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THE VERTICAL TRAFFIC SIGNS DETECTION IN DIFFERENT LIGHT CONDITIONS

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Abstract. This paper is focused on detection of vertical traffic signs in different light condition. Vertical Traffic Signs Recognition System contains two main phases – detection and recognition phase. The aim of detection phase is to find the area of the vertical traffic sign (ROI - Region of Interest) from the captured image of the real traffic and it might be based on three different methods – color-based, shape-based and combination of these two methods. The light conditions affect the success of each detection method. The detected ROIs are compared with the reference traffic sign by Optical Correlator in recognition phase.

Keywords: *detection methods, light conditions, optical correlator, recognition, traffic signs.*

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1. Introduction

The traffic signs are an important part of road infrastructure, which perform a significant role in traffic regulation, visual guidance of vehicles or other road users on the traffic and providing of service information. They are installed at specific locations and designed to be easily recognized by drivers because their color and shapes. Recognition of traffic signs has been a challenging problem for many years. Nowadays, there are several systems for the recognition of the traffic signs. In these systems, digital image processing or intelligent techniques like neutral networks are used. The images are analyzed and processed by various techniques like color segmentation, shape detection or edge detection. The procedure of the traffic signs recognition has usually two phases. The first is the localization of the Region of Interest - detection phase. The second phase is the traffic sign recognition – recognition phase.

Goal of this paper is to present Vertical Traffic Signs Recognition System, more specifically impact of light conditions on the vertical traffic detection. There are three ways of the vertical traffic detection – color-based, shape-based and combination of both methods. So, the detection phase in VTSRS is based on these methods. Optical Correlator is used as a comparator in the recognition phase. This system was tested on the real traffic of Slovakia in different light conditions [2,3, 8-13].

2. Vertical traffic signs recognition system

The Vertical Traffic Signs Recognition System is a smart system designed to help drivers react properly in dangerous traffic situations. In our research, a system to detect and recognize vertical traffic signs was designed. VTSRS is mounted directly in vehicles and interprets traffic signs for driver. This system analyzed captured images of real traffic and provided recognizable vertical traffic sign to the driver. The VTSRS configuration is illustrates on Figure 1 [3, 6, 8-10, 12].

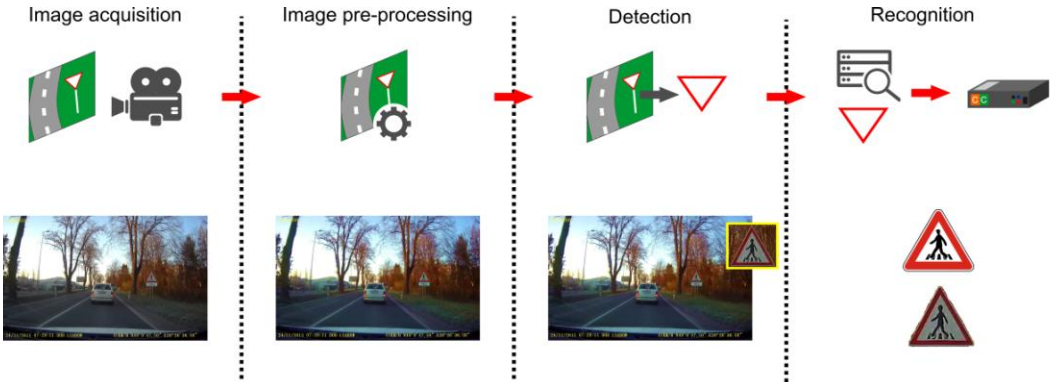

Figure 1. Procedure of VTRSR

2.1. Image Acquisition

The first section in VTSRS is the Image Acquisition. It is process of acquiring an image and to do this, the color HD video camera is used. The color HD video camera is installed into vehicle and it captures images of the scene front of the vehicle. Example of the captured image is shown on Figure 2.

Figure 2. Example of the captured Image

2.2. Image pre-processing

The next section after the *Image Acquisition* is the Image Pre-processing. The Image Pre-processing section is not a mandatory one, but it may increase the efficiency of the following sections. The fundamental function of the Image Pre-processing is to modify the captured image to easier obtain the necessary information from it (Figure 3.). The properties such as brightness, a contrast and a gamma are changed and to remove the noise from the image, a Gaussian filter is used. Thus, the pre-processed image is prepared to the next section – Detection [2,10].

Figure 3. a) Original image, b) Pre-processed image

2.3. Detection

The first section in VTSRS is the Image Acquisition. It is process of acquiring an image and to do this, the color HD video camera is used. The color HD video camera is installed into vehicle and it captures images of the scene front of the vehicle. Example of the captured image is shown on Figure 2.

