Cambridge Correlator in Driver Assistance Systems

[1]T. Harasthy, [2]Ľ. Ovseník and [3]Ján Turán

Abstract—**This paper discusses the very actual and important issue of current time, the safety of road traffic. Many car designers are presently concentrating on proposing cars with modern design, but driver and crew safety is also necessary. Traffic Signs Recognition Systems are presently implemented in many cars to obtain better safety of the driver and comfortable driving. Traffic Sign Recognition system presented in this paper as a part of Driver Assistance System uses Cambridge Correlator as image comparator. Two images (reference traffic sign and input traffic sign) are compared according to two criteria, similarity and relative position.**

***Index Terms*— Color filtering, Joint Power Spectrum, Optical Correlator, Traffic Sign Recognition**

I. INTRODUCTION

THE Driver Assistance System (DAS) is nowadays usual and required accessory in many types of cars. There are many forms of DAS. The major role of DAS could be various, because each DAS can be specialized to different target [1,2,3,4]. There are systems as The Park Assistance System, Traffic Sign Recognition System, etc., which are situated in cars to protect the driver and the passengers of the vehicle [1,5,6,7,8]. These individual parts of DAS are connected with each other to obtain safe and comfortable drive. Each of these individual parts of DAS has its requirements to captured input information. The paper concentrates on Traffic Sign Recognition System based on Optical Correlator. This part of DAS requires captured color video scene which can include Traffic Sign. Video scene is captured from color CMOS sensor situated in car. These captured video scenes are preprocessed with proposed algorithm and then ROI is compared using Optical Processor (Correlator). As Optical Correlator (OC), the Cambridge Correlator (CC) is used [9,10,11].

Cambridge Correlator is a device which can compare two images or two-dimensional (2D) data sets at very high speed. There are two types of OCs. The first one is based on Vanderlugt filter called also Matched Filter Correlator (MFC). Cambridge Correlator belongs to second group of OCs, based on Joint Transform and is called Joint Transform Correlator (JTC) [12,13,14,15]. Both types of OCs compare images according to two criteria: similarity and relative position. JTCs require reference image (database of traffic signs) and preprocessed input image (ROI from input scene) aligned each other in input scene of correlation process. Output of correlation is pair of correlation peaks per match. Intensity and position of correlation peaks give information about which traffic sign from database was recognized [14,15].

Due to rapid progress in key elements technology (SLM, CMOS, LD and Fourier optics), the optical correlators are now commercially available and widely used for various applications in military target detection, navigation, security (face and fingerprint detection), medical and industrial image analysis [12,13,14,15].

The goal of this paper is to present experiments with DAS based on Cambridge Correlator used in recognition stage of the proposed new traffic sign recognition system [9,10,11].

The paper is organized as follows. Chapter II is devoted to basic color models. Block diagram of the whole proposed Traffic Sign Recognition System is described in Chapter III. Main blocks and their functions are discussed. Chapter III also explains the details of pre-processing of input scene and detection of ROI. Also it is devoted to describing applications of optical correlation with using Cambridge Correlator and explains identification traffic signs from correlations peaks. Experiments and results with proposed system are described in Chapter IV. Conclusions are covered in Chapter V.

II. BASIC COLOR MODELS

Color images can be modeled as three-band monochrome image data where each band of data corresponds to a different color. The actual information stored in the digital image is the brightness information in each spectral band. When the image is displayed, the corresponding brightness information is displayed on the screen by picture elements that emit light energy corresponding to that particular color.

Typical color images are represented as red, green and blue, or RGB images. Using 8-bit monochrome standard as a model, the corresponding color image would have 24 bits/pixel – 8 bits for each of the three color bands. RGB color model is shown in Fig. 1 [16,17].

The final color depends on combination of these colors. As it's known, every byte can encode values in range from 0 to 255, so we can create 16777216 various colors by combination of three basic color values [17].

Manuscript received July 6, 2012, revised September 26, 2012.

F. T. Harasthy. Technical University in Košice, Department of Electronics and Multimedia Communications, Košice, Slovakia (corresponding author phone: 055 602 4277; e-mail: tomas.harasthy@ tuke.sk).

S. Ľ. Ovseník, Technical University in Košice, Department of Electronics and Multimedia Communications, Košice, Slovakia.

