EDN LLULXP DOI 10.5281/zenodo.10974603
УДК 004.932

IMAGE FILTERING METHOD FOR RECOGNIZING THE DESIRED OBJECTS

© 2024 ***Mukhamedieva D.K., Mukhamadieva K.B., Bozorboev ZH.U.***

The article formulates the task of preliminary processing of scene images to identify specific objects - route numbers of vehicles on color images obtained by shooting on camera devices. As accessible high-speed methods of pre-processing the Otsu method - a method of reception of optimum approach of the half-tone (grey) image, and also a number of standard methods of local processing in a sliding window is considered. The authors propose two heuristic pre-processing methods: nonadaptive transformation of a color image into gray (sharpness predictor); grey image blur method (BNS method - blurring the neighbors' shades) used to select the contours on the image. The test images show the effect of applying different methods to highlight contours and localize the area of the vehicle route number location on the images. The methods are also compared on other data - color photographs and a three-color cartographic image 1100 data with a dimension of 32x32 pixels.

Keywords: contour highlighting, pixel conversion, object localization, function Otsu.

Introduction. Video surveillance systems are widely used in railway traffic monitoring tasks. These tasks are extremely relevant and affect many aspects of human life. With the advent of digital video cameras, it became possible to process measurement data using a computer, which led to a wide range of new tasks in digital signal processing. Examples of such tasks are perimeter monitoring and detection of a moving object, recognition of a moving object, and identification of an object. Research and development of algorithms for processing video data, as a rule, requires a labor-intensive computational experiment on model and real data of a large volume. Therefore, it is important to correctly organize the computational process when modifying and testing algorithms.

This article discusses ways with low computing power requirements to distinguish wagon numbers from the background. The task is driven by the need to improve the quality and speed of filtering and semantic segmentation of objects in images, to accurately segment wagon numbers from the video stream in real time and to improve the stability and performance of the algorithm in cases of heavy contamination, non-contrast and non-standard of carriage numbers.

In this research, we try to identify the best algorithms that solve the problem of preprocessing the identification number of a railroad car in an image. Then on the image the identification number of the transport is searched by its schematic representation. Subsequently, digits are recognized on the specified sections and registered in the monitoring system [1].

When processing and analyzing digital images, the following steps are usually performed [2]:

- Segmentation of images using binarization and contour selection algorithms;
- Define (search) and describe linked areas;
- Comparison of characteristics of found areas with the standard.

The key stage of identification is comparison of the selected section of the source image with some reference image, using different characteristics such as center of gravity [2], spectral brightness functions [3], principle of estimations consistency or estimation of maximum plausibility [4].

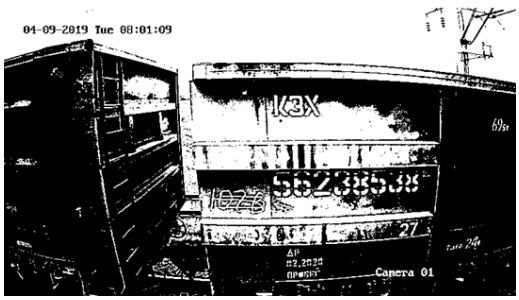
The stage of description of connected areas can be carried out in different ways: calculation of geometrical features [2], application of random sampling algorithm [5], analysis of hyperspectral information, training of neural networks [6]. In this paper the method based on the calculation of geometrical features of the image - relative length and width, the ratio of the perimeter square to the image area, format, center of gravity - was used to describe the regions. To select the areas present in the image, various algorithms are used, such as regional sprawl [7-8], wave growing areas tobogganing. These algorithms are not applicable in tasks with increased image detail, because the main objects in the image are divided into dozens of smaller, no analyzable areas.