The main task of the Detection is to find the area of the traffic sign from the complicated captured image background. This area represents the Region of Interest, e.g. a region in which the traffic sign should be located. The output of this section represents real candidate of vertical traffic sign.

The traffic signs are designed to be principally distinguishable from natural or human-made backgrounds. They are characterized by many features which make them recognizable. They are designed in the standard geometrical shapes like triangles, circles, rectangles and octagons. The main colors of the traffic signs are chosen to be far away from the environment, so they are easily recognizable by the drivers. They use colors to represent the main information to the drivers. The typical colors used for the traffic signs are red, blue and yellow. So, information about shape and color can be used in the detection. The detection can be based on shape, color or both [3,6,8-10,12,13].

VTSRS can use three different detection methods – color-based, shape-based and hybrid, which combine these mentioned methods together. Color-based detection method is based on color segmentation, e.g. process of partitioning image into multiple sets of pixels that have similar color properties. In VTSRS, HSL color space is used. The base of shape-based detection method are algorithms that are used to search some well-known traffic shapes of traffic signs. Of course, the color segmentation in this method is omitted. Hybrid detection method combines above mentioned methods together [11,13].

In these methods, digital image processing is used. We can divide digital image processing to simple operations that process image in different way. Each method uses different number of operations in different orders (Figure 4.) [2,10-13]. In VTSRS these following operations are used:

- **Grayscale** – process of the image transformation to a grayscale image. A grayscale image carries brightness information only. There is no information about a color.
- **Thresholding** – the simplest method of image segmentation that converted gray scale image to binary image by a thresholding process. White pixels represent the pixels of the image which value is within the threshold range. Black pixels represent out of the threshold range value.
- **Dilatation** – the morphological operation that allows objects to expand, thus potentially filling in small holes and connecting disjoint objects.
- **Edge detection** – process of finding complex object boundaries by marking potential edge points corresponding to place in an image where rapid changes in brightness occur. After these edge points, have been marked, they can be merged to form lines and object outlines. In our case, Canny edge detector is used.
- **Blobs filtration** – process of blobs removing, e.g. objects, which are smaller or bigger then specified limits.
- **Color segmentation** – process of using color segmentation based on red, blue and yellow color for obtaining three simples images. These images contain only pixels, which refer to that color.
- **Shape detection** – process of searching same well-known traffic sign's shapes.
- **Extraction of ROI** – process of selecting and bounding the Region of Interest. The largest object is bounded and subsequently extracted from image.

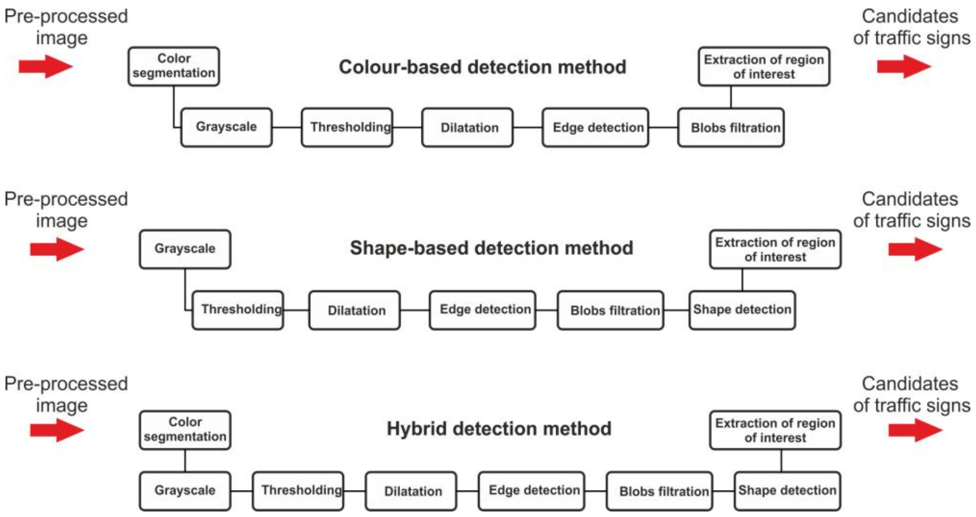

Figure 4. Procedure of detection methods.

2.4. Recognition

The last section is Recognition. The output of the Detection is list of candidates that might represent the vertical traffic signs. This list is forwarded to the recognizer for further evaluation, and then based on the result of recognition this recognizer decided whether the candidates in the list are traffic signs or either rejected objects.