T. J. Turán Technical University in Košice, Department of Electronics and Multimedia Communications, Košice, Slovakia.

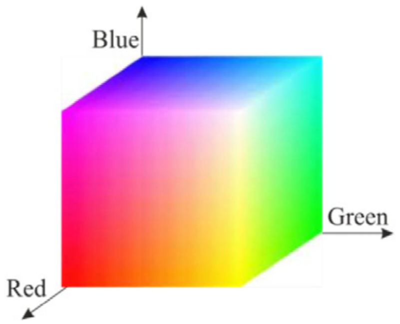

Fig. 1. RGB color model.

In many applications, RGB color information is transformed into mathematical space that decouples the brightness information from the color information. After this is done, the image information consists of one-dimensional brightness, or luminance, space and a two-dimensional color space. Now the two-dimensional color space does not contain any brightness information, but it typically contains information regarding the relative amounts of the different colors. An additional benefit of modeling the color information in this manner is that it creates a more people-oriented way of describing the colors.

For example, the Hue/Saturation/Value (HSV) color transform allows the description of colors in terms that we can more readily understand (Fig. 2) [16,17].

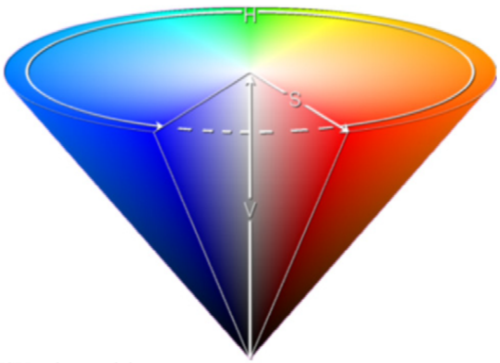

Fig. 2. HSV color model.

The Value represents quantity of white light or specifies the rate of light reflectivity. The Hue is what we normally think of as “color” (e.g. blue, purple, red, yellow etc.). It can be in range from 0 to 360 degrees. The value of Saturation labels quantity of grey color in proportion to basic hue. It can be in range from 0 to 100 % [16,17,18].

III. TRAFFIC SIGN RECOGNITION SYSTEM

Traffic Sign Recognition is one of most important part of DAS [1,5,6,9,10]. These systems provide information of the road signs on the way and guide the driver. DAS helps the driver to recognize the traffic signs earlier and accurately. In ideal conditions this system could avoid false recognition (or misleading recognition) of traffic signs caused by various human factors (inattention, tiredness, sleepiness or micro-sleep). Thus, the traffic sign recognition system makes the driving safer and easier. The outdoor traffic scene, due to illumination changes (day, night, haze, snow, fog, rain, etc.), shadows, partial occlusions, sign rotation and damage becomes a very challenging and difficult task [7,9,10].

Fast preprocessing time is very important to operate the recognition system in real time environment. The systems consist of four main components (Fig. 3).

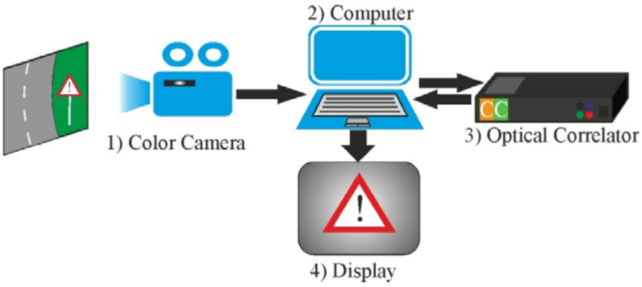

Fig. 3. Hardware scheme of developed system.

1) Color Camera, traffic scene has to be captured by the color camera (CMOS is mostly used). Color interpretation of input traffic scene is required due to remove background of traffic sign (color filtering).
2) Computer, pre-processing of input scene is necessary due to minimize of DC noise in correlation process. ROI is defined in input scene using color filtering and background removing.
3) Optical Correlator (Cambridge correlator) is used to compare ROI with database of traffic signs. Output of correlation consist of two correlations peaks per match, situated in exactly defined positions. Intensity of correlations peaks is measure of similarity between compared objects.
4) Display serves to caution of driver.

These four main components are used in the whole system.

