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PROPOSAL OF AUTOMATIC TRAFFIC SIGNS INVENTORY SYSTEM WITH USE OF OPTICAL CORRELATOR

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Abstract. This article describes a proposal of automatic traffic signs inventory system with use of optical correlator. The most critical step of automatic inventory is a recognition of traffic signs in video sequence from camera. Similarity rate of two pictures is given by their cross correlation. Optical correlator is a device which is able to provide the correlation optical way. Advantage of its use is a high speed of image processing. Set of transformation lenses is able to provide a Fourier image in one step. This processing is independent of input image resolution. Result of optical correlation process is an image with correlation peaks. These peaks describe a similarity rate and relative position of compared images from input plane. The main role of automatic inventory system is to search traffic signs in recorded video sequence. Proportion and color homogeneity check of recorded sample describes an actual condition (rate of damage) of traffic sign. Each traffic sign has assigned an information about global position using a coordinates obtained from GPS receiver. Access to inventory result and to control of inventory process is provided through organized graphical user interface.

Keywords: *automatic inventory, Fourier transform, GPS coordinates, optical correlator, traffic signs.*

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1. Introduction

Current development of the transport infrastructure brings a need for effective control and maintenance of the used equipment. Automatic inventory of traffic signs can make the information about actual status significantly more efficient. According to the collected data, it is possible to evaluate the need for maintenance and minimize a failure rate in critical areas based on statistical analysis. This article presents a proposal for an inventory system that utilizes an optical correlator as the core for the detection and classification of individual traffic signs. The first part of the article deals with optical image processing and optical correlator. In the core, the concept of an automatic inventory system is presented, explaining the general functionality and the principle of processing of data obtained from individual peripherals. The next part describes the graphical user interface and the inventory database. There are described the individual parts of the app and the data and relationships that characterize the items of the final inventory list. Finally, the mentioned methods of processing the information and the reasons for their use or their absence in the real inventory system are evaluated. There are also described options for improving the system in the future and plans for developing another version of the automatic inventory system.

2. Optical image processing

The main advantage of optical image processing is a high processing speed. In the case of optical processing, it is not necessary to compare each pixel separately, as it is in the case of conventional electronic processing.

The correlation is defined as the Fourier transform of Fourier images of the input and reference signals *s* and *r* according to Eq. (1):

$$r * s = FT[R \times S] \tag{1}$$

where *R* and *S* are Fourier images of the corresponding *r* and *s* signals. The optical correlation in the 1/f JTC system is realized in two steps of the basic optical Fourier transform.

In the first step, the r and s functions are located and spatially separated at distances

$$(x_0, y_0) \text{ a } (-x_1, -y_1) \tag{2}$$

from the center of the area, which creates an input scene

$$s(x - x_0, y - y_0) + r(x + x_1, y + y_1). \tag{3}$$

Applying the Fourier Transform to the input scene image, we obtain an intensity distribution called a joint power spectrum and defined as:

$$\begin{aligned} &\left|R(u,v)^{-2\pi j[-ux_1 - vy_1]} + S(u,v)^{-2\pi j[ux_0 + vy_0]}\right|^2 = \\ &= (|R(u,v)|^2 + |S(u,v)|^2) + \\ &+R^*(u,v)S(u,v)^{\left[-2\pi j\left(u(x_1 - x_0) + v(y_1 - y_0)\right)\right]} + \\ &+S^*(u,v)R(u,v)^{\left[-2\pi j\left(u(x_0 - x_1) + v(y_0 - y_1)\right)\right]} \end{aligned} \tag{4}$$

Correlation can be obtained by applying another Fourier transform to the obtained joint power spectrum. The intensity distribution obtained in the second step contains the required correlation intensities which are displayed as a pair of symmetric points. The intensity of these points corresponds to the rate of similarity between the reference and the input image. The relative position of these points corresponds to the relative position between the input and the reference image. [8]

3. Optical correlator

The optical correlator is a device that performs a Fourier transform of the two-dimensional signal (image) optical way. Its advantage is the independence of the processing speed from the size of processed image at one moment. The carrier in optical processing is circularly polarized laser light. The light modulated by the input signal is processed by transform lenses system into a Fourier image. Suitable signal processing and multiple transforms in the optical correlator can provide a very fast search and comparison of image samples at the input. The optical correlator consists of several parts necessary for proper operation. The individual parts are described in the text below.

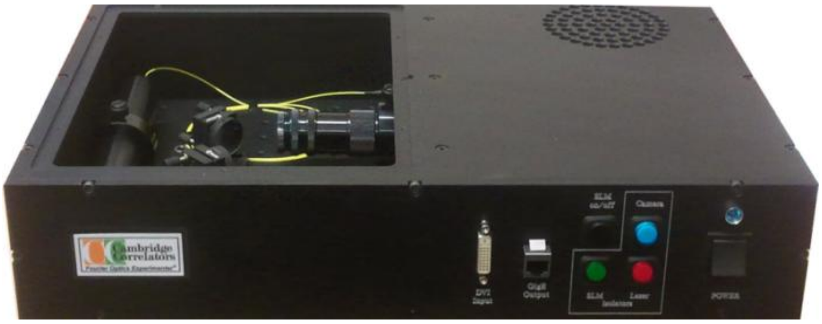


Figure 1. Optical correlator [3]

3.1. Laser Light Source

The optical correlator uses coherent laser light as the carrier. The light source is a laser diode. The light from the laser diode is transmitted by optical fiber to the collimation lenses system. The output of the light source in the optical correlator is the parallel beam of coherent circularly polarized light.

