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DESCRIPTION OF VEHICLE PASSAGE THROUGH A MULTISEGMENT DETECTION FIELD

Summary. This paper presents the video-based description method for vehicles passing a detection field. A sequence of source images is created by consecutive frames of the input video stream. The source images are converted into binary target images using the analysis of small gradients. Binary values of the target images represent edges and surfaces comprised in the source images. For all images, the same detection field composed of segments is defined. Inside each segment of the detection field, the sum of edge values is calculated. For the entire detection field, an adjusted sum of the edge values is determined. A vehicle passing the detection field changes the number of edge values within individual segments and the adjusted sum of the edge values for the entire detection field. Vehicle passage through the detection field is described by a discrete function that associates the adjusted sum of the edge values determined for the entire detection field in the current binary image to the ordinal number of the current image in the sequence of source images.

Keywords: vehicle passage description, multisegment detection field, image processing

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1. INTRODUCTION

Present-day road traffic systems employ vision data for the determination of traffic parameters and traffic surveillance [6]. The main aim defined for road traffic systems is vehicle detection [7,10]. Aside from vehicle detection, processing and analysis of vision date allow determination of a number of vehicles moving along a road during an assumed time period, vehicle classification into type categories, tracking of vehicles, and vehicle speed estimation. Description of vehicles passing through detection fields allows vehicle detection and determination of traffic parameters.

In [1], the traffic system using corner features for vehicle detection is presented. The regions with brightness changing in more than one direction are analysed, then vehicle trajectories are described and traffic parameters are determined. In [4], vehicles are separated through the determination of the difference between the current image and the background image, thresholding and binarization of the difference image, and updating of the background image. In [5], the difference image is calculated, then lane-dividing lines are determined, shadow-elimination is performed and Kalman filtering is used for vehicle tracking. In [2], high-level and low-level modules are applied. The low-level modules are utilised for the extraction of image objects, and the high-level module is employed for vehicle tracking. In [3], captured images are segmented, then static and dynamic analysis is performed for traffic monitoring. The static analysis is intended for single processed images and the dynamic analysis encompasses previous images. In [9], vehicles are detected with the use of time-spatial images created on the basis of virtual lines. The virtual lines are defined for the frames from the input video data. In [8], vehicle tracking at intersections is performed. For vehicle tracking, a stochastic algorithm is applied. In the applied algorithm, image division into square blocks is required. In [11], background modelling based on application of a mixture of Gaussian distributions is presented. Background modelling allows detaching vehicles from the background.

The proposed description method of vehicle passage through the multisegment detection field assumes the conversion of source images into a binary form on the basis of the small gradient analysis. Description of vehicle passage allows determination of the state of the multisegment detection field and efficient vehicle detection. The increase of the number of the detection fields makes possible estimation of vehicle speed and classification of vehicles into type categories.

2. IMAGE DATA

Image data are obtained at the measuring station. The measuring station includes the stationary video camera mounted over a road and directed towards the approaching vehicles. An input greyscale video stream is obtained from the video camera. Consecutive frames taken from the input video stream make the sequence of the source images. Size of each source image is M columns by N rows. Image coordinates m and n point the position of the individual pixels in columns and rows, respectively. The ordinal number of each individual source image is denoted by i and indicates the image position in the sequence of the source images.

Subsequent source images are processed separately. The single source image is represented by source matrix $\mathbf{A} = [a_{n,m}]$. Each source image is converted into a binary target image represented by target matrix $\mathbf{B} = [b_{n,m}]$. Pixels of the source images are processed by

rows. For each processed pixel, the magnitude of small gradients in rows, in columns and in two diagonal directions are successively compared to the preset threshold value.

For magnitudes greater than the threshold value, binary values corresponding to the pixels employed for the gradient magnitude determination are set to the logical value 1, otherwise, these binary values are appropriate set to the logical value 0. Elements of binary target matrix **B** equal to 1 corresponds to edges in the source image unlike elements equal to 0 which represent smooth surfaces. Binary elements of the target matrix **B** which are equal to 1, are called the edge values. The location of edge values in target images is consistent with the content of input images.

3. MULTISEGMENT DETECTION FIELD

Individual detection fields are defined for analysed road lanes. A single detection field is a rectangle specified by four vertices. The location of the vertices is indicated by the coordinates of the column (left m_L or right m_R) and the row (upper n_U or bottom n_B), respectively. Thus, the detection field is described by the set of coordinates $\{m_L, m_R, n_U, n_B\}$. The width w of the detection field is given by $w = m_R - m_L + 1$, and the height h of the detection field is expressed by $h = n_B - n_U + 1$.