Block diagram of developed Traffic Sign Recognition System is shown in Fig. 4 [9,11]. It consists of three major functional blocks:
1) Preprocessing,
2) Optical Correlation
3) Traffic Sign Identification

Traffic scene is captured with the CMOS color camera. From traffic video stream the key frame is extracted and then used in next processing. As key frames are referred only PCM coded reference frames from coded video sequence, which usually define also the starting point of any smooth transition in the scene. So key frames can be simply extracted from coded video and processed using PC.

Next processing consists of converting key frame from RGB to HSV color space. The RGB color representation is far from human color concept. Image processing in RGB color representation has several disadvantages: the RGB components depends on light intensity, colors, which for a human vision system might be perceptually close, do not have to be close (in Euclidean distance) to each other in RGB space and smoothly shaded surfaces might correspond to several cluster in a RGB color space [16,17].

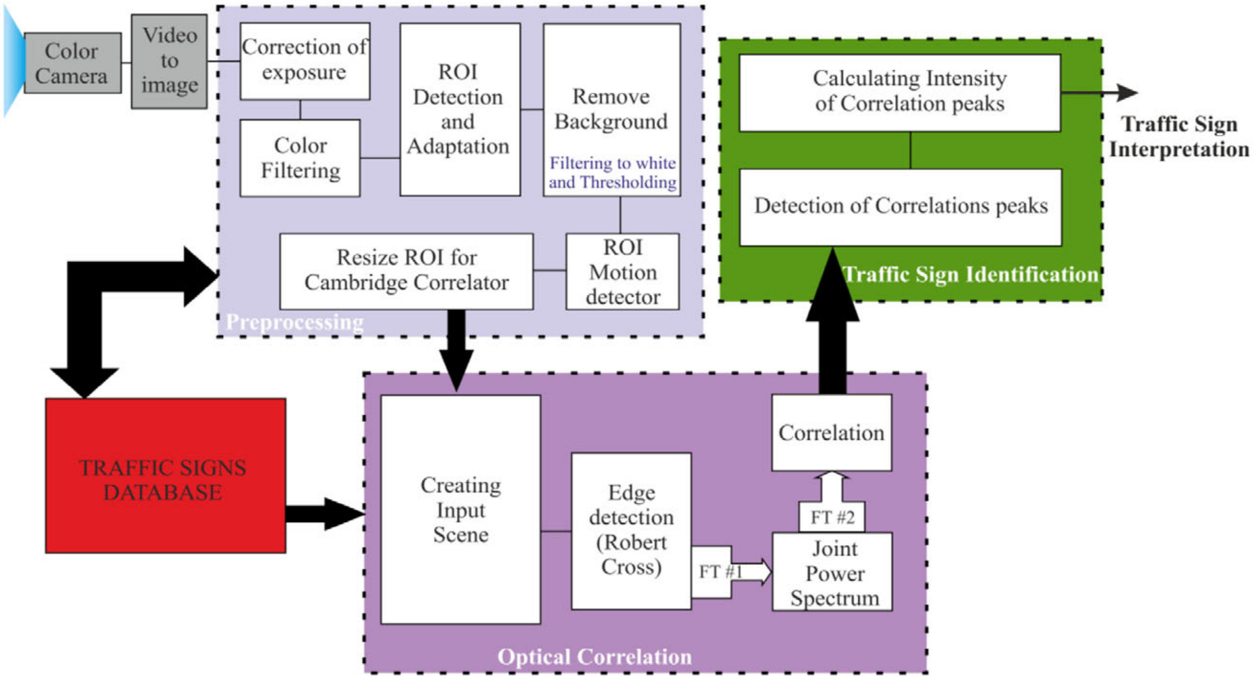

Fig. 4. Block Diagram of Traffic Sign Recognition System with Cambridge Correlator.

This indicates that color filtering in RGB space is very affected by light condition changes in the processed traffic scene. The used HSV color space is much less sensitive in light condition changes than the RGB color space [16,17].

A. *Preprocessing of input scene*

Traffic scenes used in our experiments were obtained from a real road (Fig. 5a). The correction of exposure is required due to different light conditions when the traffic scenes were grabbed [9].