3.2. Spatial Light Modulator

The role of the spatial light modulator is to include information about the input signal (image) into the carrier (laser light). The spatial light modulator consists of liquid crystal matrix that can change its orientation based on the input signal from the control interface. By displaying the input plane on the surface of the spatial light modulator, the corresponding part of the laser light is reflected.

3.3. Transform lenses set

Modulated light passes through transform lenses which perform an optical Fourier transform. The image of the Fourier transform of the input scene is projected in the back focal length of these lenses.

3.4. CMOS sensor

The last step of image processing in the optical correlator is the CMOS sensor field. Transformed light is projected on the CMOS field and the intensity of the individual pixels is transformed into a digital image. This is available at the output of the optical correlator via the GigE Ethernet interface.

In the first step of optical correlator processing, the obtained power spectrum is required to be binarized before further processing. The binarized image is displayed on the surface of the spatial light modulator and the modulated light is reprocessed by transform lenses. Output of the second step represents the distribution of the Fourier transform intensity of processed joint power spectrum. [3]

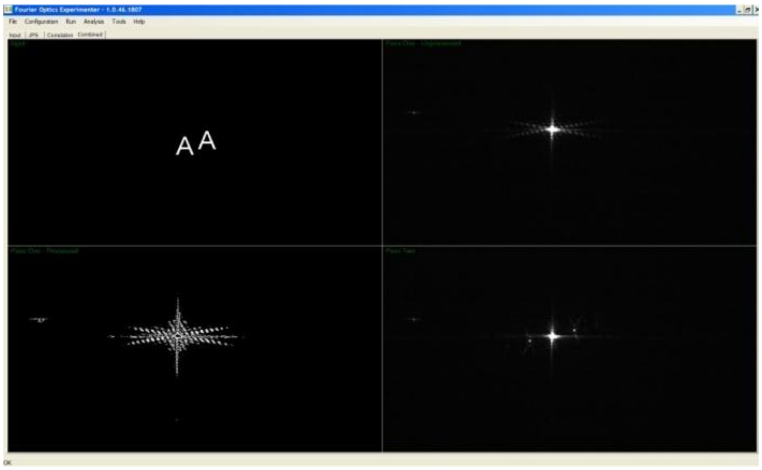


Figure 2. Steps of optical correlation [3]

4. Structure of inventory system

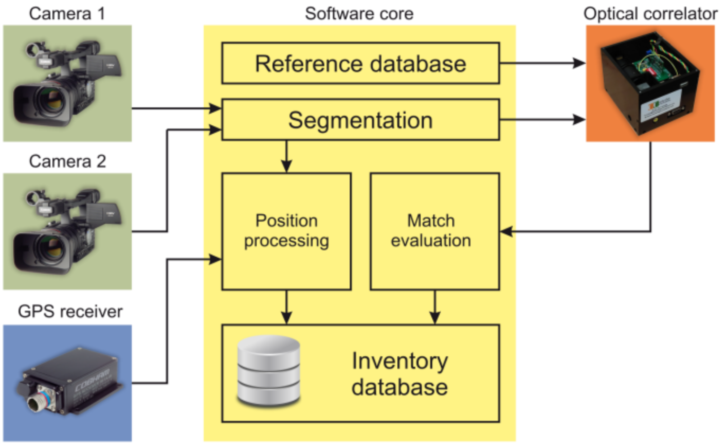


Figure 3. Block scheme of automatic inventory system [17]

The role of an automatic inventory system is to identify and classify traffic signs based on the video sequence from the camera system. Each recorded image needs to be segmented into separate areas, the content of which can be represented by the image of the traffic sign. Binarization of individual areas creates a set of images suitable for the input of the optical correlator. The optical correlator compares individual samples with samples from the reference database. In the case of similarity it writes the recognized traffic sign to the inventory database. During the inventory, information about position based on GPS coordinates is assigned to each sign. GPS coordinates obtained by the receiver near the camera system are subsequently corrected according to the distance of the traffic sign from the receiver and horizontal orientation of receiver. Based on a suitable analysis of the obtained samples, the system also evaluates the condition of the individual signs and signalizes the recorded damages. Block diagram of the system is shown in the Fig. 3, and its basic parts are briefly described in the following text. [12, 17, 20, 21].

4.1. Optical Correlator

The optical correlator is the main computational element in the inventory system. Its role is to evaluate the similarity of images displayed in the input plane. The output is the image of correlation peaks that determine the rate of similarity of compared images. The intensity of these peaks is directly proportional to the similarity of the compared images. Their relative position characterizes the relative position of the compared images in the input plane. Optical correlator communicates with the control software via DVI interface on the input and GigE Ethernet interface on its output.

