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VARIOUS ASPECTS OF VEHICLES IMAGE DATA-STREAMS REDUCTION FOR ROAD TRAFFIC SUFFICIENT DESCRIPTION

Summary. The on-line image processing was implemented for video-camera usage for traffic control. Due to reduce the immense data sets dimension various speculations of data sampling methods were introduced. At the beginning the needed sampling ratio has been found then simple but effective image processing algorithms have to be chosen, finally the hardware solutions for parallel processing are discussed. The PLA computing engine was involved for coping with this task; for fulfilling the assumed characteristics. The developer has to consider several restrictions and preferences. None universal algorithm is available up to now. The reported works, concern vehicles stream recorders development that has to do all recording and computing procedures in strictly defined time limits.

ASPEKTY REDUKCJI ROZMIARU STRUMIENIA DANYCH VIDEO DLA ALGORYTMU ROZPOZNAWANIA STANU RUCHU DROGOWEGO

Streszczenie. Wykorzystanie metod wideo detekcji do sterowania ruchem drogowym wymaga realizacji operacji przetwarzania obrazu w czasie rzeczywistym. Rozpatrywane są różne możliwości zastosowania metod próbkowania umożliwiających zmniejszenie rozmiaru zbioru danych wejściowych. W pierwszym etapie należy określić wymaganą częstotliwość próbkowania danych, następnie dokonywany jest wybór odpowiednio prostego i zarazem efektywnego algorytmu przetwarzania obrazu. Na tej postawie opracowana zostaje metoda implementacji sprzętowej. Biorąc pod uwagę przyjęte założenia zaproponowano zastosowanie układu PLA. Projektant takiego układu musi uwzględnić różnorodne ograniczenia i wymagania. Niniejsze opracowanie dotyczy metod projektowania systemów wideo detekcji ruchu drogowego, których zadaniem jest realizacja określonych procedur przetwarzania w ściśle zdefiniowanych ramach czasowych.

1. INTRODUCTION

Defining criterions of video images usage, we have to consider various principles of their extraction, description and classification methods. Many well-known techniques of images processing were analyzed to be used within specific implementation areas. The discussed bellow investigations concern analysis of digital camera usage for road traffic registration as an input data for the traffic-controllers development.

The on-line image registration expects fast processing machines. That is why the computing speed is a key task that has to be solved by the controller developer. There are four areas where this improvement can be searched:

- data sampling reduction into necessary rate that reduces the data size that is efficient for traffic modelling, defining the necessary granule for the traffic state description, defining the traffic flow within the rough modelling items,
- image processing algorithm simplification, providing us with satisfying recognition level, improving the computing facilities, the most effective processing algorithms selection
- simple and fast algorithms for the video image processing,
- fast processing hardware units implementation, to be able selecting the needed data.

The image data recorder that was under development has to work in accordance with various fundamental principles. The developer has to consider the implemented algorithms restrictions and preferences. None universal algorithm was elaborated till now and no universal and best solutions are available. Their estimation depends on many conditions that were discussed as an example of recent works, at the department, done with participations of the authors contribution.

2. THE GRANULES EXTACTION FOR DATA SAMPLING RATE REDUCTION

The road traffic modelling needs some spatiotemporal characteristics of vehicles streams density description. The definitions of the traffic data concern the sampling time granulation, needed for traffic control algorithms implementation. These data granules have to be identified, for discrete traffic model finding [1]. In this field the cellular traffic models became very useful. The cellular model assume a road surface division into segments called cells, occupied by vehicles [2]. In a more often used macro-modelling one cell is dedicated to vehicles group [3], [4]. Every cell is considered as a data unit / granule for the road traffic stream description.

The granulation modelling methods start from a division of the traffic lane into the cells. The state of a cell is defined as a value of their occupation by number of vehicles present in the cell. The granulation value is defined by set of cells $\{i\}$ and their configuration, describing current states of the cells $C_L = \{c_{1,L}, c_{2,L}, ..., c_{n(L),L}\}$, where L denotes level of granularity, $c_{i,L}$ is the state of the i-th cell at the granularity level L and $n(L)$ is cells number of level L.

