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A FAST METHOD FOR A REAL-TIME VEHICLES SHAPE ANALYSIS AND COMPARISON WITH PATTERN IMAGES

Summary. The reported works, concern vehicles stream recorders development. They have to do all recording and computing procedures in very short, strictly defined time limits. The data processing methods simplification are in a key position of image pre-processing methods finding. The on-line video data processing provides the Programmable Array Logic [1] with binary sequences in the computing unit of the control system. The well-known techniques of images processing are discussed, with their specific preferences analysis for fulfilling the assumed characteristics and their restrictions. None universal algorithm was elaborated till now and none universal and best solutions are available. Their estimation depends on many conditions that were discussed as an example of recent works, with participation of the paper authors.

SZYBKA METODA ANALIZY KSZTAŁTU POJAZDÓW W CZASIE RZECZYWISTYM Z ZASTOSOWANIEM PORÓWNANIA WZORCA

Streszczenie. Praca dotyczy problematyki projektowania wideo detektorów i rejestratorów pojazdów oraz zdarzeń ruchu drogowego. Urządzenia wideo detekcji wykonują operacje rejestracji obiektów i przetwarzania danych obrazowych w krótkim, ściśle zdefiniowanym czasie. Zastosowania systemu wideo detekcji strumieni pojazdów wiąże się z poszukiwaniem mało złożonych i szybkich metod ekstrakcji obiektów; to zadanie należy dziś do kluczowych pozycji w różnych pracach badawczych. Dyskutowany system sterowania czasu rzeczywistego, wykonano w technologii przetwarzania sprzętowego, na Programowalnych Matrycach Logicznych (PAL – Programmable Arrays Logic) [1], binarnej sekwencji danych sterujących. W pracy przedyskutowano różne znane metody przetwarzania obrazów, oraz zbadano ich przydatność dla realizacji zadanego systemu sterowania. Do chwili obecnej nie dysponujemy algorytmami uniwersalnymi, dla każdego przypadku sterowania. Ich dopasowanie zależy od wielu czynników, których cechy poddano szczegółowej analizie.

1. INTRODUCTION

Defining criterions of video images technologies implementations, the principles of their description, extraction, classification and compression methods have to be considered. The research investigations presented in this contribution concern the well known techniques of images processing analysis; under their specific preferences, for fulfilling the assumed control unit characteristics. The control unit developer has to take under consideration several restrictions and preferences.

None universal algorithm for image analysis is available till now. The image processing techniques selection depends on many conditions, discussed as an example works of vehicles stream recorders development.

One of the methods selection criterions, a strictly defined time limit was assumed. The computing algorithms are performed by Programmable Arrays Logic (PAL), used for the machine hardware construction. The real-time input interface, of a traffic control system video-recorder, defines this time interval for data recording and processing. Below, one can find analysis for more criterions that were considered, for the image processing techniques selection.

2. OBJECT EXTRACTION

2.1. Edge detection

The source image is being processed in several steps, like: noise filtering, objects edges detection, the filtering threshold finding.

The noise reduction goes by no linear median filtering for extremes of pixels light and local noise of the image deleting. This operation is free of image quality destruction, as by convolution filters.

The edges recognition algorithm uses gradient detectors, by first derivation of the image description functions; the rapid change of the image light using the Sobel operator.

Several orthogonal masks used in the method were presented in fig. 1.

-1	0	1
-2	0	2
-1	0	1

-1	-2	-1
0	0	0
1	2	1

Fig. 1. Orthogonal masks of Sobel operator
Rys. 1. Ortogonalne maski operatora Sobela

In successive steps the gradients comparison of two directions, produces the image edges layout. For the algorithm simplification a modular formula (1) was applied:

$$M_{i,j} = \left|M_{H\,i,j}\right| + \left|M_{V\,i,j}\right| \tag{1}$$

where: $M_{Hi,j}$ - assigns lightness of the pixel attribute value for horizontal edges, $M_{Vi,j}$ - assigns lightness of the pixel attribute value for vertical edges, $i = 0 \ldots n-1$, $j = 0 \ldots m-1$.