In VTSRS the Cambridge Optical Correlator is used as a recognizer. The Cambridge Optical Correlator is a basic device that uses the optical processing technology. It is a type of Joint Transform Correlator where process of optical correlation is formed by two consecutive Fourier transforms. The Cambridge OC is used to compare the input images with the reference images based on their similarities. The input scene is created by these images and then process of optical correlation is done. The optical output of the Cambridge OC contains highly localized intensities – correlation peaks, which size reflects measure of similarity of the images at the input scene. The position of these peaks is the same as the position of the input images [1,4,5,7].

3. Experiments and results

Firstly, we created videos of real traffic in Slovakia. These videos capture the same road section, but in different light and weather conditions. We created two videos in early hours with ideal (Figure 5(a)) and low light conditions, mostly with fog (Figure 5(b)). The next videos were created in cloudy weather (Figure 5(c)) and at night (Figure 5(d)). Our experiments were realized with static images captured from created videos. Each captured image had to contain least one vertical traffic sign. We obtained about 38 static images from each video. After that, the database of reference vertical traffic signs was designed. The database includes only these vertical traffic signs that were found in created videos. Our experiments consist of two parts – Detection and Recognition.

The main task of the Detection is to find real candidates of vertical traffic signs from captured images. These candidates represent the Region of Interest, e.g. an area in which the traffic sign should be located. As it mentioned above, VTSRS can use three different detection methods – color-based, shape-based and hybrid. So, these detection methods were used to find candidates from 38 obtained static images of each videos. In this part of our experiments were obtained 38 candidates from each video by each detection method. Figure 6 contains reference traffic signs and some obtained candidates of traffic signs from video created in cloudy weather.

In the second part of our experiments, the Recognition is used to determine the content of the obtained candidates (38 images from each video by each method) which possibly contains one or more vertical traffic signs. The recognition process is carried out by the Cambridge Optical Correlator which function is to compare input and reference images situated in the input scene. In our case, the candidate represents the input image (Figure 6) and it is compared with the reference vertical traffic signs. The reference vertical traffic signs are stored in created database.

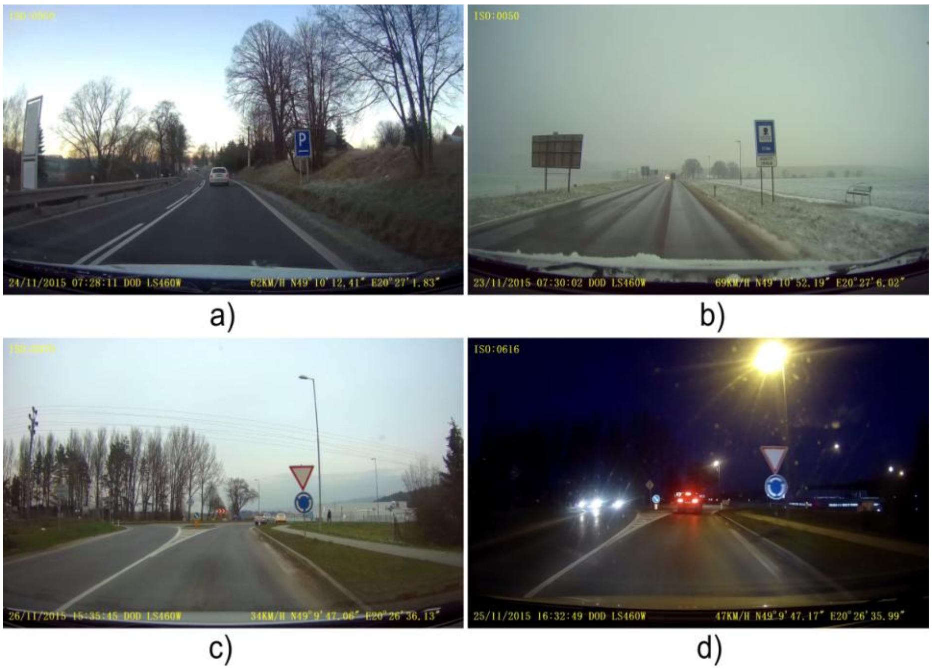

Figure 5. a) Early hours with ideal light conditions,
b) Early hours with low light conditions (fog), c) Cloudly, d) Night

Figure 6. Example of traffic signs used in experiments

Cambridge Optical Correlator is coupled with simulation software, "Fourier Optics Experimenter (FOE)", to learning and easy understanding Fourier Optics, especially optical correlation. FOE allows make process of optical correlation based on Cambridge Optical Correlator between two or more images (Figure 7).