Next step of preprocessing is Color Filtering. In this step the irrelevant color clusters are removed from input traffic scene. Colors filters are designed to remove all colors expect Red, Blue and Yellow. As is mentioned above all input traffic scenes are converted in HSV color space. The color segmentation is processed. Every traffic sign has its dominant color. On the Slovak roads most often Yellow, Red and Blue color are used. This means we need to create three binary maps, one for each of these colors. By analyzing hue component (H), we can identify Blue, Yellow and Red regions in our processed image.

For each image pixel is possible to use hue-based detection for Blue, Red and Yellow color. For each color the following equations are used

$$Y = e^{\frac{-(x-42)^2}{30^2}} \tag{1}$$

$$R = e^{\frac{-x^2}{20^2}} + e^{\frac{-(x-255)^2}{20^2}} \tag{2}$$

$$B = e^{\frac{-(x-170)^2}{30^2}} \tag{3}$$

Equations (1) gives values for Y close to 1 for Yellow regions, Eq. (2) gives values for R close to 1 for Red regions and Eq. (3) gives values for B close to 1 for Blue regions. In this equations we can see, that H can be in the range of 0-255 [9,10,16]. Yellow can be detected near value 42, Red near values 0 and 255 and Blue value is 170. These equations can be tuned for every other needed color.

Saturation detection value is described by the following equation

$$S = e^{\frac{-(x-1255)^2}{115^2}} \tag{4}$$

From equations (1), (2) and (3) we got 3 values. Every value is multiplied by S value. This value will be D_n, which means normalized. Values D_n close to zero will be discarded, others are processed with following equation

$$D_n = \begin{cases} 0, \mathit{if}\ \det < 0,3 \\ \left(\dfrac{\det - 0,3}{0,7-0,3} \right)^2 \\ 1, \mathit{if}\ \det \geq 0,7 \end{cases} \tag{5}$$

After threshold for detected colors three binary maps (Red, Blue and Yellow) are created.

After color filtering, just relevant colors are available. If the “RED” filter is used, bitmap looks as in Fig. 5b. Images after color filtering also contains color clusters, which are irrelevant for detecting traffic signs. In the next step, the irrelevant color clusters are deleted (Fig. 5b,c). Too small regions and too big regions are discarded. In the first step white point in image is found. Searching is done by rows. After finding the first white point, a method called seed-fill is used. With this method we are finding regions. If the region’s size is lower than 400 pixels, then it is discarded. If the region has more than 16000 pixels then it is also discarded [9,10,11,16].