The image binarisation, is carried on after the image edges are defined. This procedure allows remarkable reduce to the image file size. The threshold for elaborated method finding, concerns two values of the image gray scale, by the function (2) of the lightness medium square:

$$p = \sqrt{\frac{\sum_{i=0..n-1} \sum_{j=0..m-1} {M_{i,j}}^2}{n \cdot m}} \tag{2}$$

where: $M_{i,j}$ - assigns lightness of pixels with co-ordinates indexes $\langle i, j \rangle$, n - width and m - height of the camera observation field.

The threshold value is used for data binarisation of the image and its edges that describe the source data unit (3):

$$P_{i,j} = \begin{cases} 0 & for \quad M_{i,j} \geq p \\ 1 & for \quad M_{i,j} < p \end{cases} \tag{3}$$

where: $i = 0 \ldots n-1$, $j = 0 \ldots m-1$, n - width, m -height of the camera observation field.

2.2. Background recognition

The crucial task of a background attributes estimation uses a number of tables containing information on the frequency of pixel values. It was experimentally verified that dividing the range of pixel values, into three partitions, is sufficient to prepare a useful statistical model of pixel values list [8]. The model of background is updated every 25 video frames and rebuild every 6,4k frames. fig. 2. shows the outline of the background calculations algorithm.