In Figure7 we can see process of optical correlation between candidate and reference traffic sign. The input scene (Figure 7(a)) is created by images mentioned above. Joint Power Spectrum (JPS) we can see in Figure 7(b) and this JPS binary or threshold processed in Figure 7(c). The optical output is showed in Figure 7(d). As was mentioned above, the optical output contains highly localized intensities and their value might be in within range <0;255> where value “255” refers to total match and value “0” refers to mismatch [1, 4, 5, 7].

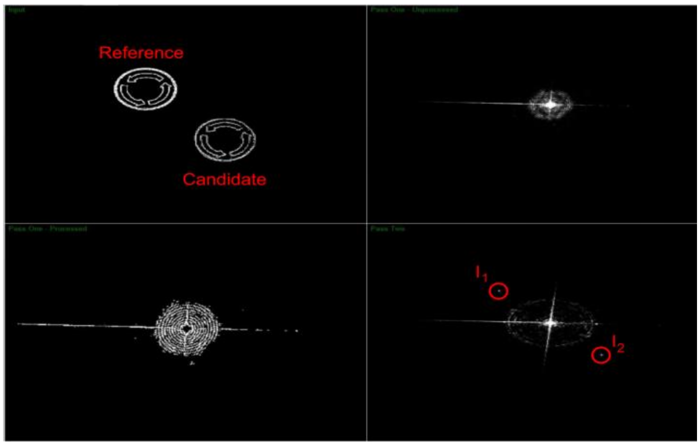

Figure 7. Process of optical correlation between two same images

The equation (1) means percentage match between images situated in the input scene, where I_1 and I_2 are intensities of the correlation peaks

$$\text{Match} = (I_1 + I_2)/510 * 100. \quad (1)$$

We decided that if value of percentage match is greater than 70 %, the candidate is considered as vertical traffic sign. Values of intensities of correlation peaks of experiments shown in Figure 7 are I1 = 229 and I2 = 214. So according to equation (1) match of input images is 86,9%. From that fact match is 86,9% that candidate refers to reference traffic sign. The resulting values of the average intensities and percentage match between candidates obtained from each video by each method and reference traffic signs are shown in Table I.

Table 1. Resulting values of analysis

Video created in early hours with ideal light conditions						
Detection method	**Colour-based**		**Shape-based**		**Hybrid**	
Number of recognized traffic signs	26		26		31	
Average intensity value (all candidates)	146,1	57,3%	148,2	58,1%	164,5	64,5%
Percentage intensity value (only recognized)	188,5	73,9%	187,2	73,4%	190	74,5%
Video created in early hours with low light conditions (fog)						
Detection method	**Colour-based**		**Shape-based**		**Hybrid**	
Number of recognized traffic signs	23		25		28	
Average intensity value (all candidates)	140,8	55,2%	151	59,2%	148,9	58,4%
Percentage intensity value (only recognized)	182,6	71,6%	184,6	72,4%	184,6	72,4%

Video created in cloudy weather						
Detection method	**Colour-based**		**Shape-based**		**Hybrid**	
Number of recognized traffic signs	24		26		30	
Average intensity value (all candidates)	152,5	59,8%	153,8	60,3%	157,1	61,6%
Percentage intensity value (only recognized)	184,9	72,5%	183,9	72,1%	198,5	74,3%
Video created at night						
Detection method	**Colour-based**		**Shape-based**		**Hybrid**	
Number of recognized traffic signs	11		15		13	
Average intensity value (all candidates)	76,8	30,1%	80,8	31,7%	80,1	31,4
Percentage intensity value (only recognized)	187,9	73,7%	190	74,9%	191,8	75,2

4. Conclusion

Vertical traffic signs recognition system is a system for vertical traffic signs detection and recognition. In this paper this VTSRS have been describes in previous chapters in detail. The lists of candidates of vertical traffic signs obtained from each video have been founded by three different methods. Each list contains 38 real candidates of vertical traffic sign. These candidates were compared with the reference vertical traffic signs stored in database by Cambridge Optical Correlator. The average values of intensities and percentage match of compared images were obtained. If the threshold was set to lower value than 70%, the number of recognized traffic signs will increase.

Each of detection method (color-based, shape-based and hybrid) have different advantages and disadvantages. Because of the complex environment of the traffic and the scene around them, traffic signs can be founded in different conditions. The color of the traffic signs fades with time by exposure of sun beams. The visibility of the traffic sign depends on the weather condition like rain, clouds, fog or snow and time of day or season. The objects in the scene like vehicles, buildings, billboards or others might be similar to traffic signs by color, shape or booths. In addition to this, the surface of the traffic signs might be polluted, distorted, content unreadable or damaged. All of that had significant impact on detection and recognition.

The videos were obtained by HD color video camera in different light and weather conditions. These conditions affected the success of each detection method in different way. So, each method might have different success rate in different light and weather conditions.

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