Image segmentation starts by applying binarization, contouring, and noise reduction methods individually or in combination. The result of further image processing depends on the quality of this stage. Figure 1 shows a test image on which the quality of the various algorithms of binarization and selection of contours will be checked. test 1 - the image used for tests. The quality result of test 1 processing will be considered a binary image, on which the following criteria are met:

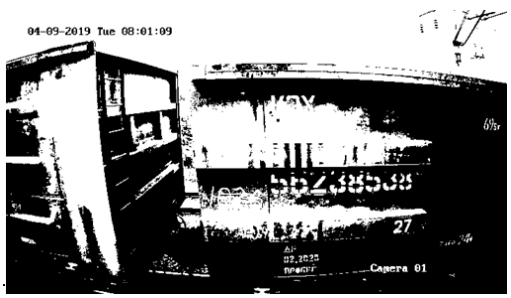
1. The contours of the transport identification number are clearly defined (criterion 1);
2. The number is saved exactly in the image (criterion 2), the information to which must be saved.

Fig. 1. Test image (test 1)

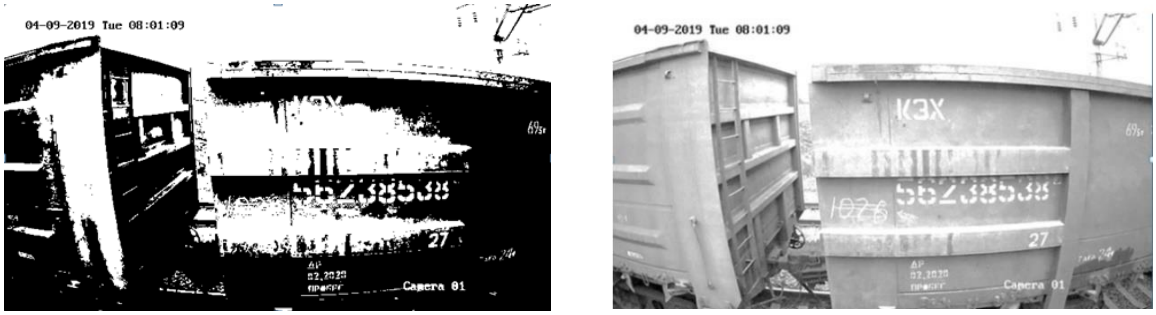
As part of this work, we have implemented and tested various well-known binarization algorithms: the Otsu method (figure 2a), Bradley Roth algorithms (figure 2b), Nibblack, Savuola and Christian Wolf algorithms, and the algorithm for analyzing the arithmetic mean color of a pixel (figures 2c) in the RGB model. The given circumstance has not allowed qualitatively to carry out binarization of images. However among the given group of methods separately stands the approach used in Otsu hierarchical method. The Otsu method is used for grey images, but that it successfully worked in a considered problem, it is enough to apply it repeatedly to each of two clusters of the pixels initially received by an original Otsu method and, then, analyzed as independent images (figure 2c). In fig. 2d is clearly enough to see the identification number of the vehicle.



a)