Table 1. Optical correlator parameters [3]

SLM	
Resolution	1024x768
Bit-depth	8-bit
Pixel pitch	9x9 um
Reflectance	62% at 633nm
Active area dimensions	9,3x7mm
LC	Twisted Nematic Mode
Operationg Wavelength	430-650nm
Input Polarisation	Parallel with longest side
Contrast Ratio	350:1
LC response time	200us
Interface	DVI
Input voltage	5V DC
CAMERA	
Interface	GigE Ethernet
Max Frame rate	Up to 196 fps
Resolution	656x494 pixels
Output	10-bit output
LASER	
Type	635nm laser diode launch with pigtail single mode fibre
Power	2.5mW variable output

4.2. Stereoscopic Camera System

Using the stereoscopic camera system, the inventory system acquires an image of the road and the surroundings from the segment the inventory is realized on. The cameras are horizontally displaced, which makes it possible to reconstruct the location of the recorded objects in the space. The connection between the camera system and the control software is provided via the USB interface.

Table 2. Video cameras parameters [14]

Native resolution	640x480px
Enhaced resolution	1280x720px
Max Frame rate	Up to 30fps
Interface	USB 2.0
Power supply	5V DC

4.3. GPS Receiver

GPS receiver acquires information about the position and horizontal orientation of the inventory system. Information is based on time stamps received from several satellites in the orbit of the Earth. The obtained values are available in the form of NMEA sentences with exactly defined structure. The control software communicates with the GPS receiver via the USB interface.

Table 3. GPS receiver parameters [16]

Chipset	u-blox 6 UBX-G6000-BT
Frequency	GPS: L1, 1575.4200 MHz
Auto Baud Rate	Up to 115200 bps
Sensibility	Max. -162 dBm
Positioning accuracy	2.5 m CEP (Circular Error Probable) 2 m CEP with SBAS
Interface	USB 2.0
Power supply	5 V DC

4.4. Control Software

The control software of the inventory system communicates with the connected peripherals and receives the information needed for processing. It prepares the image obtained from the cameras for the input of the optical correlator, assigns the GPS coordinates to the recorded image and evaluates the output of the optical processing. Finally, the processed information will be written into the inventory database with all the information that corresponds to the list items.

5. Segmentation of input scene

Since the optical correlator uses coherent (one-color) laser light for its function, it can process only images in binary form. It is needed to extract the required areas from the input scene recorded by the color camera, which may include an image of one of the searched traffic signs. In the following text there are described a possible methods of pre-preprocessing and the advantages and disadvantages of using them. [9, 21].

5.1. Color Filtering

Color filtering is the basic method used for image pre-processing and segmentation. By color filtering, we can divide the overall image into segments corresponding to the defined parameter. The result of monochromatic conversion and thresholding is a group of shapes in the form of binary images. Color filtering parameters can be defined using different color spaces. The primarily used color space is RGB (R-red, G-green, B-blue), which determines the filter values for each basic color component. A more effective model for use in an inventory system is the HSL (H-hue, S-saturation, L-lightness) model whose parameters better match the perception of colors with the human eye. This model allows you to define hue of filtered color independently from saturation and intensity. This makes it possible to define a relatively narrow range of parameters for filtering under different lighting conditions.

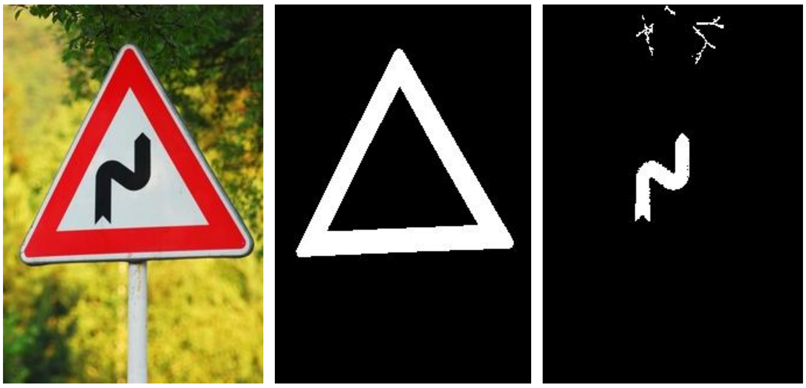


Figure 4. The image segmentation based on color filtering [17]

5.2. Edge Detection

Edge detection in the recorded image is based on searching for areas with sharp color difference. The only edge detection input parameter is the minimal gradient that this method should respond to. Since it isn’t possible to select a specific color by this pre-processing method, it can not be used separately. However, the edge detection method can be used as an additional method for color filtration. By comparing the edge of the object after color filtration with the edge obtained by edge detection, it is possible to increase the probability of correctly recognized and classified traffic sign.

Figure 5. The image segmentation based on edge detection [17]

5.3. Stereoscopic Reconstruction

Stereoscopic reconstruction is based on image capture by two cameras that are displaced horizontally. This method simulates the human perception of spatial layout of objects. The principle of estimating spatial placement of objects is based on different locations of individual objects in corresponding images from cameras of stereoscopic camera system. The result of total image matching is a group of separated object shapes with the same distance from the camera system (Depth map). Stereoscopic depth map generation is the ideal method for increasing the probability of correct identification of traffic signs. By verifying the accuracy of the shape from a depth map, we eliminate cases of false recognition, e.g. due to a similar picture on a billboard placed in the field of vision of the camera system. However, the method of stereoscopic reconstruction is a computational solution that is not usable in real-time applications, due its computational power requirements. [4]

5.4. Structure from Motion

The structure from motion method is an algorithm for reconstruction of spatial layout of objects based on interframe analysis. A moving camera is a prerequisite for using this method. Areas representing separate objects have different relative horizontal dynamics. This means that the objects near the camera system have a greater horizontal distance between the frames than the more distant objects. By comparing the motion vectors, it is possible to create groups of objects with the same direction of motion and the same velocity. The result is a depth map with shapes of separate objects in the space. The method requires recording with a high resolution camera and a high dynamic range for its operation. Processing of high-quality images eliminates significant errors in capturing of traffic signs with a relatively homogeneous background. [2, 5, 11, 13].