The multisegment detection field consists of $K > 1$ segments that cover the entire detection field. Each segment k is described by the set of segment coordinates $\{m_{Lk}, m_{Rk}, n_{Uk}, n_{Bk}\}$. The segment coordinates satisfy

$$m_L \leq m_{Lk} \leq m_{L(k+1)} \leq m_R, \quad m_{Lk} < m_{Rk},$$
$$n_{Uk} = n_U, \quad n_{Bk} = n_B. \tag{1}$$

The width w_k and the height h_k of the segments are given by $w_k = m_{Rk} - m_{Lk} + 1$ and $h_k = n_{Bk} - n_{Uk} + 1$, respectively.

For the current image denoted by i, the features of the segments of the multisegment detection field are calculated. The relative arithmetic sums of the edge values inside the individual segments of the multisegment detection field are given by

$$S_{k,i} = \frac{1}{w_k h_k} \sum_{n=n_{Uk}}^{n_{Bk}} \sum_{m=m_{Lk}}^{m_{Rk}} b_{n,m} : b_{n,m} = 1. \tag{2}$$

The maximum value of the relative arithmetic sums of the edge values within the individual segments of the multisegment detection field is taken as the adjusted relative sum of the edge values for the entire multisegment detection field

$$S_{\mathrm{MDF}i} = \max\{S_{1,i}, \ldots, S_{K,i}\}. \tag{3}$$

Taking into account uneven distribution of the edge values, the averaging adjusted relative sum of the edge values inside the entire multisegment detection field is calculated (a form of lowpass filtering), on the basis of the current image i and the preset number P of previous images, using the equation

$$R_{\mathrm{MDF}i} = \frac{1}{P+1} \sum_{j=i-P}^{i} S_{\mathrm{MDF}j}. \tag{4}$$

For comparison to the uniform detection field of the same entire size, the relative arithmetic sum of the edge values inside the uniform detection field is given by

$$S_{\mathrm{UDF}i} = \frac{1}{wh} \sum_{n=n_U}^{n_B} \sum_{m=m_L}^{m_R} b_{n,m} : b_{n,m} = 1, \tag{5}$$

and the averaging relative sum of the edge values is expressed by the equation

$$R_{\text{UDF}i} = \frac{1}{P+1} \sum_{j=i-P}^{i} S_{\text{UDF}j} \,. \tag{6}$$

Application of the multisegment detection field improves the quality of the description of vehicles passing the detection field and allows increasing efficiency of proper vehicle detection.

4. EXPERIMENTAL RESULTS

Measurements have been taken at the measuring station in daytimes and under good light and weather conditions. Traffic conditions during measurements were normal off-peak and without congestions. The result of measurements is a registered video stream containing traffic scenes. The video stream was registered with the use of a typical video camera. Video stream frame rate is 30 frames per second. Analysed sequences of input images are created on the basis of the video stream and present particular traffic scenes. Sequences of input images consist of consecutive greyscale images with intensity resolution of 8 bits per pixel and of size 384 x 384 pixels. The multisegment detection field consists of 3 segments of size 52 x 5 pixels. The segments horizontal overlap with one another and they are shifted in relation to one another by half the length.

Inside particular segments, the arithmetic sums of the edge values are calculated relative to the maximum number of the edge values within the segment. On the basis of the segment sums, the adjusted relative sum of the edge values is calculated for the entire multisegment detection field. On the basis of the adjusted relative sums, the averaging adjusted relative sums of edge values are calculated in the setting $P = 0$ (without consideration of previous images) and $P = 4$ (with consideration of 4 previous images).

The test sequences of the source images were considered. These sequences of source images present varying types of vehicles moving through the measuring station.