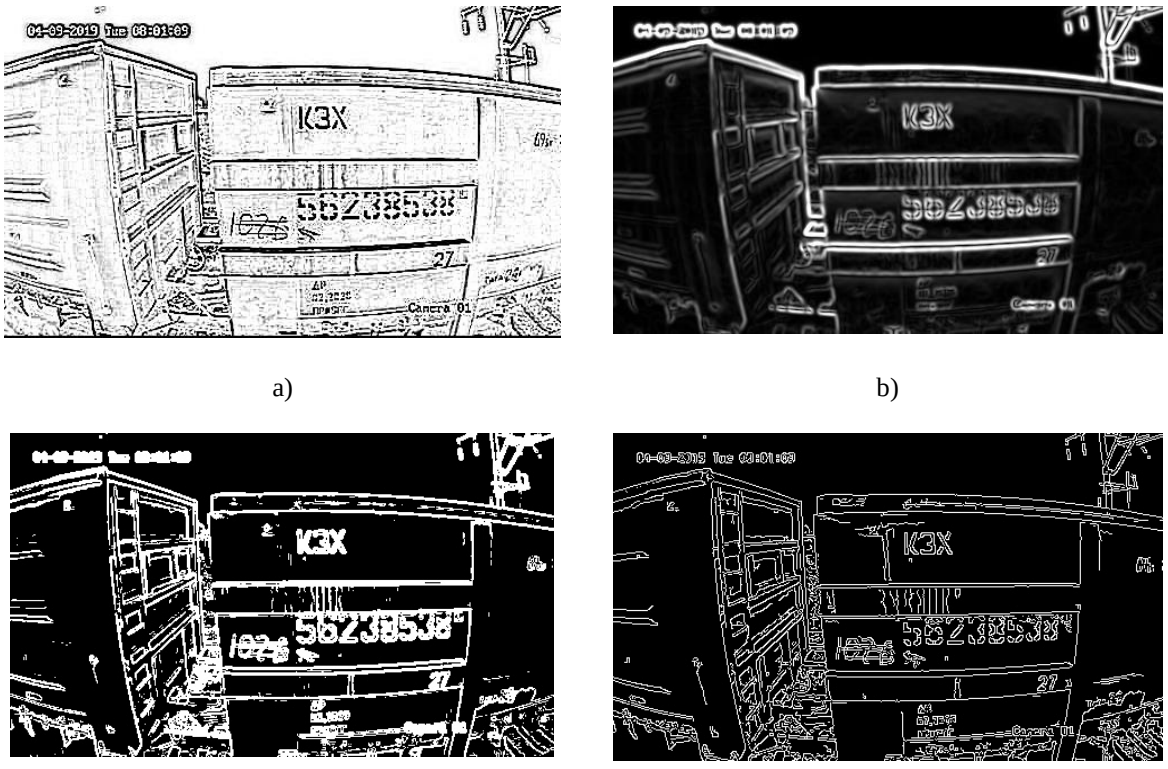
b)



c) d)

Fig. 2. Binarization of test image (test 1):
a) by Otsu method; b) by Bradley Roth algorithm;
c) using the arithmetic mean of pixel colors; d) using hierarchical Otsu method

The following algorithms of contour selection were also implemented and tested: different combinations of Laplacean and Gaussian (fig. 3a), Roberts' operator, Sobel's operator (fig. 3b), Pruitt's operator, Kirsch's operator (fig. 3c), Canny's operator (fig. 3d). The qualitative result was obtained using Laplacean 5x5. Only this operator allowed keeping high informativeness without loss of information quality. Kirsha operator showed also rather qualitative visual results, but the thickness of the received contours does not allow using it further for computer processing. Other algorithms managed to process qualitatively, but with different level of informativeness.



a) b)

c) d)

Fig. 3. Selection of the test image contours (test 1):
a) Laplacean 5x5; b) Sobel operator; c) Kirsch operator; d) Cannie operator

As it is visible from results of processing, the images appear superfluous information besides the important detail, namely - besides an identification number in addition figures of a mode of transport that is inadmissible within the limits of a solved problem. Only Otsu hierarchical method sometimes shows acceptable results.

Blurring the neighboring shades. The idea of the method of blurring the neighboring shades (BNS method). To solve the problem we use a low quality image as a test. Figure 4 shows, for an example, the results of the representation of the number "52600707" of the vehicle. The first figure shows the number as seen by its person, and the second figure shows the number as "seen" by its computer in the form of a screenshot. In case of digital raster images there are some shades (presence of a gradient) which can be both shades of the basic colour, and at all absent in a site of the considered image (figure 3b). The idea of the offered method of preliminary processing of images (POC) consists in blurring of "unnecessary" shades at transition from one pixel to another. Transition from one "necessary" pixel to another will be considered as a contour line, everything else - as background.

a)

b)

Fig. 4. Example of image representation (test 2):
a) by the human eye; b) as a raster

Let the digital image with the size of *DimX* x *DimY* pixels be given, which from the mathematical point of view can be represented by a two-dimensional matrix Im. The element of matrix Im[*i, j*] contains an integer value of the brightness display function $f \in [0,255]$ according to RGB color model, where $i \in (0, DimX-1)$, $j \in (0, DimY-1)$. To select a contour it is necessary to convert initial digital image Im[*i, j*] into monochrome *G*[*i, j*].