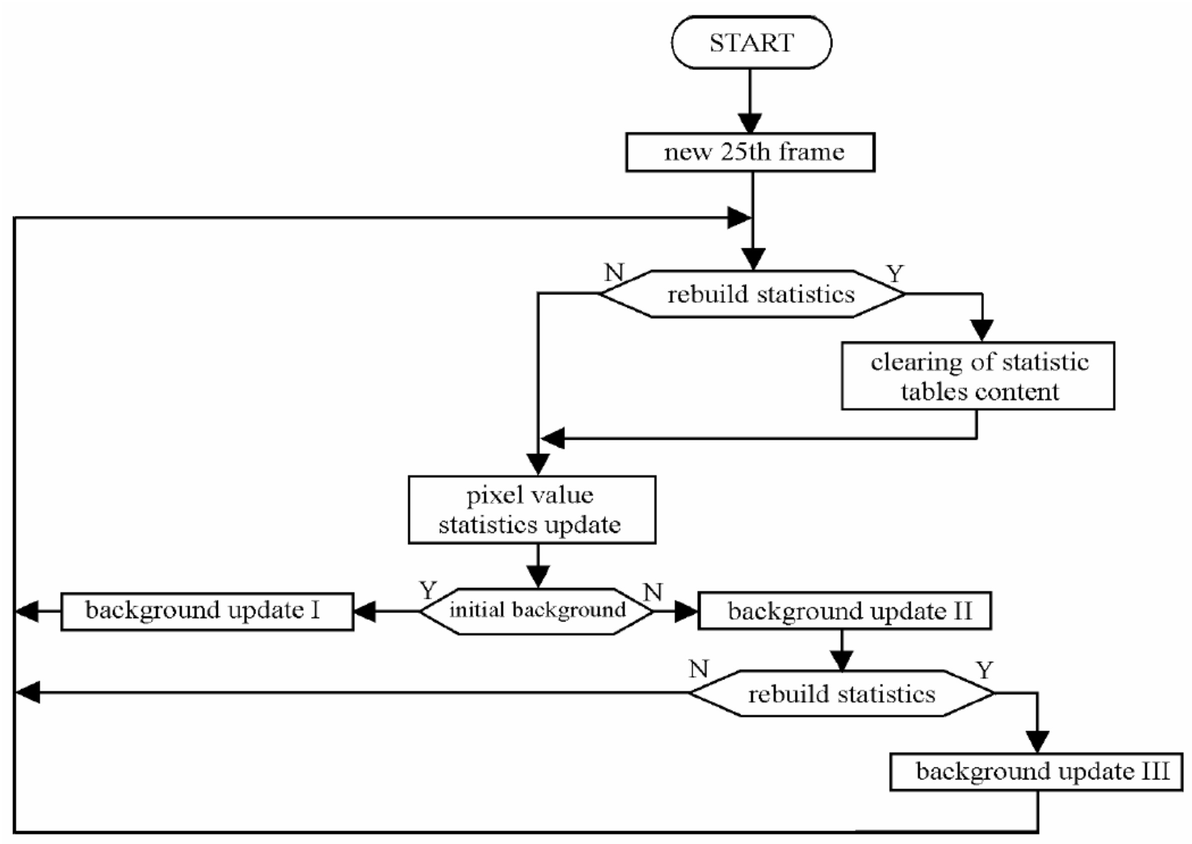

Fig. 2. Background calculation
Rys. 2. Algorytm wyznaczania tła

The background update algorithms I and III assign the most suitable mean values of pixels relations to the image background pixels. Background update III derives the new values, assigning a linear function of previous background value with relations to current pixel's value. When the absolute difference of the current object (frame) and its background is larger than a given threshold the background is defined as:

$$B(t) = \alpha F(t) + (1-\alpha)B(t-1) \tag{4}$$

where: B- background value, F – pixel value, $\alpha \in (0,1)$, t – update count otherwise it is not updated.

2.3. Mask of the object

The vehicle-class definition uses a mask of the object *O*. It needs more data for the recorded image (resolution 768x512) description. The extraction results are obtained by the object edges detection [7] and the background rejection [8], using the Sobel operators. The 2D data table describes the vehicle identification procedure, assigning the gradient of image lightness, for every pixel.

The value 2 assigns the object's mask. The value 1 corresponds to the pixel that is different from the background, 0 concerns the background pixels (fig. 3). This way the pixels different from a background are distinguished.

Fig. 3. Vehicles extraction
Rys. 3. Ekstrakcja pojazdu

The algorithm for vehicles extraction was checked by number of image sequences of the traffic scenes, taken in different lighting conditions and using various cameras [10]. Results proved satisfactory accuracy and sufficient speed of the traffic scenes analysis.

3. THE VEHICLE MASK FINDING

3.1. The vehicle model

The vehicles' masks extraction algorithm was based on finding medium dimensions of vehicles. The model is symmetrical in surface XY, where lengths of dv_i i dh_i for every vehicle-class define vertexes $P_i \in R^2$. Converting these two dimensions of the model, into 3D space, the representation in $P_i \in R^3$ was obtained (fig. 4).

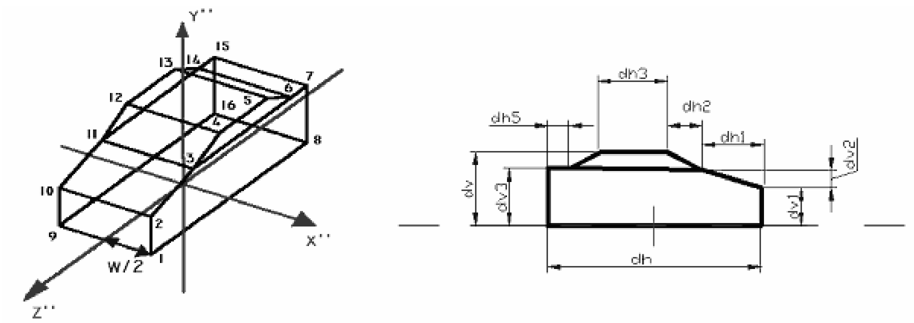

Fig. 4. The three dimensions example vehicle model
Rys. 4. Trójwymiarowy przykładowy model pojazdu

The long vehicle class illustrates the example unit in fig 5a, bus assigns the example mask in fig. 5b, a lorry assigns fig. 5c and a small carrier in fig. 5d.

