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AUTOMATION OF RECOGNITION OF A RESEARCH AREA AT WEAKLY CONTRAST BORDERS ON THE IMAGE OF TRANSPARENT OBJECTS

Recently, due to the active development of computer technologies, in the field of science dealing with visual objects, there are problems of creating systems for automatic image recognition. This class of problems does not have a universal way of solving and this leads to the fact that, depending on the needs of a branch of science and engineering, the developers of such systems are forced to solve problems of a private nature.

The purpose of this work is to create a software product by the authors that would allow automatic recognition of the study area of objects having a weakly expressed boundary between the separation of object and background to further determine the values of the optical characteristics of transparent objects, as common features in identification trace evidence analysis the whole by parts.

One of the main problems of detecting the boundaries of the separation of objects in an image is the poor contrast of the transition region between adjacent areas of the divided space, which leads to the need for image processing to segment and correct the contrast. To develop an effective way to limit the recognition area and identify the boundaries of the studied object under the condition of low contrast between the light background and the space occupied by a transparent medium, which differs from the background in optical properties, there is a need to analyze existing image enhancement algorithms and their further practical implementation using mathematical software products of numerical analysis.

Thus, the paper reviews modern algorithms for image recognition methods and algorithms for changing image quality by segmentation and contrast correction. The proposed algorithms are implemented in a computer program developed by the authors of the Sumy Research Institute of the Ministry of Internal Affairs of Ukraine based on the mathematical software MATLAB, which allows to carry out automatic comparative analysis of the studied samples based on their digital images. The questions posed to the authors for further development of this topic are outlined.

Keywords: image recognition; identification of trasological studies of the whole by parts; segmentation; contrast correction; brightness gradient

Formulation of Research Problem. Any field of science or engineering that deals with visual objects gets the benefit of creating their own image recognition systems. The very need to develop such a system arose in the identification of tracological studies of the whole in parts, in the framework of the study of the optical properties of transparent media, on the example of glass. The authors of the Ministry of Internal Affairs of Sumy have started designing a software product that would allow to automatically identify the area of study of objects that have a weak boundary between the separation of object and background and to perform a comparative analysis of their optical properties. Thus, the initial task of creating this program is to develop an effective way of limiting the area of recognition and detection of the boundaries of the object under the condition of a weak contrast of the transition between light background and space occupied by a transparent environment that differs from the background in optical properties.

Analysis of recent researches and publications. As is known, a great deal of information is presented in the form of static or dynamic images, which are viewed and analyzed by a person through the mechanism of visual perception. The human eye is a unique mechanism that provides adaptive adjustment according to external conditions. The visual system responds differently to radiation, which is identical in power but differs in the radiation range (spectral sensitivity of the eye).

Ability of the eye to distinguish the minimum difference in brightness of adjacent areas of the image is characterized by contrast sensitivity. Also, the visual system is characterized by different sensitivities to the color tone, that is, to radiation from different parts of the spectrum. The visual system is also characterized by a sensitivity to color saturation.

Thus, the feeling of color is determined by three main characteristics – luminosity, color tone and saturation. Color spaces are used to classify colors.

Based on properties and characteristics of visual systems, various models of color vision are created, enabling the construction of image recognition systems based on algorithms, the general structure of which is presented in Fig.1[1].

Information tasks of image recognition systems consist of two stages:

– conversion of the original data to a view that is easy to recognize;
– direct recognition (setting an object to a class).

[1] URL : http://old.ci.ru/inform03_06/p_24.htm (accessed 29.05.2019).

In these tasks, you can introduce the concept of analogy or similarity of objects and formulate rules by which the object is assigned to one class or to different classes.

It is difficult to identify formal theories and use classical mathematical methods for recognition problems. This is due to the limitation of the information for the exact mathematical model or the lack of benefits from using the model compared to the cost.

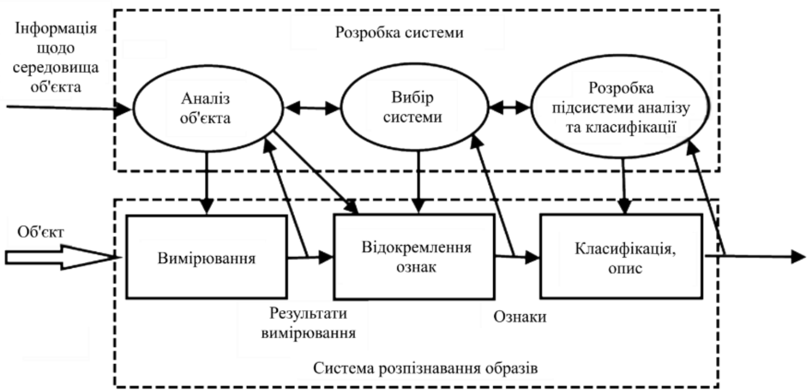


Fig. 1. Structure of the pattern recognition system.