By an integer operator that calculates the arithmetic mean of a pixel color $Pix_{i\,j}\{r,g,b\}$ with a coordinate *(i, j) as* follows:

$$Pix_{i,j}\{\varphi_{i,j},\varphi_{i,j},\varphi_{i,j}\},$$

where $\varphi_{i,j} = \dfrac{r_{i,j} + g_{i,j} + b_{i,j}}{3}$.

The image is converted to monochrome (figure 4) to limit the color spectrum to 256 colors (according to the RGB model), then the selection of the contour is made by the formula:

$$B_{i,j} = \begin{cases} 1, tp_{i,j} \le G_{i+j,j+m} + \left|c_{i,j}\right| \\ 1, tp_{i,j} > G_{i,j} + \left|c_{i,j}\right| \end{cases}, \quad (1)$$

where $tp_{i,j} = \frac{1}{9}\sum_{\substack{-1\le k\le 1 \\ -1\le m\le 1}} G_{i+k,j+m}, a\ c_{i,j} = \left\{G_{i+k,j+m}, -1 \le k \le 1, -1 \le m \le 1\right\}.$

In the formula (1) $\left|c_{i,j}\right|$ - set, consisting of the color of and pixel (*i, j*) and the colors of pixels surrounding it neighbors, $tp_{i,j}$ - the arithmetic mean of the elements of this set. In the resulting binary image B[i, j] value 1 corresponds to the contour line, and value 0 - to the background. If the power of the set $\left|c_{i,j}\right|$ more than four [9], it is believed that pixel (*i, j*) refers to noise and its power is artificially set to four to increase the probability of its exclusion from the contour line. It is important to note that overlaying one's own conditions on the power of a set can lead to different results. This fact can be applied when a more specific solution is required in contour selection tasks.

The results of contour selection for test 2 are shown in figure 5. In this case, as a result of processing with this algorithm, the image remains informative, as in the case of other classical algorithms.

Fig. 5. Selection of contours by the method (blurring the gray image) of BNS

To achieve criterion 2 on test 2, we will consider pre-processing the image with some predictor that will correct the sharpness of the original image. Several different ways of pre-processing have been suggested by the author of this paper. In this article a new method will be proposed.

Image Sharpness Predictor. To improve the quality of image detail when selecting contours it is necessary to perform image pre-processing, which would average the brightness of all pixels to some constant, and the informative value of the original image should not decrease. The human eye can detect about 30 shades of grey depending on the lighting. Based on this, it is possible to average image areas to a specific grey shade based on the current pixel brightness. However, the bit depth of color (RGB model) is 24 bits, which does not allow you to correctly group 256 shades of gray into 30, so break down the color spectrum of the monochrome image into 24 groups. Thus, each group will consist of 256 / 24 = 10,67 ≈ 11 shades. Then in the processed monochrome image, the hues falling into the group are replaced by the initial hue of this group (table 1).

Table 1. Changing shades

Original shades	New shades	Original shades	New shades	Original. shades	New shades
0..10	0	88..98	88	176..186	176
11..21	11	99..109	99	187..197	187
22..32	22	110..120	110	198..208	198
33..43	33	121..131	121	209..219	209
44..54	44	132..142	132	220..230	220
55..65	55	143..153	143	231..241	231
66..76	66	154..164	154	242..252	242
77..87	77	165..175	165	253..255	253

Figure 6 shows the result of the predictor's work with the original test images. Comparing the images before (fig. 3) and after the predictor's processing (fig. 6), one can conclude that visual detail and informativeness of the image has been saved.