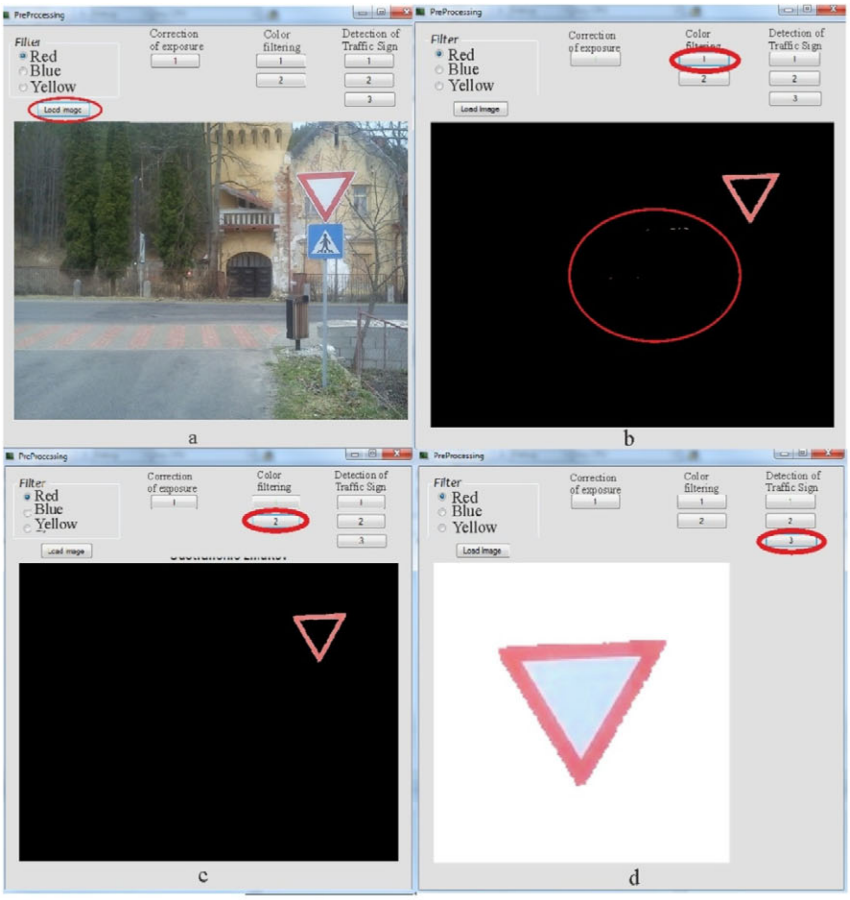

Fig. 5. Red Color Filter action.

After color filtering and irrelevant cluster removing, the potential Region of Interest (ROI) is extracted (Fig. 5b,c,d). The potential ROI is defined at the input image.

ROI crop input image to chosen traffic sign. The ROI Motion Detector uses moving vectors to discard moving features from traffic sign on moving object, i.e. on the vehicle.

The background is removed from input image and then the traffic sign without background is resized to correct size for input to the Optical Correlation (Fig. 5d).

B. Optical Correlation

Optical correlation between input Traffic Sign and chosen reference Traffic Signs is done with using Cambridge Correlator. Due to principle of JTC, the input Traffic Sign and reference sings are aligned to each other in input correlation plane. Joint Transform Correlation consists of three main steps [12,13,14].

First of all, the input correlation plane has to be made as described in Fig. 6a. Input scene is Fourier-transformed to produce Joint Power Spectrum - JPS (Fig. 6b) and then this JPS is pre-processed (mostly threshold is used – Fig. 6c). Pre-pre-processed JPS is Fourier-transformed again to produce optical correlation (Fig. 6d).

Optical correlation consists of pairs of correlation peaks per match. Position and intensity of correlations peaks give information about which Traffic Sign from input scene was recognized [14,15].

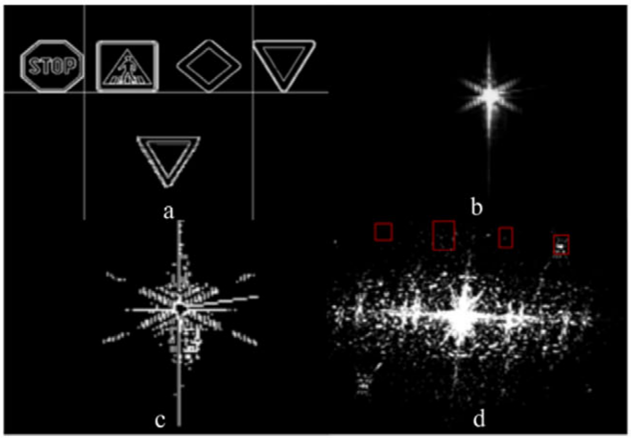

Fig. 6. Correlation process.

C. Traffic Sign Identification

Correlation peaks are monitored in exactly defined areas. If correlation peaks are situated in a defined area, traffic sign assigned to this area was recognized. In the case of Fig. 6, four types of Traffic Signs were inserted in input plane, so four ROIs were monitored in correlation plane.

As shown in Fig. 6, the highest intensity was detected in ROI#4, so in this position was recognized Traffic Sign (Yield).

IV. EXPERIMENTS AND RESULTS

A. Experiments

In our experiments, we used Traffic Sign Recognition System to warning traffic signs. Four types of warning Traffic Signs were chosen. All Traffic scenes were captured in real traffic on Slovakia roads. Tested signs were “Bend to left”, “Bent to right” “Double Bend First to Right” and “Double Bend First to Left”. Traffic Signs used in experiment are shown in Fig. 7.

a) BEND TO LEFT b) BEND TO RIGHT c)DOUBLE BEND FIRST TO RIGHT d)DOUBLE BEND FIRST TO RIGHT

Fig. 7. Tested Traffic Signs.

After preprocessing described above, information about color is irrelevant so after background removal we use edge detection to minimize energy of DC noise in correlation process. For edge detection, the Robert Cross operator were used.