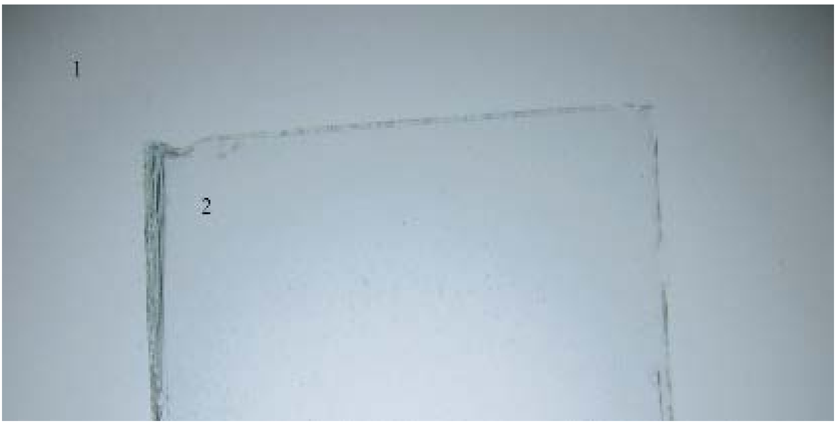
One of the most powerful tools for modeling and exploring image processing methods is the MATLAB numerical analysis software, namely the Image Processing Toolbox[1] application suite. It is based on the above software environment that the authors began to develop a program to determine the values of the optical characteristics of transparent objects, as a general feature in the identification of whole pathological studies, by which it is possible to carry out automatic recognition of the boundaries between slightly contrasting objects, to identify certain areas of study on images and more.

Research Purpose. The purpose of this work is to create a software product by the authors, which would allow to automatically identify the area of study objects that have a weak boundary separation of the object and background to further determine the optical characteristics of transparent objects, as common features in the pathological studies of the whole parts.

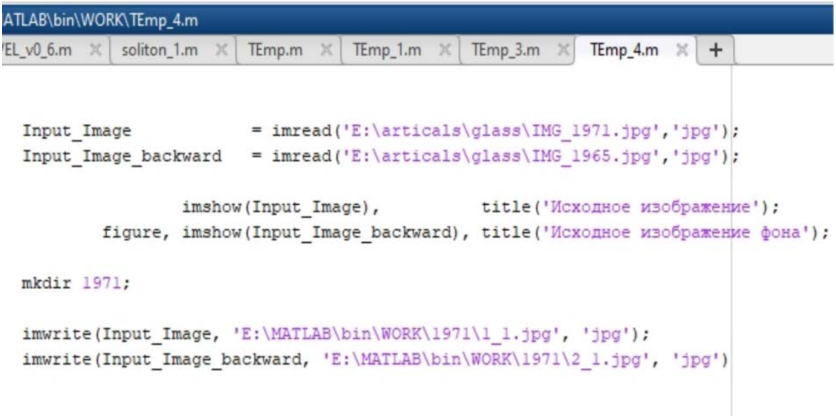
[1] URL : https://www.mathworks.com/products/image.html (accessed 29.05.2019).

Main content presentation. In the program of recognition and selection of the study area to determine the values of the optical characteristics of transparent objects, as common features in the identification of whole pathological studies developed by the authors, the input data is a photograph of the object that will be further processed (Fig. 2) . In this photo, according to Fig. 1, is presented with information about the object environment and the object of study itself. In Fig. In Fig. 3 presents a code snippet that is responsible for converting the source data to a readable look. When solving the problem of image recognition, initially there is a need to differentiate the background and the area of the study, which is the study of optical properties, ie solves the problem of isolation and localization of the boundaries of the separation of objects in the image. Along the boundary there is a sharp change in brightness or its derivatives by spatial variables. The most common types of boundaries are the areas where the orientation of the surface changes abruptly or one object obstructs another, there is a boundary of the discarded shadow or there is no continuity in the reflective properties of the surface, etc.

Brightness change noise limits the ability to separate border information. There is a contradiction between sensuality and precision and, because of this contradiction, leads to the conclusion that the short separation boundary should have more contrast than the long one, to recognize it more effectively. Separating borders be an adjunct to the task of image segmentation, since borders can be used to divide an image into areas that correspond to different surfaces.