4.1. Description of Passenger Car Passage

The examples of source and binary target images that present the passenger car approaching the multisegment detection field are shown in Fig. 1. The source image is placed at the left side in the figure and the binary target image on the right side. The multisegment detection field is indicated by the black rectangles. The black points in the binary image signify the edge values.
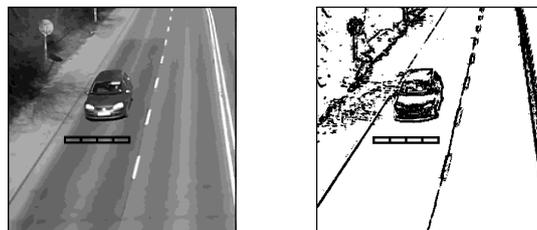

Fig. 1. Passenger car by the multisegment detection field

Descriptions of the passenger car passing the multisegment detection field in the form of dependence of the relative sum of the edge values on the image ordinal number in the sequence of images show Fig. 2 (the description without consideration of previous images) and Fig. 3 (the description with consideration of 4 previous images).
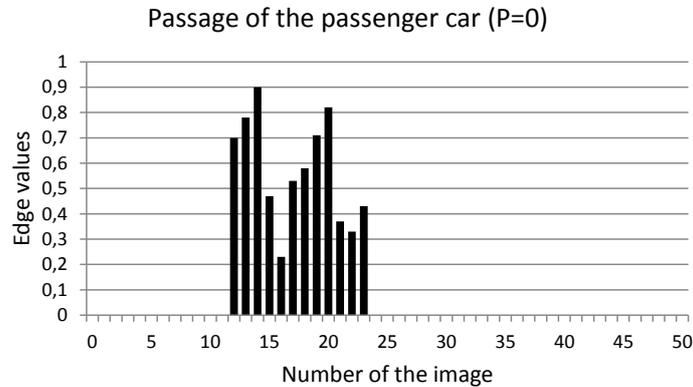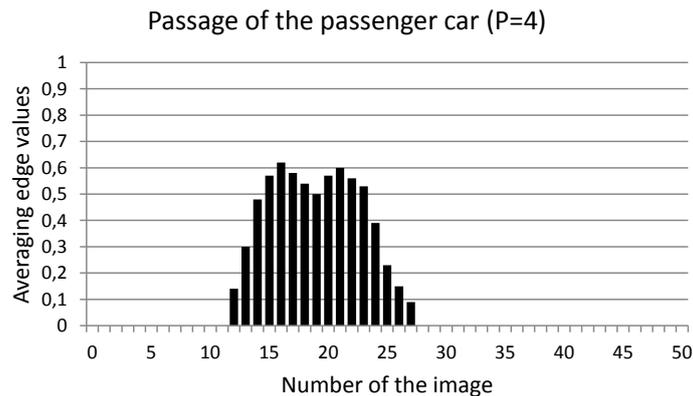
Passage of the passenger car (P=0)

Fig. 2. Passenger car passage through the multisegment detection field ($P = 0$)

Passage of the passenger car (P=4)

Fig. 3. Passenger car passage through the multisegment detection field ($P = 4$)

Description of the passenger car passing the multisegment detection field is dense. Passenger cars usually do not have large surfaces without edges. Application of the multisegment detection field gives the proper results which allow efficient vehicle detection.

4.2. Description of Van Passage

Figure 4 shows the examples of source and binary target images (at the left and right side, respectively) that present the van approaching the multisegment detection field. Similar to images of the passenger car, the multisegment detection field is pointed by the black rectangles, and the black points in the binary image denote the edge values.

Van passage through the multisegment detection field is described by the appropriate relative adjusted sums of edge values. Figure 5 shows the description of van passage through the multisegment detection field without consideration of the previous images ($P = 0$). The description of van passage with consideration of 4 previous images ($P = 4$) is shown in Fig. 6.
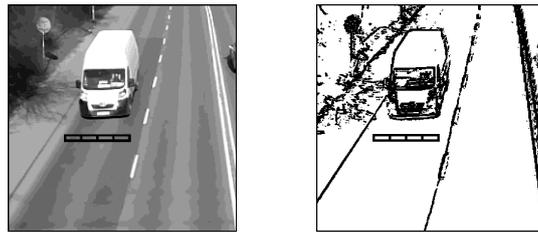
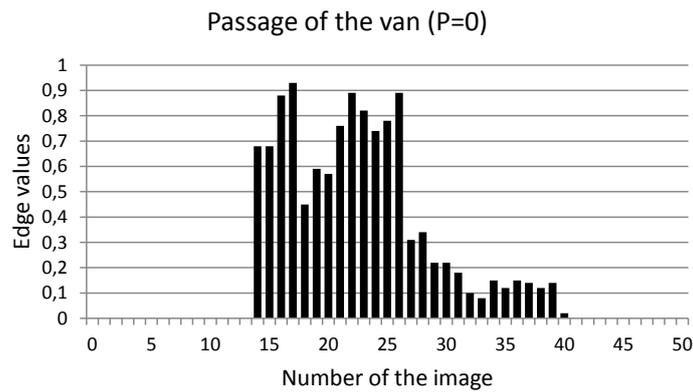Fig. 4. Van by the multisegment detection field

