hoffman [7] proposed vision based algorithms to determine vehicle orientation in images. HOG descriptors were used to recognize the orientation and the classification accuracy was 88% on a test database of 284 images.

The most important application of HOG was first introduced by Dalal and Triggs [8] who used this approach to identify the pedestrians. There were mainly two types of database: MIT pedestrian database contained 509 training and 200 test images, and INRIA pedestrian database contained 1805 images. HOG was used to extract the features of pedestrians in different positions and movements and then SVM classifier was used to train and test the input image with the sample. Although initially the focus was only static images, later they expanded their tests for human and other object detection in films and videos.

III. Warning Traffic Sign

Traffic signs in general have been designed using special shapes and colors, very different from the natural environment, which make them easily recognizable by drivers [9]. The designs of traffic signs are standardized through laws but differ across the world. Their shapes are used to categorize different types of signs: Circular signs are prohibitions including speed limits, triangular signs are warnings, and rectangular signs are used for recommendations or sub-signs in conjunction with one of the other shapes. In addition to these, octagonal signs are used to signal a full stop, and downward-pointing triangles signal a yield [10]. A sign can have three colors: a rim, an interior and a pictogram color.

Warning traffic signs indicate certain hazard on the road that is not visible to the driver. In most countries, they usually take the shape of an equilateral triangle with a white background and a thick red border. However, both the color of the background and the color and thickness of the border vary from country to country. Figure 1 shows some of the warning signs frequently used.

Figure 1: Different categories Warning Traffic Signs

IV. System Overview

The block diagram of the proposed system is shown in Figure 2. The image under consideration is first segmented and filtered from noise and other undesired blobs based on the size of these blobs, and then Canny Edge Detector is applied to extract the edges of all objects in the image. Following this process, the remaining objects are labeled using the Connected Components Labeling algorithm. All objects are tested for the presence of triangular shapes and once this shape is found using Windowed Hough Transform, the corresponding part in the image under consideration is marked and that corresponding part is cropped by the Bounding Box. HOG is applied to extract the feature of cropped triangular object and that feature is trained by SVM to classify the different warning signs. This process continues until the list of all labeled objects are exhausted. In the following sub-sections is the description of the major steps of the algorithms.