The lowest granularity level ($L = 1$) have binary values: $c_{i,1} = 0$, if the cell i is empty and $c_{i,1} = 1$, if there is a vehicle present in the cell i. Accordingly, at higher granularity levels ($L > 1$) the state values of a cell denote number of vehicles present in the cell: $c_{i,L} \in \{0,1,...,L\}$.

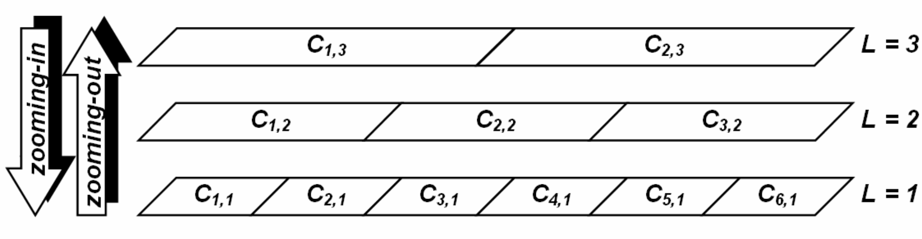

Fig. 1. The traffic lane granulation
Rys. 1. Granulacja pasa ruchu

The zooming-out operation concerns a subset of the cells extraction, where the traffic lane granulation is a mapping operation $C_1 \rightarrow C_L$, defined by formula:

$$c_{j,L} = \sum_{i=jL-(L-1)}^{jL} c_{i,1}, \quad j = 1,...,n(L), \quad n(L) = n(1)/L\ . \tag{1}$$

Zooming-in concerns a multi-valued mapping: $C_L \rightarrow \{C_1\}$. By the zooming-in operation of cells configuration C_L a set of configurations $\{C_1\}$ is found fulfilling the given condition.

The set $\{C_1\}$ is called the refinement of C_L; of the configuration $C_3 = \{3,1\}$ at a third level of granularity is a set of configurations at the first level:

$$\{C_1\} = \{\{1,1,1,0,0,1\}, \{1,1,1,0,1,0\}, \{1,1,1,1,0,0\}\}$$

The granulation approaches take into account several practical aspects of the traffic control systems. The algorithms of traffic signals control, e. g. [5], [6], utilize the traffic characteristics, extracted for the defined regions – so called detection zones.

These zones are usually located in a particular traffic lane, at approaches of a crossroad, where passing vehicles are registered, the occupancy is defined or other measurements are performed (e. g. velocity).

In case of video camera implementation, many detection zones may be defined, within the camera watching field. For this video camera's data collecting units, the cellular automata was found the most suitable [7]. The cells are directly belonging to the granulation ratio providing the control unit with the most adequate data set.

3. IMAGE EXTRACTION ALGORITHMS

3.1. Segmentation

In case of the machine had to be supplied by properly extracted data set, the computing algorithms have to be defined. A first step of a video image processing concerns its segmentation, where the image characteristics features have to be extracted.

In the segmentation procedure, the image is divided into fragments with the same or similar features. This way all pixels are denoted as the extracted objects elements. The investigated data source (video streams) was provided by various digital cameras, placed in many points in a town.

The depth of colours was limited for the computing complexity reduction [8], [9]. The vehicle recording is finding a method of objects edges detection that is limited by closed curves. The object's edge and its content are defined by set of numbers that can also be representative of another object. A simple algorithm implementation means that not continuous edges bring us faults that imply additional analysis of the image.

Implementation of a Smith algorithm in segmentation processes [10], reduces the algorithm of objects filling-up. It is done by operation called „sowing"; causing multiple checking of the same pixel at one image.

In the Smith algorithm row of pixels are analyzed. The segment of image n is denoted by index of pixels $P(x, y)$ in line y.

Then, the neighbourhood of the edge is checked. According to the condition (1), hence to the stack, the address of the pixel is pushed $P(x, y+d)$.

$$P(x, y) = 0 \cap (P(x, y+d) = 0 \cap (P(x-1, y+d) = 1) \cup (P(x+1, y+d) = 1)). \tag{2}$$

where $d \in \{-1,1\}$.

The pixel $P(x, y)$ value is equal to 0 for an internal object area, 1 for the edge, In the output image pixel value $P(x, y) = n$ denotes number of the segment.

The stack content is increasing by all pixels fulfilling the condition (1). The carried out segmentation provides several image parts that are analyzed further by another algorithms. In fig 1 the image map with visible edges after the lower level extraction procedures were introduced. In fig. 2 we can observe some indexing results appointed by different colors.

