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SEGMENTATION OF DIGITAL IMAGES FROM A ROAD TRAFFIC VIDEORECORDER

Summary. The proposed segmentation method uses the two-layer data model of digital images. The two-layer data model consists of a different value layer and a base value layer. An original image pixel values are obtained by appropriate combining pixel values of both layers. A base pixel value together with corresponding difference pixel values constitute a data cluster. The principle of segmentation is division of an image greyscale into disjoint ranges and assigning of individually base values to the proper ranges. The segmentation process utilizes the base values mainly and therefore proposed technique is computationally attractive.

SEGMENTACJA OBRAZÓW CYFROWYCH Z WIDEOREJESTRATORA RUCHU DROGOWEGO

Streszczenie. W proponowanej metodzie segmentacji wykorzystuje się dwuwarstwowy model danych obrazów cyfrowych. Model ten składa się z warstwy wartości różnicowych oraz warstwy wartości bazowych. Pierwotna wartość piksela jest otrzymywana przez odpowiednie łączenie wartości pikseli z obu warstw. Wartość bazowa piksela wraz z odpowiadającymi mu wartościami różnicowymi tworzą klaster danych. Zasada segmentacji polega na podziale przedziału poziomów szarości na rozłączne zakresy oraz przyporządkowaniu poszczególnych wartości bazowych do odpowiednich zakresów. W procesie segmentacji wykorzystywane są głównie wartości bazowe i dlatego proponowana technika jest obliczeniowo atrakcyjna.

1. INTRODUCTION

In contemporary transport systems traffic parameters are utilized for monitoring and control of road traffic. Traffic parameters can by determined on the basis of computer image analysis. Computer image analysis uses various techniques such as: segmentation an image into regions or objects, description of objects, classification of objects. The result of image analysis process is a set of attributes extracted from an analyzed image.

Segmentation is a process that merges into regions image parts on the basis of common attributes. The basic attribute for image segmentation is pixel value. Segmentation can be carried out by region growing or region splitting. There are known various segmentation techniques: boundary segmentation [1, 4, 6, 10], texture segmentation [6, 10], segmentation using graph formulation of groupings [2, 8, 9], segmentation using random walks [5] and other e. g. [11].

Image analysis methods can include preliminary format transforms, which improve effectiveness of used algorithm. The effectiveness of image processing and image analysis also depends on an applied image scanning technique that defines a one-dimensional input form of image data.

Conversion into the two-layer data model utilizes predictive coding [7]. The two-layer data model of digital images [3] forms a new image representation. This image representation is created as a result of image format conversion and consists of two layers. One layer called a base values layer contains base pixel values, the other layer called a difference values layer determines differences between an image pixel value and a corresponding base value. Original pixel values are obtained by appropriate joining together pixel values of the base values layer and the difference values layer.

2. DESCRIPTION OF THE TWO-LAYER IMAGE DATA MODEL

A digital image can be described as a two-dimensional matrix of digital values that determine image pixel levels of a grey or colour component. The proposed model assumes greyscale images with an intensity resolution of 8 bits per pixel. The data representation of a greyscale image of 8 bits per pixel is interpreted as a one-layer model of the image. Image conversion into the two-layer data model constitutes a new data representation.

Some classes of images contain regions of pixel values similar to one another. The two-layer image data model assumes that pixels are described by sequences of a base value and a set of difference values determined as differences between the current pixel value and the base pixel value. The entire image representation includes all individual region sequences. All base values form the base values layer and all difference values form the difference values layer. Each layer is encoded separately.

Assuming that difference between minimum and maximum pixel difference value do not exceed 15, one different value requires 4 bits for encoding and two difference values can be encoded in one byte by joining together neighbouring pairs of difference values. Base pixel values are encoded without the change as unsigned 8 bit numbers.

The two-layer data model of digital images is defined for images with spatial resolution M x N of pixels. The examined image is described by image matrix X containing elements $x_{m,n}$. Image vector Y, conversion vector B of base values and conversion vector D of difference values are created during processing.

Elements of image matrix X are entered into image vector Y as a result of image matrix conversion into image vector according to the scanning order of image matrix X. The applied scanning order of image matrix X assumes dividing of image matrix X into blocks 2 x 2 of pixels and scanning pixels in the block by columns simultaneously with scanning blocks by rows. Figure 1 shows a scanning order of conversion of image matrix X into image vector Y (blocks N=0, N=1, N=128, N=129).