Using edge detection, just relevant information for correlation process left and correlation peaks in correlation plane are easily detectable. In this case the four types of traffic signs are tested so monitored areas in correlation plane are situated similarly, as shown in Fig. 6.

As we can see, all tested traffic signs belong to same group of traffic signs (Warning Traffic Signs).

Fig. 8. Symbols of chosen Traffic Signs.

Each traffic sign contains red triangle which is necessary in detecting the traffic sign by using color filtering. However this triangle is adverse in correlation process because match was detected between each of traffic signs.

This triangle was in remove background process marked as background. As input image to correlation process was marked just symbol inside triangle (Fig. 8). This method can be used in many other cases, when are tested Traffic Signs from same category, e.g. Speed Limit traffic signs.

Traffic Signs were captured with ideal and low light conditions, mostly fog. Weak light conditions influence on detection and recognition part of system. In traffic scenes captured with lower visibility were correctly recognized less traffic signs, than in traffic scenes captured with ideal light conditions (ideal visibility).

Example of traffic scene with low visibility is shown in Fig. 9. If traffic scene is captured with low visibility, the two cases can occur. Traffic scene captured with weak visibility has less saturation and red (or other) color is not exactly defined.

Fig. 9. Traffic Scene with ideal (a,c) and low (b,d) visibility.

If color will not detect in traffic scene, ROI will not be defined and Traffic Sign recognized (no correlation peak in correlation process). If color will be detected just partially, ROI can be defined imprecisely. In this case there will be correlation peak in correlation plane with lower intensity than with traffic scene with ideal visibility.

Intensity of peaks obtained by correlation is represented in 8 bit depth grayscale, so every peak can take values from 0 to 255. Correct setting decision level of intensity of peak is necessary.

In the next experiment, the Speed limit traffic signs were used. Three traffic signs were chosen and tested. All speed limits traffic signs contains red circle, so in preprocessing the “RED” filter was used. Every red circle on the traffic scene was defined as a ROI. After defining ROI, the background was removed. The red circle of the traffic sign was defined as a background, because every speed limit traffic sign contains this circle and correlation is too high between any two signs. Background was deleted first to red color, and then to black color. After this preprocessing, just black symbols inside the red circle were left. As an input to the correlator only numbers 40, 60 and 80 were used. Fig. 10a illustrates the input scene of the correlation process. Output of correlation is illustrated in Fig. 10b. Fig.10c describes the output of the correlation process in more detail. Since the input scene consists of symbols containing number “0”, correlation peaks were detected between any two compared symbols. Correlation between the same symbols was much higher, so as a match between symbols “40” was defined.

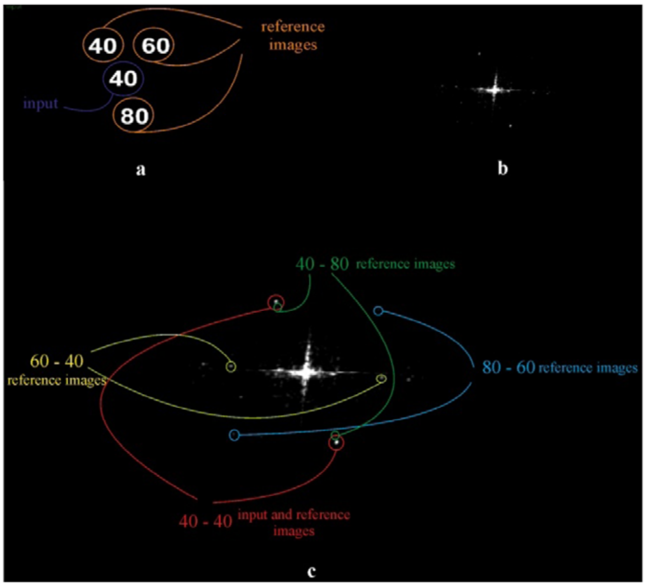

Fig. 10. Compare of similar Traffic signs.

B. Results

The developed Traffic Sign Recognition system was tested on real traffic scenes captured by color CMOS sensors and preprocessed with the algorithm described above. Traffic scenes were captured with ideal and low visibility. Traffic scenes with lower visibility were not recognized because of strong destruction of color. If the color of the traffic sign cannot be determined, no ROI can be defined and the output of the correlation does not contain any correlation peaks.