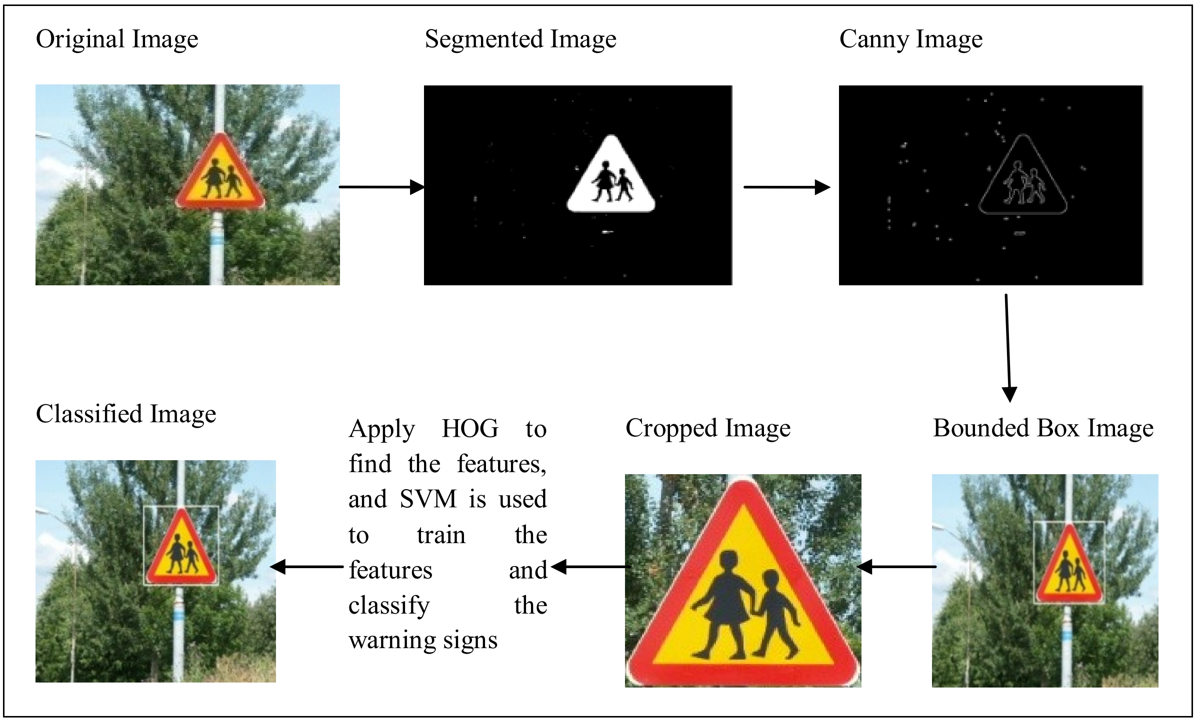

Figure 2: Block diagram of the proposed system

1.1 Segmentation

Detection of any Warning traffic sign is accomplished by several steps. The image under consideration is first treated in such a way that it reduces the search space of the desired traffic sign in the image. In the work, there is no color segmentation invoked. Instead, a simple and fast technique is invoked to segment the traffic sign from the image.

Let R, G, and B be the RGB components of a traffic scene and g is the gray image of this scene. Then the segmented image S, which is given by Eq.1, is as simple as subtracting the pixels in the gray channel from their corresponding pixels in the red channel:

$$S = R - g \qquad (1)$$

The advantage of the step is to remove all undesired objects in the scene and keep the small number of candidates which represent all objects with similar characteristics to the traffic sign. The next step in the warning traffic sign detection is to apply Canny Edge Detector to extract the edges of all objects in the image. Following this process, the remaining objects are labelled using the Connected Components Labelling algorithm. All objects are tested for the presence of triangular shapes and once this shape is found, the corresponding part in the image under consideration is marked. This process continues until the list of all labelled objects is exhausted.

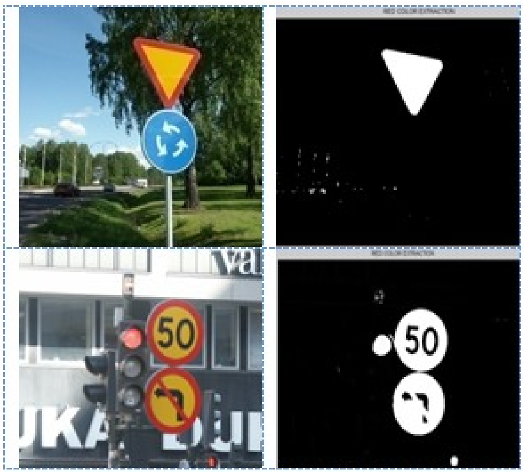

Figure 3: Results of segmentation

1.2 Triangular Object Detection

Hough Transform is used combined with the triangle properties to detect the triangular traffic signs. A perfect equilateral has three sides, thus there are three points of intersection in the Hough space as shown in Figure 4 which are represented by θ_a, θ_b and θ_c where $\theta_a > \theta_b > \theta_c$. The corresponding normal distances are p_a , p_b and p_c.

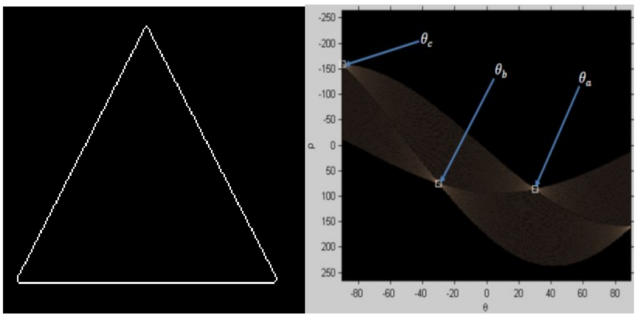

Figure 4: Hough Transform of the Triangle

The triangle in Figure 5 contains one circle whose center is located in the centroid of this triangle. Let a, b, and c be the lengths of the sides BC, AC, and AB, respectively.