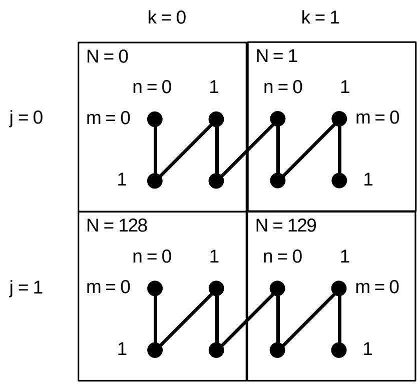

Fig. 1. Scanning order of image matrix conversion into the image vector
Rys. 1. Porządek skanowania przy konwersji macierzy obrazu na wektor obrazu

Each image block is described by block coordinates j (rows of blocks), k (columns of blocks) and ordinal block number N. Pixels of each block are described by inner block pixel coordinates m (rows of pixels) and n (columns of pixels).

Image conversion into two-layer data model involves conversion vector B containing base values and conversion vector D containing difference values. The first step of conversion is determination of an initial base value and writing it into conversion vector B

$$b_0 = y_0 . \tag{1}$$

The first value written into conversion vector D is marker denoted c

$$d_0 = c . \tag{2}$$

Elements y_i of image vector Y (y_i =1, 2, …, MN) are successively read and two cases are considered for each element. In the first case the difference between the current pixel value and the base value of the region allows 4 bit coding and then the difference value is written down into conversion vector D. Index i of the vector elements indicate current writing position

$$d_i = \Delta\, y_i . \tag{3}$$

In the second case the difference between the current pixel value and the base value of the region is too big and it cannot be encoded as a difference value. In that case the marker c is written into conversion vector D

$$d_i = c \tag{4}$$

and the full pixel value is written into conversion vector B

$$b_{i-\Delta i} = y_i . \tag{5}$$

Index i of the vector elements indicate current writing position, Δ_i determines index offset of conversion vectors D and B. Output stream S consists of two sub-streams, sub-stream S_D of difference values and sub-stream S_B of base values.

$$S = S_D + S_B \tag{6}$$

Sub-stream S_D is created by joining together neighbouring difference values of conversion vector D

$$s_{Di} = d_{2i} \cdot 16 + d_{2i+1}\,, \qquad i = 0, 1, \ldots, \frac{MN}{2} - 1 \tag{7}$$

and sub-stream S_B is conversion vector B

$$S = S_B \tag{8}$$

Back conversion from the two-layer data model into the one-layer data model is performed in reverse order and the individual steps follow as: input stream S is split in sub-streams S_D and S_B, conversion vector D and conversion vector B are reconstructed appropriately on the basis of sub-stream S_D and sub-stream S_B, image vector Y is filled with pixel values reconstructed on the basis of elements of conversion vector B and conversion vector D, image matrix X is filled with pixel values reconstructed on the basis of elements of image vector Y. The image obtained as the result of the reconstruction from input stream S and the source image are the same.

3. TEST IMAGES

The conversion into the two-layer model is applied to three test images: Image 1, Image 2 and Image 3. The original test images and the layouts of base values are shown in Figure 2.

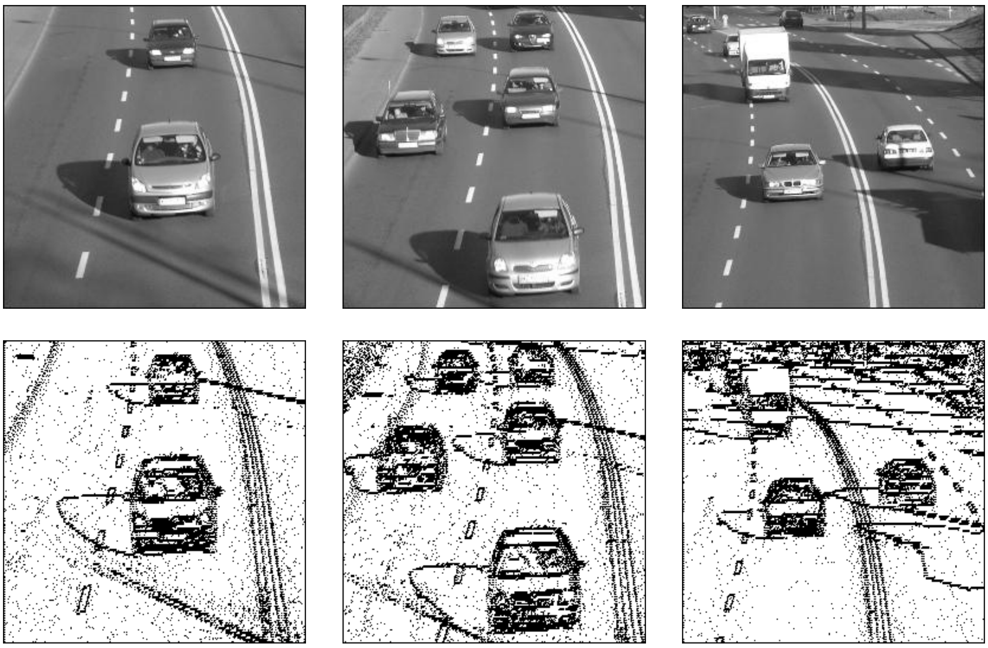

Fig. 2. Test images and layouts of base values
Rys. 2. Obrazy testowe i rozkłady wartości bazowych

The original test images are placed at the upper part of the figure and the images showing the layout of base pixels are placed at the lower part of the figure. The test images differ in the degree of detail. All test images are in greyscale 8 bits per pixel and with spatial resolution 256 x 256 of pixels.