Fig. 6. Predictor treatment result

Figure 7 shows the results of image contour selection by the BNS method using the proposed predictor.

Fig. 7. Selection of contours by BNS method after predictor processing

On the received images all necessary information is saved (requirement of criterion 2 is fulfilled). An additional effect of this approach is excessive detail, but by varying the number of shades (instead of the suggested 30) in the group it is possible to increase or decrease the level of detail of the binary image.

Comparison with other algorithms. The proposed approach (BNS method and predictor) is compared with other popular contour extraction algorithms, such as Cannie and Kirsch operators, and Laplacean 5x5. The results of the algorithms were compared by the following estimates:

- Human visual evaluation of contour extraction quality using fuzzy sets;
- Estimating the thickness of the contours of the obtained images;
- Calculated boundary quality assessment based on peak signal-to-noise ratio;
- Estimating the time spent on algorithm execution.

Each of these criteria is discussed in more detail below:

Human visual evaluation. As you can see from the images, each algorithm has its advantages and disadvantages, depending on the original image. To assess the visual quality of the results of each of the algorithms was conducted a survey of fifty respondents who were asked to evaluate the results on a scale of ten points (1 - worst, 10 - best) on three criteria: accuracy of detail, sharpness of contours, image quality in general. The weighted average score of each algorithm's criteria is presented in the table below (table 2). The Otsu hierarchical method has not been considered in comparison, as it applies to grayscale images (with good results on tests).

Table 2. Weighted average score of criteria

Algorithm	Detail assessment	Evaluation of circuits	Quality Assessment
BNS with predictor	5.2	4.94	5.31
BNS w/o predictor	6.16	5.71	4.70
Operator Canny	5.25	5.1	5.03
Operator Kirsha	6.96	7.38	6.81
Operator Laplace	6.57	6.69	6.48

The weighted average score of the evaluated criterion is used as input variables of the fuzzy output system to assess its quality. Each variable is described by one of three terms: P - "bad", U - "satisfactory", X - "good". For each of the three variables, the function of belonging of the kind $\mu(x)$ = (1.5,10,10) was set. The output variable "quality of algorithm execution results" is also described by one of the three specified terms. Table 3 provides some rules for determining the relationships between input and output variables.

Table 3. Rules for Relationship between Variables

Details	Contours	Image Quality	Quality of algorithm results
X	X	X	X
X	U	X	X
U	X	U	U
P	U	P	P

After the defuzzification procedure using the center of gravity method and application of the fuzzy conclusion rules, the following results were obtained (table 4). It can be concluded from the obtained results that the results of Kirsch and Laplace operators are the most preferable by visual evaluation. Obviously, this preference was given by the respondents due to the thickness of the obtained contour lines and the accuracy of detail transmission necessary to understand the information that the image carries. It is therefore quite surprising that the use of the Laplace operator is rarely mentioned in other works.

Table 4. Evaluation results in fuzzy sets

Algorithm	Quality of results
BNS with predictor	Satisfactory
BNS w/o predictor	Satisfactory
Operator Canny	Satisfactory
Operator Kirsha	The good one is
Operator Laplace	The good one is

Evaluation of contour thicknesses. When obtaining the contours, the thickness of the selected boundary must tend to one point. To evaluate the feasibility of this criterion in this paper, the contours are selected on the test image. The borders of the image are delineated by a single contour. From the received images without additional calculations it is visible, that method Otsu and the offered method BNS satisfy the given criterion.