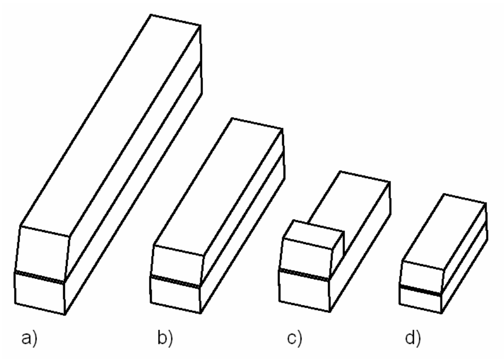

Fig. 5. Four example classes of vehicles
Rys. 5. Cztery przykładowe klasy pojazdów

For the vehicle class recognition the 3-D model of every vehicle class was defined. They also are set into the road scenery. The 16 points (P_i) are used for the vehicle class description (according to dimensions defined in fig. 4). They are used for further modeling of the vehicle class in observation field of the camera.

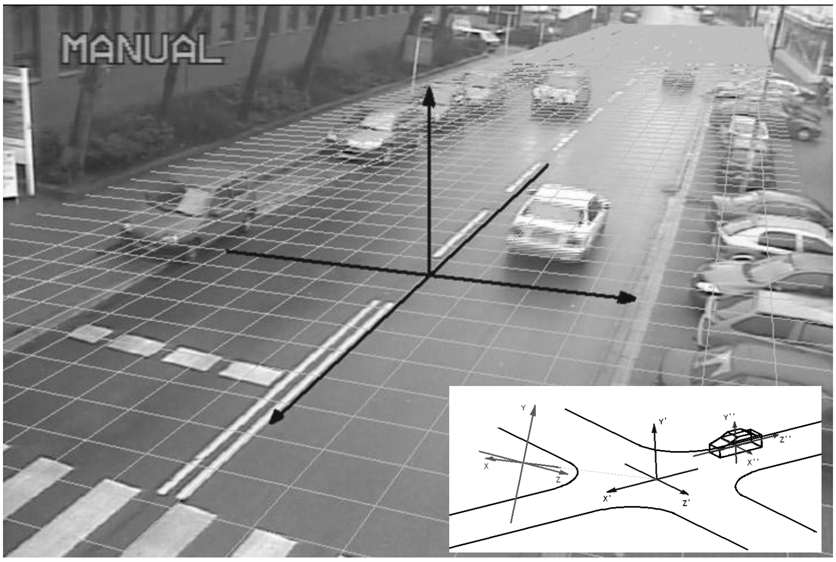

Fig. 6. 3D scene with an example vehicles
Rys. 6. 3D Model sceny z przykładowym pojazdem

The scene model was related to coordinates n' = 0, 1, 0, of a road surface. It was also assumed that the scene and vehicles axes OY' and OY" of both models are parallel. It considerably simplifies the conversion and rotation α processes in coordinates XZ:

$$x' = x'' \cos \alpha - z'' \sin \alpha, \qquad (7)$$
$$z' = x'' \sin \alpha + z'' \cos \alpha.$$

The coordinates of the scene are converted into camera coordinates by cosine angle multiplication [15].

Finally, for any selected vehicle class, a set of sixteen nodes in the camera coordinates $P_i \in R^3$ is defined:

$$x = a + a_{11}x' + a_{12}y' + a_{13}z'$$
$$y = b + a_{21}x' + a_{22}y' + a_{23}z'$$
$$z = c + a_{31}x' + a_{32}y' + a_{33}z'$$

3.2. The invisible walls and perspective projection

The set of vehicle descriptors in 3D space has to be put into the surface of the image; the conversion result contains only the visible walls.