Conversion into the two-layer image data model creates a new image representation that consists of two layers. The pixel layout of the base pixels values corresponds directly to image content. The two-layer data model of so called "nature images" is usually a smaller size than a bitmap format.

4. SEGMENTATION TECHNIQUE

In the two-layer image data model a base pixel value and difference pixel values of a region constitute a kind of cluster. Segmentation of the two-layer image data model uses the criterion of homogeneity for only base value pixels. This solution allows reducing the number of required operations.

In segmentation of the two-layer image data model is necessary to divide the greyscale into R ranges (R>1). Each range r_k (1<k<=R) is described by the beginning value of the range r_{kmin}, the end value of the range r_{kmax} and the characteristic value of the range r_{k0}.

$$r_{k\min} \le r_{k0} \le r_{k\max}. \tag{9}$$

In the course of the segmentation process input stream S is analyzed. In the beginning the first current base value is determined

$$r_0 = s_{B0} \tag{10}$$

then the current base value is assigned to the proper range

$$r_{k\min} \le b_0 \le r_{k\max} \tag{11}$$

and the current base value is changed

$$r_0 = s_{B0}. \tag{12}$$

The position of markers c in input sub-stream S_D indicates a new current base value.

The difference values are successively reconstructed and the current base value is written into image matrix X according to the scanning order (m, n, i indicates current writing parameters).

$$x_{m,n} = b_i \tag{13}$$

The applied algorithm assumes division of image greyscale into disjoint segmentation ranges. The greyscale can be split into ranges of a regular or various sizes. Boundaries are detected by comparison of neighbour pixels during image scanning by rows and by columns.

5. RESULTS OF SEGMENTATION

Segmentation of the two-level data image model is applied to all test images. Figure 3 to Figure 5 show the result of segmentation applying regular ranges. The number of ranges is respectively R=2 (size of each range is equal 128), R=4 (size of each range is equal 64) and R=8 (size of each range is equal 32).

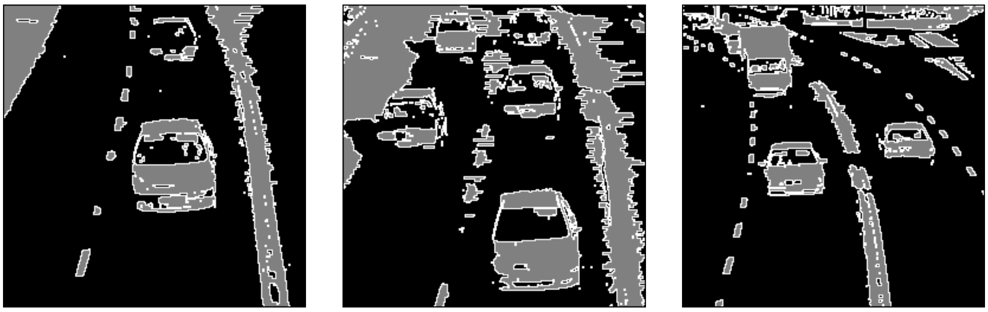

Fig. 3. Results of segmentation of test images (R=2)
Rys. 3. Wyniki segmentacji obrazów testowych (R=2)

Fig. 4. Results of segmentation of test images (R=4)
Rys. 4. Wyniki segmentacji obrazów testowych (R=4)

Fig. 5. Results of segmentation of test images (R=8)
Rys. 5. Wyniki segmentacji obrazów testowych (R=8)

An increase of the number of segmentation ranges causes an increase of the degree of segmentation detail. The number of segmentation ranges should be suitable to the class of images and to the task of segmentation.

Figure 6 to Figure 8 show the result of segmentation applying various ranges. The number of ranges is R =3. The range sizes are in a ratio of 4:8:4 in Figure 6 (the range sizes are respectively equal 64, 128, 64), in a ratio of 6:4:6 in Figure 7 (the range sizes are respectively equal 96, 64, 96) and in a ratio of 7:2:7 in Figure 8 (the range sizes are respectively equal 112, 32, 112).