Fig. 2. The edges map defined by morphological operations
Rys. 2. Mapa krawędzi po przeprowadzeniu operacji morfologicznych na obrazie

3.2. Parameterisation

By all values of pixels the quantity measures of images can be defined. The objects classification can be carried out by general parameters of their shape coefficients analysis (available indirectly for the image).

These general parameters concern their geometrical dimensions (as: surface, edges length periphery, projections length, the Feret diameters, etc.).

The Feret coefficient [11], with the object content measures is used for list of objects $\{O_j\}$ analysis. That is expressed by numbers describing their characteristic features (3):

$$O_j = (x_s, y_s, L, S, I_z, I_p, R_z, R_F) \tag{3}$$

where: j – is an object number, (x_s, y_s) – coordinates of the object load centre, L – periphery (the edge length), S – object surface, I_z – medium value of projections length; in accordance to traffic direction, I_p – medium value of projections length (opposite to traffic direction),

R_z – the content coefficient:
$$R_z = \frac{L^2}{4\pi S}, \tag{4}$$

R_F – the Feret coefficient,
$$R_F = \frac{L_h}{L_v}, \tag{5}$$

L_h – maximal horizontal dimension, L_v – maximal vertical dimension.

3.3. Objects selection

For the analyzed objects number reducing, the set of objects is being pre-selected. The objects under consideration, of a size above or below the assumptions, are noticed as not vehicles. They are erased from the data set, as:

- to small; surface S below the threshold tS = 100 pixels,
- objects to dense; where the content coefficient value is above the threshold tz = 15.

In fig. 2 and fig. 3 the example images before and after these selection procedures were presented. This way the number of the recorded data is remarkably reduced.

Fig. 3. Image after segmentation
Rys.3. Obraz po operacji segmentacji

Fig. 4. Image after the objects extraction
Rys.4. Obraz po przeprowadzeniu selekcji obiektów

3.4. The image analysis

After images pre-selection the next step of the computing algorithm is executed; the aggregation process, of their neighbourhood. The surface of all objects and their total sum is calculated. Finally the centre of this products and medium values of vehicles projections lengths has to be found:

$$OA_i = (x_s, y_s, S, I_z, I_p) \tag{6}$$

Checking the range of OA_i the class of the vehicle can be extracted. This data is used for dimensions and localizations of objects can be defined; in objects sequence analysis for passing objects at the traffic lane.

4. THE VEHICLE CLASSES EXTRACTION

4.1. Vehicles classes

The vehicle model for an algorithm of mask definition is defined on base of medium and real dimensions of the vehicle. In fig. 5 a three dimensions vehicle model was presented. For our investigations five classes of vehicles were defined. The long vehicle was introduced in fig. 6 a, bus in fig. 6 b, lorry in fig. 6 c and small carrier in fig. 6 d.

For every vehicle class the 3-D model was elaborated; in road scenery; by a set of 16 points P_i that describe the vehicle class. Lengths of dv_i i dh_i, for average model of every class define vertexes $P_i \in R^2$ of the model.

Converting the two dimensions model into 3D space, we obtain its representation in $P_i \in R^3$. The 3D description of the scene has been presented in fig. 7. The scene model was related to coordinates n' = 0, 1, 0, of a surface of the road. It was also assumed that the scene and vehicles axes OY' i OY" of both models are parallel situated. It considerably simplifies the translation and rotation processes in coordinates XZ:

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

This operation allows changing the coordinates of the scene into coordinates of video camera (fig. 8).