Figure 6. Structure from motion example [17]

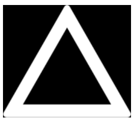
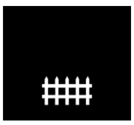
6. Recognition and classification

Each traffic sign is represented by a combination of shapes and colors. Its surface consists of one or several color parts. Individual parts of the traffic sign represent their role in the recognition and evaluation process. The most important part is the basic shape of the traffic sign, according to which it is possible at least to determine the category of traffic sign. In most cases, the exact type can be determined according to the pictogram in the center of the traffic sign area. The number of steps of one traffic sign recognition depends on its category. The informational signs consists of continuous surface of a single color. They are identified both type and category of traffic sign during the processing of this category. Restriction and command traffic signs contain an internal pictogram in addition to the basic shape. The basic shape in this case determines only the traffic sign category. The exact type is determined according to an internal pictogram.

6.1. Structure of Reference Database

The reference traffic sign database consists of three groups of three colors, representing the basic shape of traffic signs. The core of each group is a set of possible shapes of a particular color. Each shape has subsequently defined color groups of reference pictograms that can be inside the shape. The tables above show various examples of corresponding shapes with color grouping and with the information about the function of a particular shape in the recognition process. [22, 24]

Table 4. Red shape based traffic signs

<table>
<tr><td rowspan="2">Red category</td><td rowspan="2"></td><td rowspan="2">Black type</td><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

		Black status		
		-		

Table 5. Blue shape based traffic signs

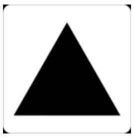
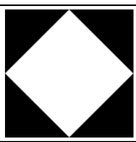
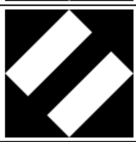
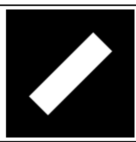
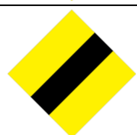
Blue category		Black type		
				
		-		

Table 6. Yellow shape based traffic signs

Yellow		-		
		Black status		

7. Position of traffic sign

One of the functions of the inventory system is to determine the exact GPS position of the traffic sign. The GPS receiver receives the coordinates of the position of inventory system located in the vehicle that performs the automatic inventory. Since the location of the traffic sign is different from the current position of the inventory system, it is necessary to correct these coordinates. The correction is based on the distance of the traffic sign from the camera system. Consideration is also given to the orientation of the camera system, which ensures the precise determination of the absolute position of the traffic sign in the space. Measuring the distance of a traffic sign from a camera system is based on the principle of stereoscopy. By comparing the position of a particular object on the two corresponding frames, it is possible to determine the distance of the object from the camera system.

7.1. Determination of Position

Coordinates acquired by the GPS receiver determine the current position of the camera system. However, this position is more or less different from the position of the traffic sign itself. To determine the precise position of the traffic sign, it is necessary to make a correction of the obtained position based on the distance of the traffic sign from the camera system and its horizontal orientation. Information about horizontal information is a part of the NMEA sentences obtained from a GPS receiver. The distance of the traffic sign can be obtained by stereoscopic measurement. The input parameter of this measurement is the difference in the location of a particular traffic sign between the corresponding pictures recorded at one moment. A necessary part of measurement is a dependency curve between the difference in position on the frames and the real distance. This curve is obtained during the calibration of camera system before recording. The second parameter obtained from the video is the relative position of the traffic sign relative to the horizontal orientation of camera system at the moment of measurement.

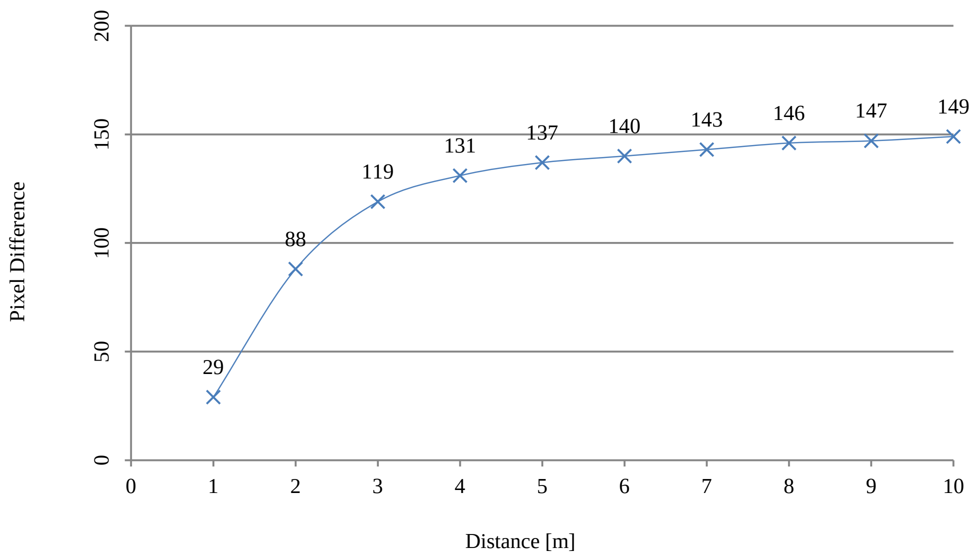


Figure 7. Pixel difference from distance dependency curve

The obtained distance and angle are used to correct data from GPS receiver. The exact GPS coordinates of traffic sign are determined by the following relationships.