Results of experiments are recorded in Table I.

TABLE I
RESULTS OF EXPERIMENTS

Traffic Sign	Average Recognition Success [%]		
	Ideal visibility	Low visibility	Entire Recognition Success
Bend to left (35)	92	83	87
Bend to right (23)	94	86	90
Double bend first to right (32)	91	86	88
Double bend first to left (30)	90	83	86
Speed Limit “40” (10)	92	88	90
Speed Limit “60” (12)	90	88	89
Speed Limit “80” (10)	93	89	91

V. CONCLUSIONS

Nowadays the Driver Assistance System is a necessary part of almost each type of automobiles. DAS can consist of many parts which can actively or passively assist the driver when driving a car. In this paper one part of assistance system, the Traffic Sign Recognition System was presented based on Optical Correlator.

The system recognizes Traffic Signs from captured traffic scenes by color CMOS camera. The major information about basic color model was described. Block diagram of the whole Traffic Sign Recognition System was shown. The block diagram consists of three main parts, which can be independently modified, supplemented and improved.

Color filters were designed and used to detect relevant colors of traffic signs. In our experiments we used red color filter to detect red traffic signs. In these experiments the warning traffic signs were tested. ROIs were detected using these filters and other processing like irrelevant cluster removing etc. (Fig. 4). Experiments were done with four types of warning traffic signs. In experiments real traffic scenes were used captured at low and ideal light conditions (foggy and sunny days). The results of experiments demonstrate that the main advantage of this system is the usage of the optical correlator. Very fast processing time can save a lot of time and the driver can be earlier warned. Recognition of traffic signs using optical correlator is much faster than other pure software implementations running on PC. There are many Traffic Sign Recognition Systems mostly based in shape detection and color segmentation such as Automatic Detection and Classification of Traffic Signs [5], Real Time Road Signs [2] and Traffic Sign Recognition System [3,6]. All of these systems are based on pure software realization, so using hardware implementation can speed up process of recognition. The proposed system uses detector of traffic signs similarly as in other systems, but the process of recognition is done using optical processor so it is performed in real time. Processing time of Driver Assistance System using optical correlator is limited just with detection part, which can be improved using FPGA modules.

Using Optical Correlator in Driver Assistance System is not limited just to Traffic Signs Recognition System. Using optical processing can be very helpful in systems for detection of road lane markings as well. Thanks to fast processing time of optical processors the application of Optical Correlator in many recognition systems is very attractive and requested.

ACKNOWLEDGMENT

We support research activities in Slovakia / Project is co-financed from EU funds. This paper was developed within the Project "Centrum excelentnosti integrovaného výskumu a využitia progresívnych materiálov a technológií v oblasti automobilovej elektroniky", ITMS 26220120055.

REFERENCES

[1] J. C. Noyer, P. Lanvin and M. Benjelloun, “Correlation-based particle filter for 3D object tracking,” *Integrated Computer-Aided Engineering*, 16:2, pp. 165-177, 2009.

[2] A. Broggi, P. Cerri, P. Medici and P.P. Porta, “Real Time Road Signs Recognition,” *Intelligent Vehicles Symposium,* 2007 IEEE Volume, Issue, 13-15, 981 – 986, june 2007.

[3] M. Fifik, J. Turán and Ľ. Ovseník, “Traffic Signs Recognition Experiments with Transform based Traffic Sign Recognition System,” *17th Symposium IMEKO TC 4, 3 rd Symposium IMEKO TC 19 and 15 th IWADC Workshop*, Instrumentation for the ICT Era, September 8 – 10, 2010, Kosice, Slovakia.

[4] L. Luo and X. Li "A method to search for color segmentation threshold in traffic sign detection," Fifth International Conference on Image and Graphics, 2009.

[5] F.P. Paulo, L.P. Correia, "Automatic detection and classification of traffic signs", *Image Analysis for Multimedia Interactive Services,* WIAMIS, 6-8 June 2007.

[6] M. Fifík, J. Turán, Ľ. Ovseník and K. Fazekas, "Experiments with a Transform based Traffic Sign Recognition System"*, Proc. Of 17th International Conference on System, Signals and Image Processing IWSSIP 2010, Rio de Janeiro, Brazil,* June 17-19, 2010, 227-230.