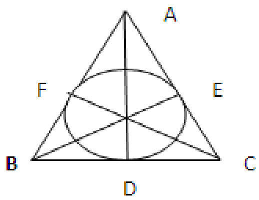

Figure 5: Equilateral Triangle with a Circle

In the analysis of He and Me [11], they applied some set of rules to detect the perfect equilateral triangle only. Using their set of rules, some modified set of rules were applied to detect any triangle in an image. These rules are as follows.

1. **Rule 1**: The difference between two adjacent Θs is more than a certain threshold. For a perfect equilateral triangle T1=T2=60°.

$$|\theta_a - \theta_b| \geq T_1 \;, |\theta_b - \theta_c| \geq T_2, |\theta_a - \theta_c| \geq T_1 + T_2$$

2. **Rule 2**: The summation of differences between any two adjacent angles equals the difference between θ_a and θ_c. This rule minimizes the number of false positive objects created in the image.

$$|\theta_a - \theta_c| = |\theta_a - \theta_b| + |\theta_b - \theta_c|$$

3. **Rule 3:** The summation of any two sides of a triangle is always greater than the third side

$$a + b > c, a + c > b, b + c > a$$

4. **Rule 4**: The normal distances ρ_a , ρ_b and ρ_c are those indicated by OD, OE, and OF in Figure 5 where O is the circle center. The algebraic difference between any two normal distances is less than a threshold.

$$|\rho_a - \rho_b| < T_3, |\rho_a - \rho_c| < T_3, |\rho_b - \rho_c| < T_3$$

5. **Rule 5**: The summation of three angles of the triangle is π. Therefore, the difference between any two angles is less than π.

$$\theta_a - \theta_b \leq \Pi, \theta_b - \theta_c \leq \Pi, \theta_a - \theta_c \leq \Pi$$

6. **Rule 6**:

$$|a^2 - (b^2 + c^2 - 2.b.c.\cos(\Pi - \theta_b + \theta_c))| < T4,$$
$$|b^2 - (a^2 + c^2 - 2.a.c.\cos(\Pi - \theta_a + \theta_b))| < T4,$$
$$|c^2 - (a^2 + b^2 - 2.a.b.\cos(\theta_a - \theta_c - \Pi))| < T4$$

7. **Rule 7**:

$$|a - (\frac{a}{\tan(0.5*(-\theta_a+\theta_b))} - \frac{a}{\tan(0.5*(\theta_a-\theta_c-))}| < T5,$$
$$|b - (\frac{b}{\tan(0.5*(-\theta_b+\theta_c))} - \frac{b}{\tan(0.5*(\theta_a-\theta_c-))}| < T5,$$

$$|c - (\frac{c}{\tan(0.5*(-\theta_b + \theta_c))} - \frac{c}{\tan(0.5*(-\theta_a + \theta_b))}| < T5$$

Based on the number of Hough peaks and their distribution, one of the following three scenarios will be employed to detect Warning traffic signs:

Scenario 1:

If the base of the triangle is located horizontally then the Hough Transform shows three Hough peaks which mean three line segments. If these three line segments satisfy the rules derived to detect triangles, then they form a triangle, as shown in Figure 4.

Scenario 2:

If the base of the triangle is not horizontal then it is shown as a set of broken lines. The Hough Transform in this case shows more than three Hough peaks which mean more than three line segments as shown in Figure 6. The selection of proper Hough peaks is achieved as follows:

- Search through the Θs and select the maximum Θ as θ_a and the minimum as θc.
- Search in the list among the remaining Θs and select θ_b - which fulfill rule 2.
- Check whether line segments fulfill the other rules.