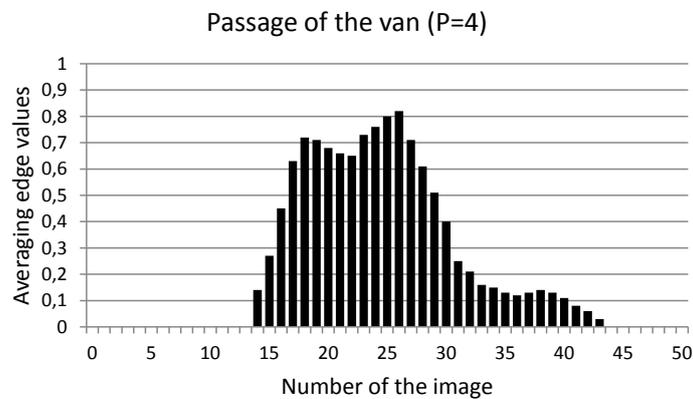Fig. 5. Van passage through the multisegment detection field ($P = 0$)

Fig. 6. Van passage through the multisegment detection field ($P = 4$)

Vans usually have large surface without edges, which is visible in the van passage description. Application of the multisegment detection field increases the number of edge values taken into account, thus improves the possibility of proper vehicle detection.

4.3. Description of Truck Passage

The examples of images of the truck moving into the multisegment detection field are shown in Fig. 7. As in the previous examples, the source image is placed at the left side in the figure, and the binary target image at the right side, also in the binary target image, the black

rectangles indicates the multisegment detection field, and the black points signify the edge values.
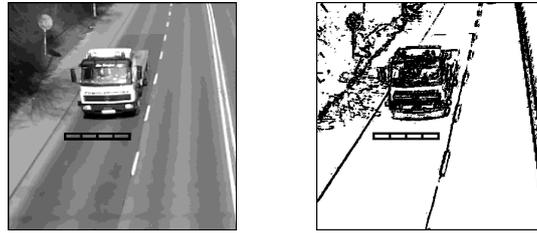

Fig. 7. Truck by the multisegment detection field

Figures 8 and 9 show a description of the truck passage through the multisegment detection field. Similar to the previous examples, the description presents the dependence of the relative adjusted sums of the edge values, inside the multisegment detection field, on the image ordinal number in the image sequence.
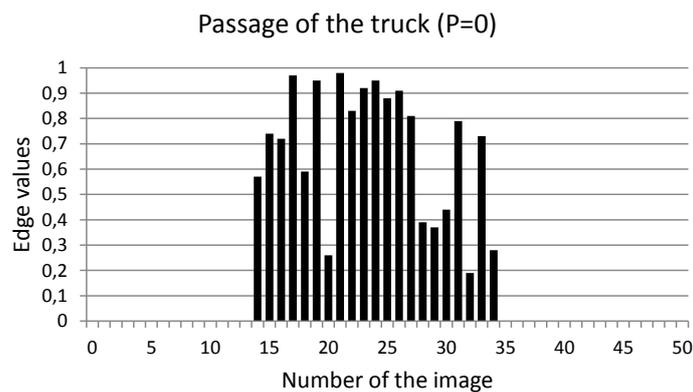

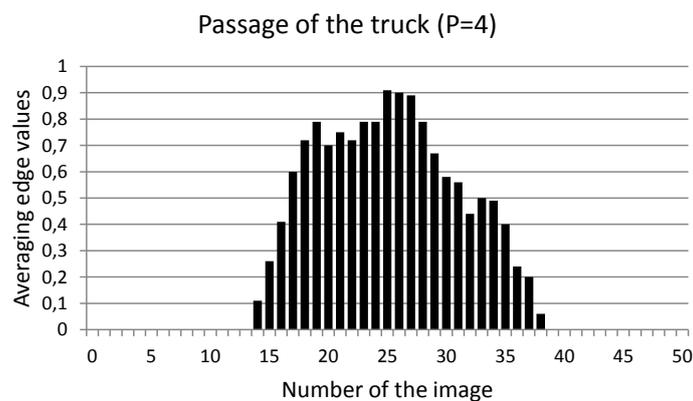Fig. 8. Truck passage through the multisegment detection field ($P = 0$)

Fig. 9. Truck passage through the multisegment detection field ($P = 4$)

Description of the trucks passing the multisegment detection field can have varying density, of which degree depends on the number and size of surfaces without edges. As in the previous examples, the application of multisegment detection field increases the number of the edge values taken into account.