$$\varphi_2 = \arcsin(\sin\varphi_1 \cdot \cos\delta + \cos\varphi_1 \cdot \sin\delta \cdot \cos\theta)$$
$$\lambda_2 = \lambda_1 + \text{arctan2}(\sin\theta \cdot \sin\delta \cdot \cos\varphi_1, \cos\delta - \sin\varphi_1 \cdot \sin\varphi_2) \qquad (5)$$

where

φ: latitude,
λ: longitude,
θ: bearing (clockwise from north),

δ: angular distance *d/R*,
d: distance travelled,
R: earth's radius

7.2. Stereoscopic Synchronization

For reliable measurement, it is necessary to ensure synchronization of both cameras of the stereoscopic system so that each pair of acquired images is recorded at one time and therefore the difference in the position of the object between the frames exactly corresponds to the distance.

The control software during camera image capture eliminates the effect of mutual delays that may be caused by the absence of hardware synchronization of these cameras. Standard recording of images on the basis of internal camera timing without synchronization causes each frame to shift over time, making it impossible to perform a reliable reconstruction of the position of objects in the space. Direct writing to a file causes image loss at the time of writing, as this may take a long time depending on the used storage device. Elimination of unwanted effects is accomplished by storing current images from both cameras into the cache at one moment. [15, 18, 23].

7.3. Accuracy of Determination

Positioning accuracy depends on several factors. The primary factor is the accuracy of the GPS receiver itself. Depending on the used technology, the accuracy of the receivers varies from a few centimeters to several meters. Another issue of accuracy is the period of getting the current GPS position by the receiver. For commonly available receivers, this period in optimal operating modes is about 1 second. As the vehicle moves, there is a problem with the assignment of accurate GPS coordinates to each frame during recording. The third factor affecting the accuracy of the positioning of the traffic sign is the accuracy of synchronization of the camera system. If the corresponding images are mutually shifted over time, measuring the distance of the traffic sign from the camera system is inaccurate. The following formulas define partial errors and the total error of the inventory system based on GPS receiver error, inventory vehicle speed, and camera system synchronization error. [19]

The error generated by the low recovery frequency can be determined by the Eq. (6).

$$\delta_T = \frac{v_v}{f_{GPS}} \tag{6}$$

If the vehicle has a constant speed within the retrieval period, we can divide this error into frames that have been recorded for a given period.

$$\delta_{T1} = \frac{\delta_T}{f_v} \tag{7}$$

Incorrect synchronization of the stereoscopic system causes the incorrect determination of the traffic sign distance from the camera system. The dependence of time shift and measurement error is expressed by Eq. (8).

$$\delta_{sync} = v_v \cdot \Delta t_f \tag{8}$$

Total error of GPS coordinates is determined by the sum of partial errors according to Eq. (9)

$$\delta = \delta_{GPS} + \delta_T + \delta_{sync} \tag{9}$$

Respectively, with corrected refresh rate error according to the Eq. (10)

$$\delta_1 = \delta_{GPS} + \delta_{T1} + \delta_{sync} \tag{10}$$

where

δ_{GPS}: error of GPS receiver [m]
δ_T: error of refreshing frequency [m]
δ_{T1}: δ_T with correcture [m]
δ_{sync}: error of synchronization [m]
Δt_f: stereo frames time shift [s]
f_v: video framerate [fps]
f_{GPS}: refreshing frequency [Hz]
v_v: speed of vehicle [m.s^{-1}]

8. Traffic sign condition

Another feature of the inventory system is to verify the condition of the recognized traffic sign. Traffic sign condition depends on several parameters. The first group consists of geometric parameters such as the correct size, position, orientation and rotation of the traffic sign. The second group consists of parameters that are dependent on the physical changes on the surface of the traffic sign. Corrosion and fading of color pigments significantly affect the total appearance and effectiveness of the visual impact of the traffic sign.

8.1. Proportion Check

The first parameter that the inventory system evaluates as part of the traffic sign verification is its proportions. Each traffic sign has defined its own dimensions. However, one type of traffic sign may have defined multiple dimensions. Finding the exact dimensions of a real traffic sign does not make sense in this process. Despite the many possible sizes of the recorded traffic sign, proportions of defined dimensions of one type are constant. By comparing these proportions between the real and the reference sample, it is possible to evaluate whether the traffic sign has the correct horizontal orientation or is deflected in a different direction.