Numerical assessment of the quality of border allocation. The peak signal-to-noise ratio (PSNR) method is used for the numerical assessment of boundary selection quality. For this purpose, three indicators are calculated: probability of correct detection, first kind error probability, second kind error probability using formulas (2-4) respectively. Here *Nj* - number of boundary points in the ideal object contour; *NB* - number of boundary points in the object contour obtained during the detection process; *TP* - number of correctly detected object points; *FN* - number of points which are boundary points of the object but which were not detected by the boundary detector; *FP* - number of points which are not boundary points of the object but which were detected by the boundary detector.

$$P_{co} = \frac{TP}{\max(N_I, N_B)}, \tag{2}$$

$$P_{rd} = \frac{FN}{\max(N_I, N_B)}, \tag{3}$$

$$P_{fa} = \frac{FP}{\max(N_I, N_B)}. \tag{4}$$

Calculation of the numerical estimation of the boundary quality is performed according to formulas (5-6), where *RE* is a relative error determined through the previously considered primitive metrics, in which α is a constant limiting *RE* from above; *b, c, d* are weight coefficients which are measures of significance of primitive metrics.

$$RE = (b * P_{co} + \alpha)^{-1} + c * P_{fa} + d * P_{rd}. \tag{5}$$

$$PSNR = 10\log_{10}\left(\frac{1}{RE}\right). \tag{6}$$

The criterion of optimal segmentation is considered as follows: $PSNR \to \max$. Since the test image is a contour, you can determine PSNRmax by comparing the images with themselves. As coefficients *a, b, c, d,* constants 2, 0.7, 0.2 and 0.1 were used, respectively. The results of the calculations are presented in table 5.

Table 5. Numerical quality assessment

Method	*Pco*	*Prd*	*Pfa*	*RE*	*PSNR*
Reference	1	0	0	0.37	4.31
BNS without predictor	1	0	0	0.37	4.31
BNS with predictor	1	0	0	0.37	4.31
Operator Canny	0.09	0.29	0.91	0.70	1.57
Operator Kirsha	0.28	0	0.72	0.60	2.21
Laplacean 5x5	0	0.20	1	0.72	1.42

From the table 5 it is visible that thanks to the property of allocation of a single line of a contour, and that the given image was initially created in digital form, method BNS in both cases has shown 100 % allocation of all lines of a contour.

Evaluation of time costs. To estimate time consumption of algorithms execution, a test image of 4140x5520 pixels was taken. The test results are presented in table 6. Testing shows that the least resource-intensive method is BNS, and the use of the predictor speeds up the execution of the main algorithm.

Table 6. Algorithm runtime

Method	Duration(ms)
Operator Canny	240
BNS method without predictor	46
BNS method with predictor	33
Operator Kirsha	71
Operator Laplacean	71

Conclusion. In the course of the research, known image processing algorithms were tested. Since the results of most of these algorithms did not meet the established criteria, were proposed empirical algorithms that can achieve the necessary results in the output image. As testing has shown, the proposed algorithms effectively cope with photos, with images with a low threshold of light sensitivity (test 2) and images that do not have a gradient (contour image), while maintaining the numerical evaluation criteria.

The proposed algorithm has some advantages over other algorithms, such as higher peak signal-to-noise ratio and high computational speed. Therefore, it can be applied in systems with low processor power without reducing the speed of filtering contaminated, low contrast of identification numbers on wagon images.

REFERENCES LIST

1. Regularized evolution for image classifier architecture search / E. Real, A. Aggarwal, Y. Huang, Q. V. Le // AAAI Conference on Artificial Intelligence. – 2018. – 16 p. – DOI 10.1609/aaai.v33i01.33014780.
2. A unified multi-scale deep convolutional neural network for fast object detection / Z. Cai, Q. Fan, R. S. Feris, N. Vasconcelos // European Conference on Computer Vision. – 2016. – P. 354–370. – DOI 10.1007/978-3-319-46493-0_22.
3. Encoder-decoder with atrous separable convolution for semantic image segmentation / L. Chen, Y. Zhu, G. Papandreou [et al.] // European Conference on Computer Vision. – 2018. – 18 p. – DOI 10.1007/978-3-030-01234-2_49.