4.4. Comparison to the Uniform Detection Field

For efficiency estimation of the multisegment detection field, the description of vehicle passage through the multisegment detection field was compared to the description of vehicle passage through the uniform detection field of the same size. The examples of images of the passenger car moving to the uniform detection field show Fig. 10. Differences of the relative adjusted sums of the edge values between descriptions of passage through the uniform and multisegment detection fields, with and without consideration of the previous images, show Fig. 11 and 12, respectively.
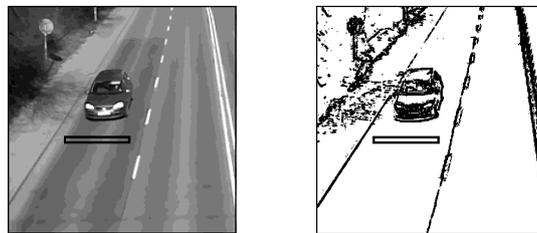

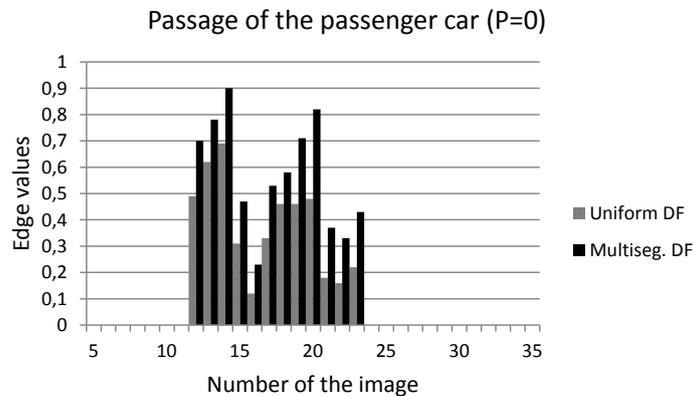Fig. 10. Passenger car by the uniform detection field

Fig. 11. Passenger car passage through the detection fields ($P = 0$)

Application of the multisegment detection field instead of the uniform detection field significantly increases the number of the edge values in the descriptions of vehicle passage through the detection field, both with and without consideration of the previous images. The increase of the edge values taken into account for the descriptions concerns all types of vehicles.
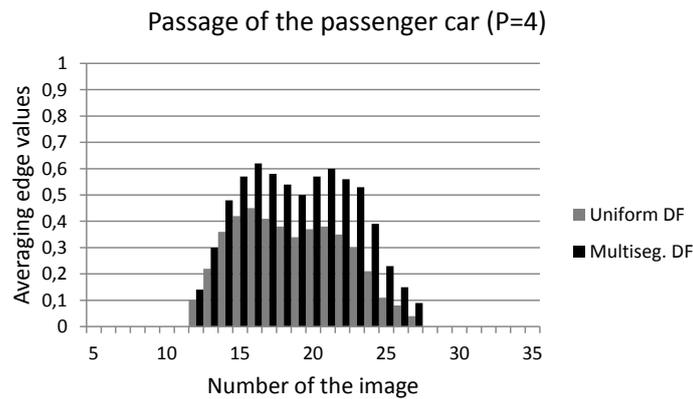
Passage of the passenger car (P=4)

Fig. 12. Passenger car passage through the detection fields ($P = 4$)

5. CONCLUSIONS

Vehicle passage through the detection field can be described on the basis of image gradients. Source images are converted into binary target images using the comparison of gradient magnitudes to the preset threshold value. The obtained binary target images contain edge values which are consistent with edges in the source images. Vehicles passing the detection field are described through the dependence of the relative sum of the edge values inside the detection field on the image number in the sequence of source images. The replacement of the uniform detection field by the multisegment detection field caused the increase of the edge values in the vehicle passage description. Application of the multisegment detection field facilitates effective vehicle detection.

The proposed method of the description of vehicles passing the multisegment detection field is computationally simple and allows effective vehicle detection. This method can be useful for determination of traffic parameters. The fundamental advantage of the proposed method is the small number of required operations. As other methods based on image data, the proposed method of vehicle description is sensitive to changes in weather and illumination. The descriptions of vehicle passages through the multisegment detection field are intended for systems of traffic measurements and surveillance.

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