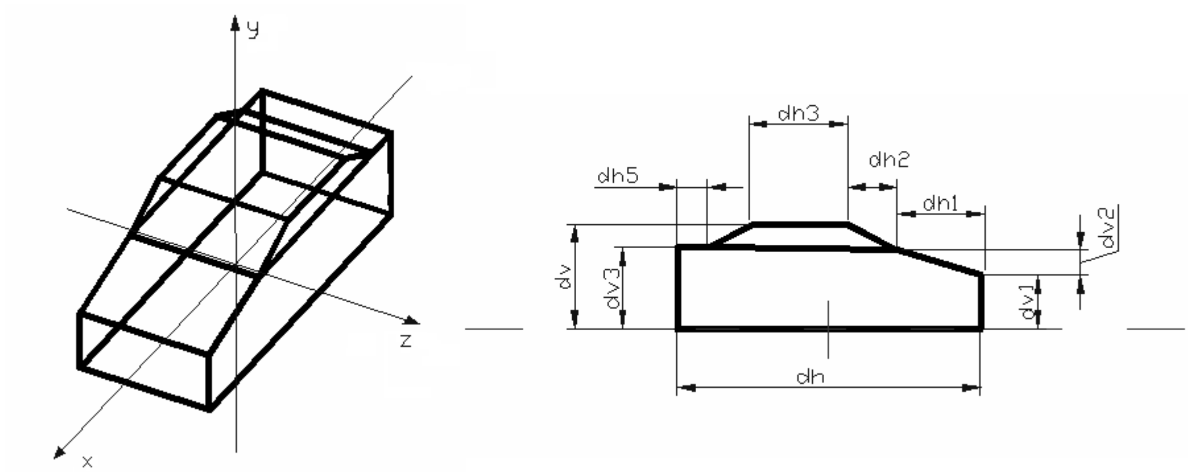

Fig. 5. Three dimensions example vehicle model
Rys.5. Przykładowy model pojazdu 3D

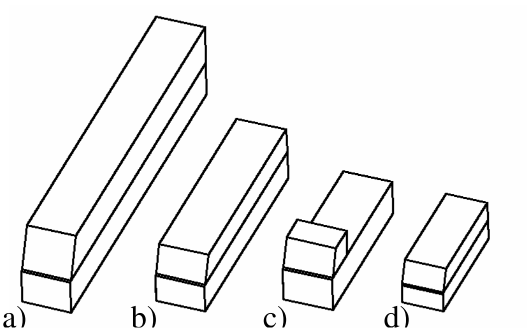

Fig. 6. Four example classes of vehicles
Rys.6. Cztery zdefiniowane klasy pojazdów

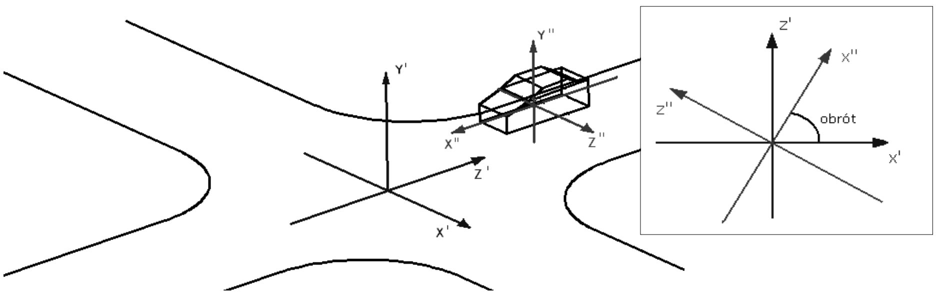

Fig. 7. 3D scene with an example vehicle model
Rys. 7. Model pojazdu w modelu 3D sceny

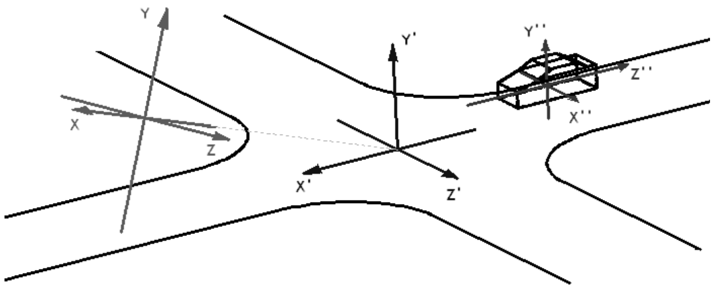

Fig. 8. The coordinates scheme for vehicle model transformation
Rys.8. Odwzorowanie układu współrzędnych sceny w układzie kamery