4. Elfwing, S. Sigmoid-weighted linear units for neural network function approximation in reinforcement learning / S. Elfwing, E. Uchibe, K. Doya // Neural Networks. – 2017. – №107. – P. 3–11. – DOI 10.1016/j.neunet.2017.12.012.
5. Megdet: A large mini-batch object detector / C. Peng, T. Xiao, Z. Li [et al.] // 2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition. – 2018. – P. 6181-6189. – DOI 10.1109/CVPR.2018.00647.
6. Islam, M. A. Gated feedback refinement network for dense image labeling / M.A. Islam, M. Rochan, N.D. Bruce, Y. Wang // IEEE Conference on Computer Vision and Pattern Recognition. – 2017. – P. 4877-4885. – DOI 10.1109/CVPR.2017.518.
7. Ramachandran, P. Searching for Activation Functions / P. Ramachandran, B. Zoph, Q. V. Le. // ArXiv: 1710.05941. – 2018. – DOI 10.48550/arXiv.1710.05941.
8. Redmon, J. Yolov3: An incremental improvement / J. Redmon, A. Farhadi // ArXiv: 1804.02767. – 2018. – DOI 10.48550/arXiv.1804.0276.
9. Jonathan, P. Yolo-lite: a real-time object detection algorithm optimized for non-gpu computers / J. Pedoeem, R. Huang // 2018 IEEE International Conference on Big Data. – 2018. – P. 2503-2510. – DOI 10.1109/BigData.2018.8621865.

Поступила в редакцию 26.12.2023 г., рекомендована к печати 30.01.2024 г.

МЕТОД ФИЛЬТРАЦИИ ИЗОБРАЖЕНИЙ ДЛЯ РАСПОЗНАВАНИЯ НУЖНЫХ ОБЪЕКТОВ

Мухамедиева Д.К., Мухамадиева К.Б., Бозорбоев Ж.У.

В статье сформулирована задача предварительной обработки изображений сцены для идентификации конкретных объектов - маршрутных номеров транспортных средств на цветных изображениях, полученных при съемке на фотоаппараты. В качестве доступных скоростных методов предварительной обработки рассматривается метод Otsu - метод получения оптимального приближения полутонового (серого) изображения, а также ряд стандартных методов локальной обработки в скользящем окне. Авторы предлагают два эвристических метода предварительной обработки: неадаптивное преобразование цветного изображения в серое (предиктор резкости); метод размытия серого изображения (метод BNS - размытие оттенков соседей), используемый для выделения контуров на изображении. На тестовых изображениях показан эффект от применения различных методов для выделения контуров и локализации области расположения маршрутного номера автомобиля на изображениях. Методы также сравниваются на других данных - цветных фотографиях и трехцветном картографическом изображении 1100 данных с размером 32x32 пикселя.

Ключевые слова: выделение контуров, преобразование пикселей, локализация объектов, функция Otsu.

Мухамедиева Дилдора Кабуловна
доктор технических наук, профессор, профессор кафедры программного обеспечения информационных технологий Ташкентского университета информационных технологий имени Мухаммада ал-Хоразмий,
Узбекистан, г. Ташкент.

Mukhamedieva Dildora Kabulovna
Doctor of Technical Sciences, Professor, Professor at Department of Information Technology Software of Tashkent University of Information Technologies named after Muhammad al-Khorazmiy,
Uzbekistan, Tashkent.

Мухамадиева Кибриё Бахадировна
соискатель кафедры информационных технологий Ташкентского университета прикладных наук,
Узбекистан, г. Ташкент.
E-mail: mkb78@mail.ru

Mukhamadieva Kibrie Bakhadirovna
Applicant at Department of Information Technologies of Tashkent University of Applied Sciences,
Uzbekistan, Tashkent.

Бозорбоев Жавлон Уткирбой угли
студент кафедры компьютерного инжиниринга Ташкентского университета прикладных наук,
Узбекистан, г. Ташкент.
E-mail: bjavlon@gmail.com

Bozorboev Javlon Utkirboy ugli
Student at Department of Computer Engineering of Tashkent University of Applied Sciences,
Uzbekistan, Tashkent.