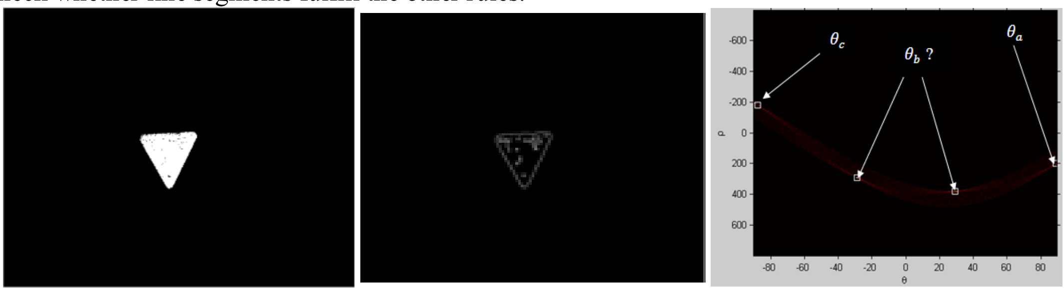

Figure 6: Detection of Rotated Warning Signs

Scenario 3:

When the image is noisy, color segmentation will produce objects which are highly imperfect. The Hough Transform in this case shows many Hough peaks which in most cases are clustered in several places on the Hough space as shown in Figure 7. To deal with this scenario, all Hough peaks within a certain threshold distance are averaged and replaced by the resultant one. Then follow scenario 2 to select the suitable Hough peaks among the list of generated ones.

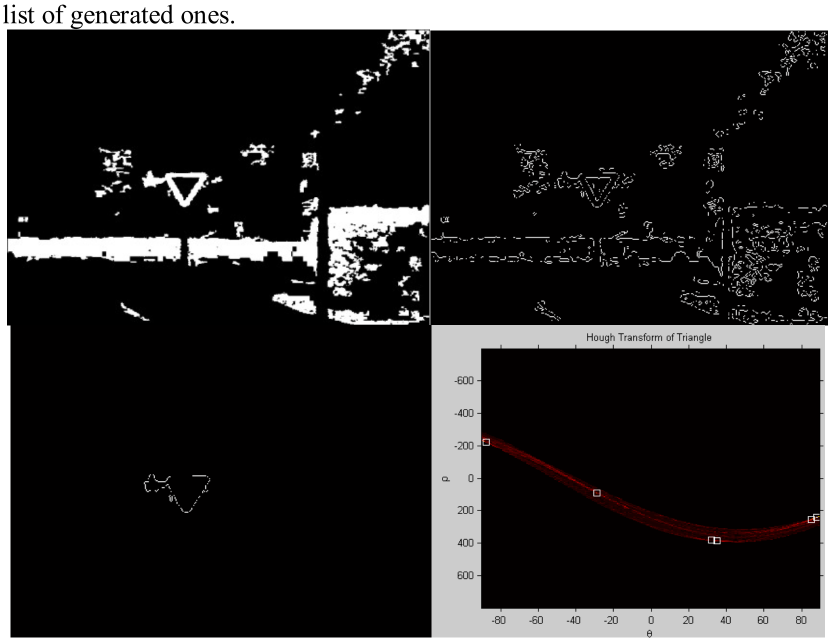

Figure 7: Detection of Imperfect Warning Signs

1.3 HOG Feature of Speed No

It is a feature descriptor used for object detection. It uses gradient orientation in localized portions of an image.

After the triangular object is detected from the input image, the following steps are performed to extract the features.

1. Compute horizontal and vertical gradients
2. Compute gradient orientation and magnitude. For color image, pick highest gradient magnitude color channel for each pixel.
3. The images are resized into 48*48
4. Divide into 6*6 blocks with 50% overlapping, thus 5*5=25 blocks in total
5. Each block contains 2*2 cells with size 8*8
6. Quantize gradient orientation into 9 bins-

- The vote is the gradient magnitude
- Interpolate votes bi-linearly between neighboring bin center. For example, if Ø=85^0 and bins are 70 and 90, then distance to bin centers are 15 and 5 respectively. Hence ratios are 5/20 and 15/20
- The vote can also be weighted with Gaussian to down-weight the pixels near the edges of the block

7. Concatenate histograms in 1D matrix of length 8100 (4*9*5*5*9) i.e. the feature dimension.

1.4 Support Vector Machine (SVM)

SVMs are set of related supervised learning methods used for classification and regression. It simultaneously minimizes the empirical classification error and maximizes the geometric margin. SVM map input vector to a higher dimensional space where a maximal separating hyper plane is constructed. Two parallel hyper planes are constructed on each side of the hyper plane that separate the data. The separating hyper plane is the hyper plane that maximizes the distance between the two parallel hyper planes. An assumption is made that the larger the margin or distance between these parallel hyper planes the better the generalization error of the classifier will be [12].