4.2. The vehicle coordinates transformation into camera coordinates

The coordinates of the scene are converted into camera coordinates by co-sinus angle multiplication, as:

$$a_{11}=\cos(fi*pi/180)*\cos(psi*pi/180),$$
$$a_{21}=\sin(fi*pi/180),$$
$$a_{31}=\cos(fi*pi/180)*\sin(psi*pi/180),$$
$$a_{12}=\cos((90-fi)*pi/180)*\cos((180+psi)*pi/180),$$
$$a_{22}=\sin((90-fi)*pi/180),$$
$$a_{32}=\cos((90-fi)*pi/180)*\sin((180+psi)*pi/180),$$
$$a_{13}=a_{21}*a_{32}-a_{22}*a_{31},$$
$$a_{23}=a_{12}*a_{31}-a_{11}*a_{32},$$
$$a_{33}=a_{11}*a_{22}-a_{12}*a_{21}, \quad (8)$$

where: variables fi and psi defined angles values that defined the camera focus in relation to the observed middle of the road lane. The relation of the co sinus angle between respective tensors was presented in table 1.

Tab. 1

The values of angle cosinus for coordinates xyz and x'y'z'

	x'	y'	z'
x	a_{11}	a_{12}	a_{13}
y	a_{21}	a_{22}	a_{23}
z	a_{31}	a_{32}	a_{33}

Values of angles fi and psi are used for calibrating the video-detector settings:

$$\begin{aligned} x &= a + a_{11}x' + a_{12}y' + a_{13}z' \\ y &= b + a_{21}x' + a_{22}y' + a_{23}z' \; . \\ z &= c + a_{31}x' + a_{32}y' + a_{33}z' \end{aligned} \quad (9)$$

4.3. Projection in perspective

The vehicle model in 3D space is not suitable for comparison with the object mask. That is why the perspective projection of the 3D model of vehicle, into the image surface was carried out. Then, every pixel has its product in the angle of the camera image.

The observation angle allows us copying each point of 3D space into 2D surface, converted by following math equations:

$$-0{,}5\frac{\alpha_V}{r_V}+\left(i\cdot\frac{\alpha_V}{r_V}\right)\le\frac{x}{z}<0{,}5\frac{\alpha_V}{r_V}+\left(i\cdot\frac{\alpha_V}{r_V}\right),-0{,}5\frac{\alpha_H}{r_H}+\left(j\cdot\frac{\alpha_H}{r_H}\right)\le\frac{y}{z}<0{,}5\frac{\alpha_H}{r_H}+\left(j\cdot\frac{\alpha_H}{r_H}\right), \quad (10)$$

where: α – expresses the angle of the camera viewing, r – is the camera resolution, i, j – pixels indexing, K – point in the space.

5. THE VEHICLE CLASSES EXTRACTION

5.1. The mask finding

After the invisible walls rejection, by the discussed 2D model, the object pattern is defined. From the apexes joins table the model edges are defined. Each pixel at the vehicle pattern-image is described by the following parameters, of:

- models - $nM = 1\ldots5$,
- edges - $nK = 1\ldots24$.

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

5.2. Mask of the object

The vehicle-class definition procedure needs a mask of the object O, hence more information abort the recorded image in resolution 768x512, is needed. The extraction results, made by edges detection process [12] and the background recognition [13], produce the 2D table was used for identifying the vehicle.

In algorithm of edges detection the morphological operator was used. It assigns the gradient of images lightness in every pixel.

This way the pixels assigned differently then the background is distinguished – assigned by value 2 in the object mask. The value 1 describes the pixel different from the background, 0 – assigns the background pixels.

5.3. The pattern measures finding

For comparison of the pattern (mask of the model) with the edges map a specific coefficient M of the measure was elaborated and numerically evaluated:

$$M = \sum_k x_k \frac{w_k}{\sum_i w_i^2} \quad (11)$$

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

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

5.4. The method characteristics

The roughly described method was practically implemented. It provides very satisfying classification coverage. For the object closed to the defined pattern the objects recognition was almost 100%.

Very important feature of this method is its low complexity at the computing algorithms. The simple operations of comparison recommend this method for an on- line video image processing; as very needed support for very fast processing machines as Programmable Logic Arrays (PLA). These hardware processing machines were applied for the video interface, being under development at the authors' research group.

6. CONCLUSIONS

The electronic equipment (PLA matrices) implemented for this camera interface development gives us these very restrictive assumptions. The classification algorithms consist of many operations that have to be made by the camera interface.

The most important condition concerns time limits for all computing procedures in on-line mode of the traffic controlling machines. That is the reason in searching the fastest although effective methods for our investigations and development works. The introduced results are now under final field testing.

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