For the invisible walls erasing, the vector notation of the model was applied. The edges of the model allow defining the normal vector n [9], [13]. The vector of optical axis *k* of camera is defined in video-detection setting calibration process.

The walls erasing procedure expresses the equation (9):

$$x_n x_k + y_n y_k + z_n z_k > 0 \tag{9}$$

where: n – is a norm vector of the wall, k – expresses the optical axe of the camera.

The vehicle model in 3D space is not suitable for the comparison algorithm that is using the objects' masks. For this purpose the 2D scene model is more adequate, obtained in a result of the perspective projection of the 3D vehicle model, into the image surface [11], [14]. Every pixel has its product in angle of the camera image.

4. THE IMAGE COMPARISON

4.1. The model mask finding

After the invisible walls were erased the apexes joins table of the model edges are searched. Each pixel, at the vehicle pattern-image (fig. 7), is described by parameters, of:

- models; $nM = 1 \ldots 5$,
- edges; $nK = 1 \ldots 24$.

The remaining details of the image define the background, with value equal to zero.

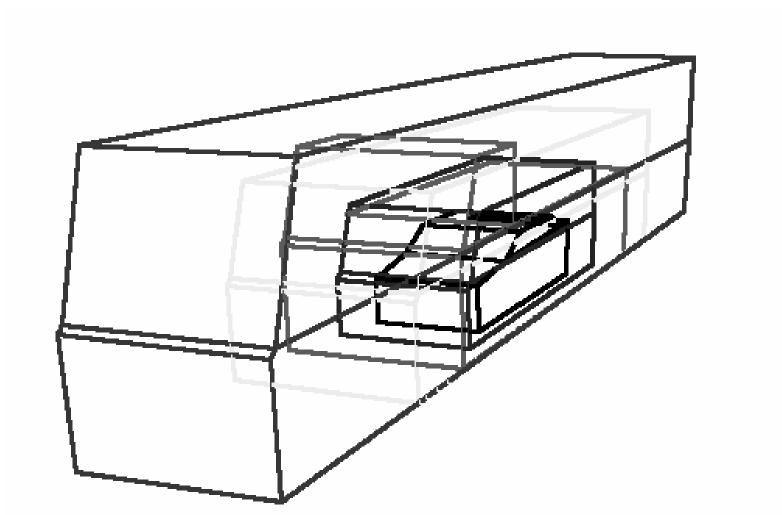

Fig. 7. Mask of model
Rys. 7. Maska modelu

4.2. The pattern measures

The comparison algorithm of the pattern (the mask) with the vehicle edges map, a coefficient M of the measure was elaborated and numerically evaluated [12], [13]:

$$M = \sum_k x_k w_k$$

where: x_k - the percentage of the edges measure matching, w_i - the coefficient of the edge weight.

The highest value of M, the matching result, indicates the vehicle class (M equal to 100% means an ideal coverage of the image by the pattern).

Fig. 8. Vehicles classification on crossroads
Rys. 8. Klasyfikacja pojazdów na skrzyżowaniu

5. CONCLUSIONS

Although the processing algorithm is very simple the chosen method was empirically evaluated, with satisfactory results. For objects similar to the defined patterns the recognition level is equal to 100%.

The investigated fast operators were recommended for image-processing real-time controllers development [3]. They effectively support a very fast processing machines elaborated in Programmable Logic Arrays (PLA) technology; used for video detectors interfaces development [13, 14].

The elaborated methods (coefficient M measure comparison) work more effectively for longer edges of the objects. The method is also more effective for a good contrast quality images.

These critical conditions concern time limitation for all computing procedures in a real-time measurement of the traffic. Various algorithms (not introduced, in this paper) were checked within their many details.

The contribution discusses selected items of investigations being at the moment in a final stage of new technology transfer into small industry; works supported by European Community funds. Now it is under final analysis and evaluations.

Research works carried on BK 300/RT6/2008 project.

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