8.2. Pictogram Check

The first step of recognition is to search for the basic shape of the traffic sign. In most cases, this shape characterizes the category of traffic sign. Recognition of the basic shape means that the traffic sign of a given category is located at a given location. Searching the pictogram in the next step has two meanings. The first is to determine the exact type of traffic sign. Another important thing is checking the status of the traffic sign. After the successful recognition of the pictogram, it is likely that the condition of traffic sign is suitable. In the case that the highest similarity to the reference database is below the critical minimum, the traffic sign is likely to be damaged by color or by various stickers.

8.3. Texture Homogeneity Check

Traffic signs may be affected by corrosion, which greatly affects the visual impact of this sign on the driver. After successful recognition of the basic shape and pictogram, it is possible to select the complement to these two parts, which represents the residual (in most cases white) area of the traffic sign. This area is the ideal place for testing the presence of corrosion on the traffic sign surface. Since the integrity of this area is not affected by the color filter, the result is a compact shape with low color dispersion. By testing the color homogeneity of this area, it is possible to detect the presence of degradation of the material on the surface, or a slight deformation of the traffic sign, which is characterized by different light reflection in different parts.

8.4. Contrast Check

Because of the different light conditions and camera sensor noise, the color filter permits a wider range of colors instead of just one specified color. The color filter can accept shapes of traffic signs whose color saturation is reduced by fading the original color. By defining the minimum required contrast, it is possible to evaluate whether the colored parts of the traffic sign have sufficient mutual contrast. This check is provided by calculating the average values of the color parameters in the individual color parts and comparing them and evaluating the difference of the corresponding parameters. [1, 6, 7, 10].

9. Graphical User Interface (GUI)

Graphical user interface is the irreplaceable tool for communicating the user with the inventory system. Its options range from the basic setting of individual peripherals, through recording to detailed monitoring of the inventory process.

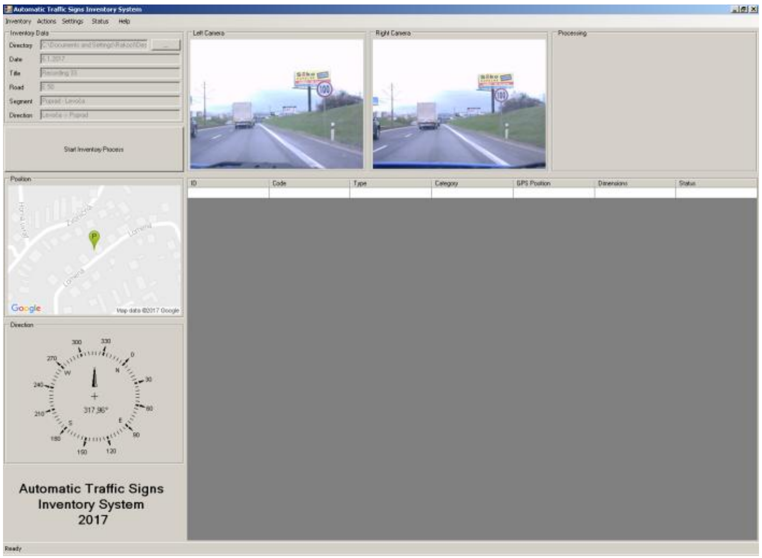


Figure 8. Main window of control GUI

The main part of the GUI is the main window. The processed inventory is displayed in the form of a spreadsheet that contains all the information about the traffic sign being recorded, including its position and the condition information. By selecting the directory with the record, the basic data about the processing section will be filled in. At the top of the window there are the initial images from both cameras of the camera system. The left side of the window is a space with a marked GPS position and orientation of the camera system that are relevant to the current image. When the inventory is started, the application starts scanning and manipulating objects in individual frames. Compared real and reference samples are displayed in pairs in the top right corner of the main window. Simple main menu commands are used to store inventory, load from a file, or prepare the application for a new inventory. In the following text, there are described the most important GUI dialogs.

9.1. Recording

The "recording" dialog primarily serves to record the segment of the road which it is needed to perform inventory on. During the recording, a preview of both cameras and also information about the current position and orientation of the vehicle are available in the dialog. Before start of recording, it is needed to complete all required fields in the form. Completed data is available in the main window during the inventory of the segment.

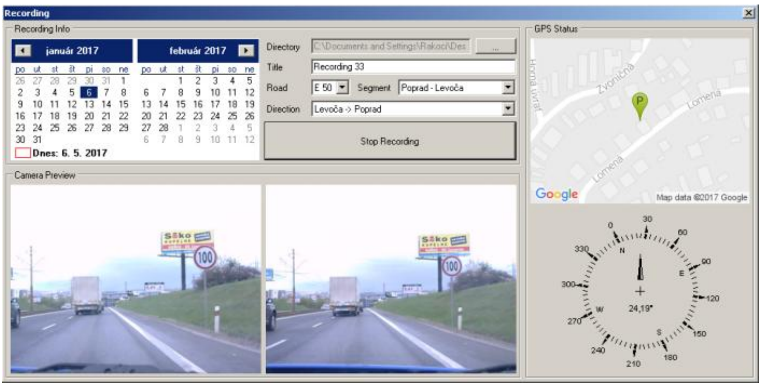


Figure 9. Recording dialog window

9.2. Preprocessing

In this dialog box, it is possible to edit image pre-processing parameters. It is possible to define the color filter parameters for each color that the inventory system uses to segment the recorded scene. Areas that match the set parameters are displayed in the thumbnails. After saving, these parameters are available globally throughout the application.