The proposed system uses one-against-all SVM in order to train and match the descriptors of the test image with the trained image. This multiclass SVM works by considering the M- class problem as a series of binary problem. There are 9 classes (yield, straight line, speed-breaker, school, animal crossing, narrow road, two arrows, road under construction and 'unknown') in the proposed solution.

V. Results And Analysis

To analyze the performance of the proposed approach, the following experiments were conducted. A standard database of traffic sign images was invoked in all tests. The database is available from [13].

1.5 Detection of Warning Signs:

The proposed approach was tested on different sets of warning images in different weather condition. The number of traffic signs in the images was 195. The current approach was also tested by 251 negative samples which represent non-traffic signs or traffic signs from other groups. Table 1 depicts the detection results achieved under different light conditions, the number of false positives and false negatives. The average detection rate was 92.3%.

Table 1: Detection of Warning signs.TP: True Positive, FN: False Negative, TN: True Negative, FP: False Positive.

Condition	**Warning Sign**						
	No. Of Images	**Positive Objects**	**TP**	**FN**	**Negative Objects**	**TN**	**FP**
Sunny	55	55	55	0	76	72	4
High Light	25	25	25	0	40	39	1
Blurred	16	16	16	0	14	12	2
Bad Lighting	24	24	24	0	26	25	1
Noisy	21	21	21	0	47	45	2
Snow Fall	24	24	24	0	7	6	1
Fog	11	11	11	0	7	7	0
Dawn/Dusk	19	22	19	3	34	33	1
Total	**195**	**198**	**195**	**3**	**251**	**239**	**12**

1.6 Categorization of Different Warning Signs:

The HOG features were extracted based on nine classes-yield sign, straight line, speed breaker, school nearby, animal crossing, narrow road, 2 arrows and road under construction belong to classes one to eight respectively. If the input image does not match any of the above classes, then it falls under the 9^{th} class which is 'unknown classes'.

The classes are represented as A-I in the Table 2. The extracted features are trained by the multiclass SVM. The current approach was also tested by 327 different triangular signs which represent warning traffic signs. Table 2 depicts the categorization of different warning signs achieved under different light conditions. The average classification rate was 94%.

Table 2: Results of HOG based Feature Extraction, SD=Successfully Detected

	No of Different Warning Signs									
Condition	A	B	C	D	E	F	G	H	I	SD
Sunny	3	5	7	7	7	8	9	4	5	54
High Light	4	4	5	9	8	7	6	3	8	53
Blurred	3	3	6	8	4	7	3	3	3	38
Bad Lighting	3	2	3	4	4	6	5	4	4	31
Noisy	2	2	3	3	5	2	4	2	3	24
Snow	3	2	3	2	3	2	2	4	2	18
Fog	2	4	6	3	3	5	8	3	3	32
Dawn/Dusk	7	6	5	10	4	6	8	4	7	56
Total	**27**	**28**	**38**	**46**	**38**	**43**	**45**	**27**	**35**	**306**