Fig. 6. Results of segmentation of test images (R=3, a range sizes ratio of 4:8:4)
Rys. 6. Wyniki segmentacji obrazów testowych (R=3, stosunek rozmiarów przedziałów 4:8:4)

Fig. 7. Results of segmentation of test images (R=3, a range sizes ratio of 6:4:6)
Rys. 7. Wyniki segmentacji obrazów testowych (R=3, stosunek rozmiarów przedziałów 6:4:6)

Fig. 8. Results of segmentation of test images (R=3, a range sizes ratio of 7:2:7)
Rys. 8. Wyniki segmentacji obrazów testowych (R=3, stosunek rozmiarów przedziałów 7:2:7)

Good results of segmentation are obtained for range sizes in a ratio of 6:4:6 and partly in a ratio 4:8:4, incorrect results are obtained for range sizes in a ratio of 7:2:7.

Figure 9 to Figure 11 show the result of segmentation applying various ranges. The number of ranges is R =5. The range sizes are in a ratio of 2:3:6:3:2 in Figure 9 (the range sizes are respectively equal 32, 48, 96, 48, 32), in a ratio of 2:4:4:4:2 in Figure 10 (the range sizes are respectively equal 32, 64, 64, 64, 32) and in a ratio of 4:3:2:3:4 in Figure 11 (the range sizes are respectively equal 64, 48 32, 48, 64).

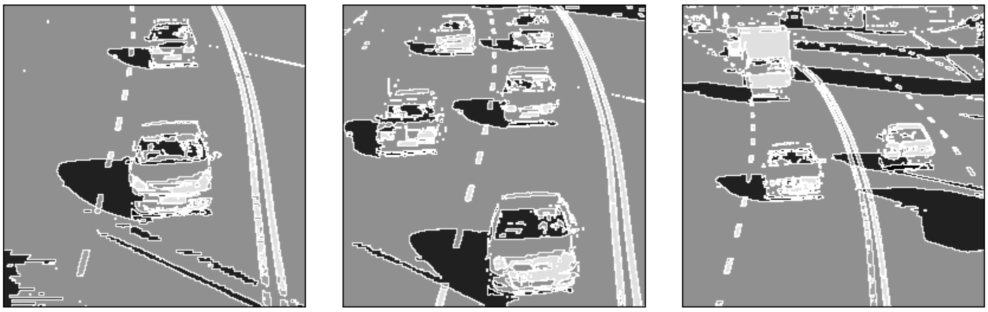

Fig. 9. Results of segmentation of test images (R=5, a range sizes ratio of 2:3:6:3:2)
Rys. 9. Wyniki segmentacji obrazów testowych (R=5, stosunek rozmiarów przedziałów 2:3:6:3:2)

Fig. 10. Results of segmentation of test images (R=5, a range sizes ratio of 2:4:4:4:2)
Rys. 10. Wyniki segmentacji obrazów testowych (R=5, stosunek rozmiarów przedziałów 2:4:4:4:2)

Fig. 11. Results of segmentation of test images (R=5, a range sizes ratio of 4:3:2:3:4)
Rys. 11. Wyniki segmentacji obrazów testowych (R=5, stosunek rozmiarów przedziałów 4:3:2:3:4)

Good results of segmentation are obtained for range sizes in a ratio of 2:3:6:3:2 and in a ratio 2:4:4:4:2, incorrect results are obtained for range sizes in a ratio of 4:3:2:3:4.

6. REFERENCE TO OTHER SEGMENTATION TECHNIQUES

Segmentation of two-layer image data model is generally a technique of region growing. This method utilizes operations on clusters of pixels and thus that kind of segmentation has also somewhat features of statistical methods. All pixels of cluster correspond to the same base value. The segmentation operations are carried out on one base pixel value for all pixels of the cluster and this allows reducing significantly a number of performed operations.

The effectiveness of segmentation of the two-layer image data model is estimated compared with standard region growing segmentation. Efficiency of segmentation of the two-layer image data model defines the operation reduction ratio equal to a product of the number of base pixel values and the number of all image pixels. The size of test images is 64 KB. The number of base values is equal 10,7 KB for Image 1, 15,8 KB for Image 2 and 15,0 KB for Image 3. The operation reduction ratios are in the range 0,17-0,25. The obtained results shows that segmentation of the two-layer image data model is effective.

The variant of the method using the various sizes of ranges is flexible and allows adapting segmentation ranges to a class of images. The class of images can be determined on the basis of image parameters, thus the change of image parameters can influence the number and the size of segmentation ranges.

7. CONCLUSIONS

The two-layer image data model is suitable for image segmentation. The advantage of the two-layer image data model is that this model applies simple processing algorithm. Conversion into the two-layer image data model creates a new image representation that consists of two layers. The layout of pixels values of the base pixel value layer is in accordance with detected boundaries.

The two-layer image model is intended for so called “natural” greyscale images 8 bits per pixel. The two-layer data model allows segmentation and boundary detection with the use of a simple algorithm and therefore this image model is attractive computationally. Image conversion into two-layer data model can be useful for hardware implementation of image processing algorithm. The two-layer image model gives usually a smaller image representation than an image bitmap and can be also used as a method of preliminary image data transform.

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