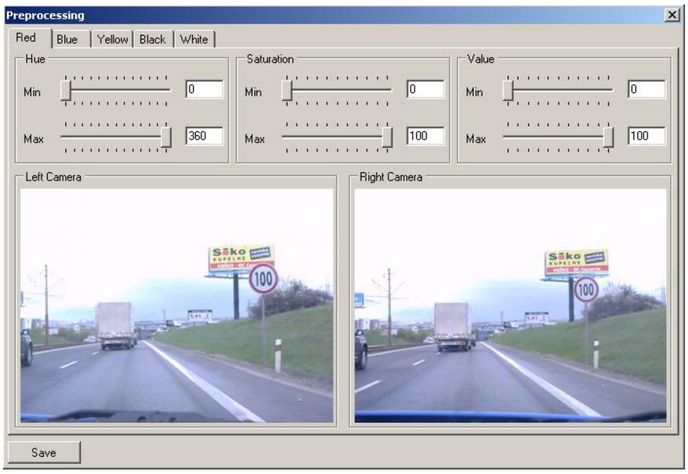


Figure 10. Preprocessing dialog window.

9.3. Distance Calibration

The distance calibration dialog is used to define the dependency curve for stereoscopic distance measurement. Using horizontal cursors, the object positions are defined at the reference distances on images of both cameras. Differences in the horizontal position of objects are sequentially assigned to individual key distances. The result is a discreet dependence of these two parameters, which is used to correct the position of the traffic sign based on the acquired GPS coordinates.

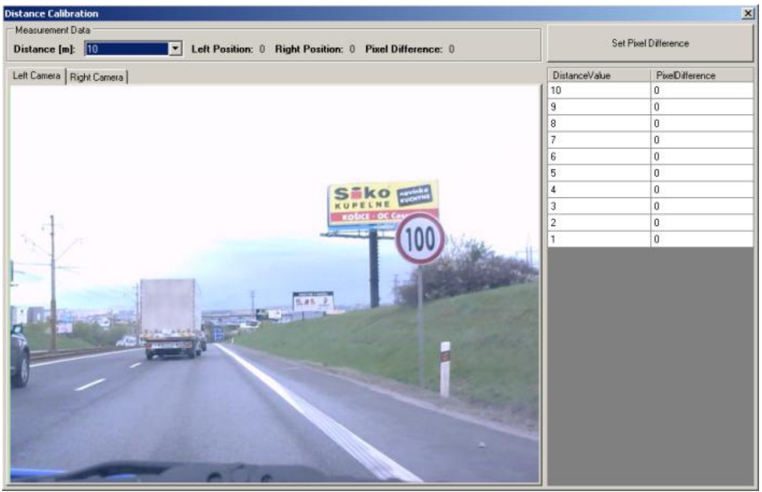


Figure 11. Distance calibration dialog window.

9.4. Settings

"Settings" is a group of dialog boxes for basic settings and testing of connected peripherals. Several necessary settings precede the inventory process and the recording itself. To record a real scene, it is necessary to set the camera system and GPS receiver parameters. Inventory itself requires setting the parameters of the optical correlator components. This includes the processing period and industrial camera parameters setting at the output of the optical correlator.