[7] K. Kastner, T. Michalke, T. Burbach, J. Fritsch and Ch. Goerick, "Attention – based traffic sign recognition with an array of weak classifiers,", IEEE Intelligent Vehicles Symposium University of California, San Diego, CA, USA, 2012.

[8] P. Paclík, J. Novovičová, P. Pudil and P. Somol "Road Sign Classification using Laplace Kernel Classifier," Czech Technical University, Prague, Czech Republic.

[9] T. Harasthy, J. Turan, Ľ. Ovsenik, K. Fazekas, "Optical Correlator Based Traffic Signs Recognition"*, Proc. IWSSIP 2012, Vienna, Austria,*11-12 April 2012, 142-145.ISBN: 978-3-200-02328-4, http://webcache.googleusercontent.com/search?q=cache:YS8e5KzC8fIJ:edas.info/web/iwssip2012/program.html+optical+correlator+based+traffic+signs+recognition+ovsen%C3%ADk&cd=2&hl=sk&ct=clnk&gl=sk

[10] T. Harasthy, J. Turan, Ľ. Ovsenik, K. Fazekas, "Traffic Signs Recognition with Using Optical Correlator"*, Proc. IWSSIP 2011, Sarajevo, Bosnia and Herzegovina,*16-18 June 2011, 239-242.ISBN: 978-9958-9966-1-0,IEEE Catalog number: CFP1155E-PRT.

[11] Ľ. Ovseník, T. Harasthy and J. Turán, "Video Driver Assistance Sytem Using Optical Correlator," 35th Jubilee International Convention on Information and Communication Technology. Electronics and Microelectronics, 21-25 May 2012, Opatija/Abbazia, Adriatic Coast, Croatia.

[12] J. W. Goodman, *Introduction to Fourier Optics*, Colorado: Roberts & Company, Publishers, 186 s. ISBN 0-9747077-2-4, 2005.

[13] T. Naughton, M. Klima, J.Toth, *Improved Joint Transform Correlation Performance Through Spectral Domain Thresholding* [online]. Maynooth, Ireland, 1998,

[14] Cambridge Correlators, http://www.cambridgecorrelators.com, June 2012.

[15] Cambridge Correlators, *Fourier Optics Experimenter*, User Guide.

[16] S. E. Umbauch, *Computer Vision and Image Processing and A Practical Approach Using CVIPtools,* Prentice Hall PTR, Upper Saddle River, NJ 07458, June 1999.

[17] Q. Ye, W. Gao and W. Zeng "Color Image Segmentation Using Density-Based Clustering," ICASSP 2003, China, 2003

[18] L. Luo, X. Li "A method to search for color segmentation threshold in traffic sign detection," Fifth International Conference on Image and Graphics, 2009.

BIOGRAPHIES

T. Harasthy (Ing.) received Ing. (MSc.) degree in 2010 at Department of Electronics and Multimedia Telecommunications, Faculty of Electrical Engineering and Informatics of Technical University of Košice. Since September 2010 he has been at University of Technology, Košice as PhD. student. His research interests include object recognition systems.

Ľ. Ovseník (doc., Ing., PhD.) received Ing. (MSc.) degree in radioelectronics from the University of Technology, Košice, in 1990. He received PhD. degree in electronics from University of Technology, Košice, Slovakia, in 2002. Since February 1997, he has been at the University of Technology, Košice as Associate Professor for electronics and information technology. His general research interests include optoelectronic, digital signal processing, photonics, fiber optic communications and fiber optic sensors.

J. Turán (Dr.h.c., prof., RNDr., Ing. DrSc.) received Ing. (MSc.) degree in physical engineering with honours from the Czech Technical University, Prague, Czech Republic, in 1974, and RNDr. (MSc.) degree in experimental physics with honours from Charles University, Prague, Czech Republic, in 1980. He received a CSc. (PhD.) and DrSc. degrees in radioelectronics from University of Technology, Košice, Slovakia, in 1983, and 1992, respectively. Since March 1979, he has been at the University of Technology, Košice as Professor for electronics and information technology. His research interests include digital signal processing and fiber optics, communication and sensing.