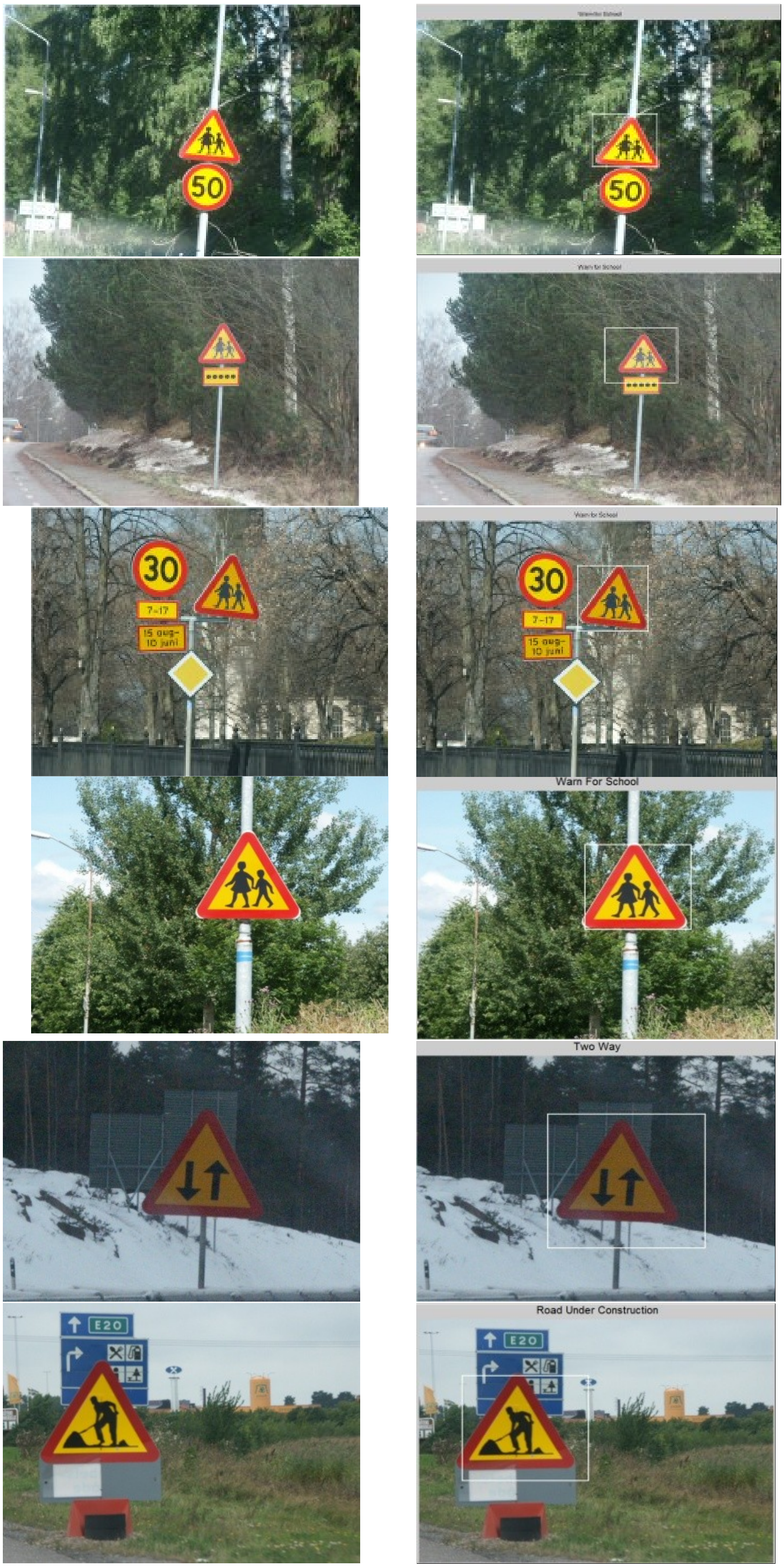
50
30
7-17
15 aug-
10 juni
Warn For School
Two Way
E20
Road Under Construction

Figure 8: Results of different warning traffic sign detection and categorization.

VI. Conclusion

In this paper, a new system has been proposed to detect warning traffic signs and categorizing the type of warning the sign conveys. This kind of sign warns about obstacles that are not visible to the driver and thus are very crucial in preventing road accidents. It consists of a simple segmentation technique followed by the Windowed Hough Transform approach for warning sign detection and trains the HOG features of the cropped area of the triangular object to confirm the speed sign by SVM. The proposed system is tested on images collected from different parts of Europe and it shows high robustness. Future work will be to work with other types of traffic signs and with real time images.

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