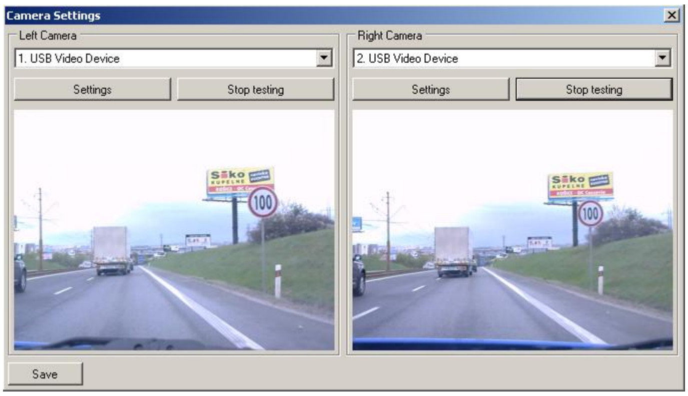


Figure 12. Camera settings dialog window

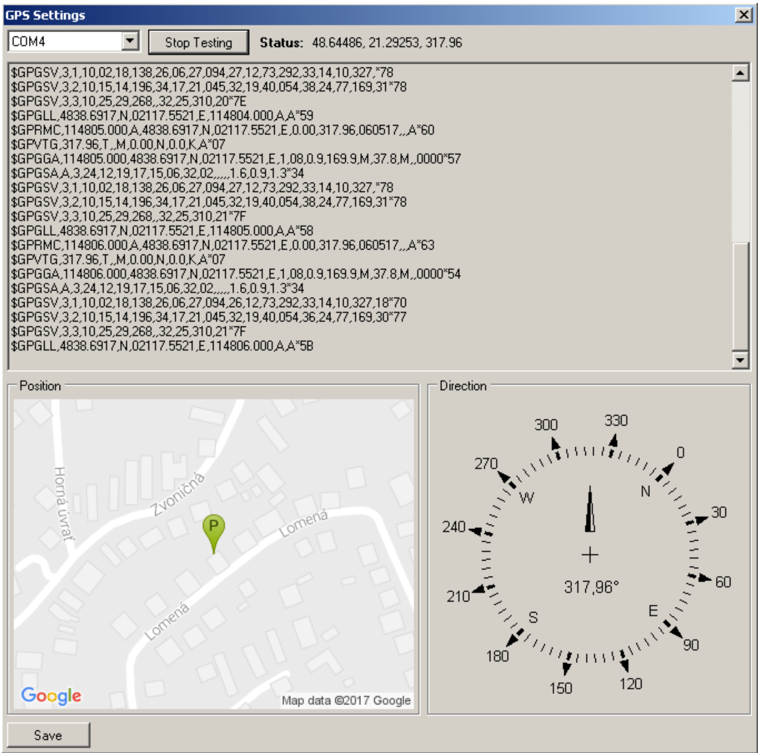


Figure 13. GPS settings dialog window

10. Inventory database structure

The inventory database represents the relational structure of the records representing the recognized traffic signs with the values of relevant parameters. Each traffic sign item in the inventory database contains, in addition to the recorded image, also information about the type, category, position and condition. This information is stored in a structured, interrelated form. The following figure shows the entire database structure. In the following, the functions of individual tables and stored data are briefly described.

10.1. Table "sign"

The "sign" table is a list of traffic signs detected during the inventory. Information about the types of individual items, belonging to a particular segments and conditions are obtained from relational tables. The table also stores information about the exact location of the traffic sign and its dimensions.

10.2. Table "type"

This table stores information about all types of traffic signs that the inventory system can recognize. The spreadsheet contains the name of the traffic sign as well as a link to the next table with information about the category of traffic sign.

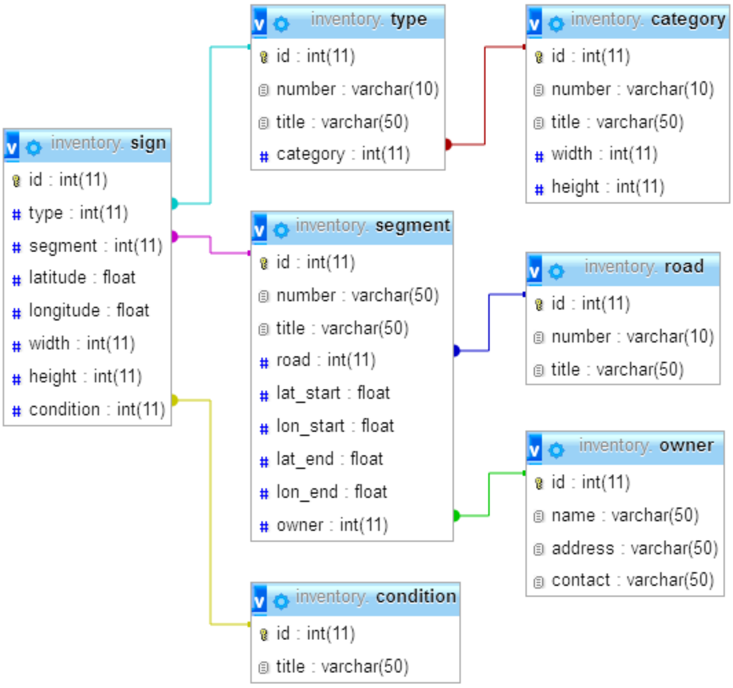


Figure 14. Inventory database structure

10.3. Table "category"

The table "category" lists the traffic sign category information. The basic information is the category name. The "width" and "height" parameters are used as the reference values of the traffic sign of the given category.

10.4. Table "segment"

The table "segment" stores the data for the individual segment of the road. It contains the coordinates of the segment beginning and also the coordinates of its end. In addition, each record contains a road record key from the table "road" and also a record of the owner of that segment from the table "owner".

10.5. Table "road"

Several segments form the whole road defined by their designation. This table stores exactly this label and the name of that road.

10.6. Table "owner"

The table "owner" gives the basic information about the owner of that road segment. This includes their name, address, and owner contact.

10.7. Table "condition"

The inventory system evaluates traffic condition during the inventory process. A particular value is not just any text but one of the defined list values. The "status" table stores these values and provides detailed information for individual entries in the table "sign".

11. Conclusion

Automatic Traffic Tracking System can significantly improve the traffic sign management. The proposed inventory system structure uses the optical correlator as the main computing element for recognizing and classifying recorded traffic signs. The main advantage of optical correlator is its speed of processing. The current version of the inventory system uses the color filtration and edge detection methods for image pre-processing. Methods of spatial layout reconstruction are computationally demanding for this purpose, and they require image recording by high resolution cameras for reliable operation. In addition to generating a simple list of recorded traffic signs, the system can determine their exact location and evaluate their condition. Positioning accuracy depends on the speed of movement of the inventory vehicle and the accuracy of the used peripheral. The evaluation of the individual traffic signs condition is provided in several steps. Proportion, color matching, color homogeneity and contrast are important factors for the evaluation. The whole process is covered by a user interface that can manage inventory and control its progress. The future plane is an optimization of spatial reconstruction algorithms and their implementation in the image pre-processing.

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