2. Outgoing image that needs further processing: 1 – background area; 2 – the area where the transparent object of study (glass) is located.




```
Input_Image            = imread('E:\articals\glass\IMG_1971.jpg','jpg');
Input_Image_backward   = imread('E:\articals\glass\IMG_1965.jpg','jpg');

                imshow(Input_Image),           title('Исходное изображение');
        figure, imshow(Input_Image_backward), title('Исходное изображение фона');

mkdir 1971;

imwrite(Input_Image, 'E:\MATLAB\bin\WORK\1971\1_1.jpg', 'jpg');
imwrite(Input_Image_backward, 'E:\MATLAB\bin\WORK\1971\2_1.jpg', 'jpg')
```

Fig. 3. The code snippet of the program responsible for uploading the original image to the computer for further processing.

When considering the intersection of the brightness function along a straight line that is perpendicular to the boundary, there is usually a jump in its values, but in practice, the difference may not be sharp due to the blurring and limitation made by the image locking device.

Brightness, in the general case, can be written in the form of some function$E(x, y)$E(x, y) and partial derivatives in the form $\frac{\partial E}{\partial x}$ $\frac{\partial E}{\partial y}$ $\frac{\partial E}{\partial x}$ $\frac{\partial E}{\partial y}$.. These differential operators are directed because the result of their action depends on the orientation of the boundary. Then the vector $(\frac{\partial E}{\partial x}, \frac{\partial E}{\partial y})$ is a brightness gradient that does not depend on the selected coordinate system. To use the brightness gradient for automatic image processing, sampling is necessary.

When considering a group of 2×2 image elements, the discrete values of the brightness function can be represented in the form proposed in Fig. 4.

$E_{i,j+1}$	$E_{i+1,j+1}$
$E_{i,j}$	$E_{i+1,j}$

4. Schematic representation of the sampling of the brightness function

Derivatives at the central point of this group are defined as:

$$\frac{\partial E}{\partial x}=\frac{dE}{dx}\approx\frac{1}{2l}\left[\left(E_{i+1,j+1}-E_{i,j+1}\right)+\left(E_{i+1,j}-E_{i,j}\right)\right], (1)$$

$$\frac{\partial E}{\partial y}=\frac{dE}{dy}\approx\frac{1}{2l}\left[\left(E_{i+1,j+1}-E_{i+1,j}\right)+\left(E_{i,j+1}-E_{i,j}\right)\right], (2)$$

where l is the distance between the centers of adjacent elements.

The gradient square can be represented as:

$$\left(\frac{\partial E}{\partial x}\right)^2+\left(\frac{\partial E}{\partial y}\right)^2=\left(\frac{dE}{dx}\right)^2+\left(\frac{dE}{dy}\right)^2\approx\frac{1}{2l}\left[\left(E_{i+1,j+1}-E_{i,j}\right)^2+\left(E_{i,j+1}-E_{i+1,j}\right)^2\right].(3)$$

While performing the proposed calculations for the whole image, where the brightness changes rapidly, the square of the gradient is greater, in places of constant brightness, the square of the gradient is zero, and in noise, the square of the gradient is small. After processing, the results are stored in a new array of images in which the edges are already enhanced.

If the signal obtained because of the reinforcement of the boundaries substantially exceeds the noise, one can conclude that a point of the boundary is present. This is not an absolute solution, as point noise can be significant. Therefore, to reduce the likelihood of such an event, you must select the input data so that the number of misclassified points is irrelevant within acceptable limits. If the data value is too high, the low bounds will be omitted. Thus, there is a contradiction between the two types of errors. By increasing the size of the areas under which the approximation is made, it is possible to reduce the impact of noise and simplify the possibility of delimitation. However, with the increase of sites, they may reach other boundaries. Thus, border recognition requires that they be more contrasting.

Sharp-edged images will have more brightness not only in pixels placed directly at the border, but also in some adjacent ones. This is especially evident in images where pre-smoothing is performed to reduce noise.

In addition to using a gradient square to enhance the image, it is possible to use the Laplace operator. The difference is that when processing an image using a gradient square, a crest with a height proportional to the square of the difference of brightness will correspond to the image, and in the case of a Lapsasian, two parallel crests will appear on each side of the border, these ridges will have opposite signs and a border will pass along the line of change of sign.

One of the problems with the development of boundary methods is that the assumptions on which they are based are often inapplicable in real cases. Although most surfaces have a constant reflectivity, their images can have an irregular brightness, the value of which depends on many factors. On the other hand, image elements that correspond to the points of the surface of different objects may have identical halftone images[1].

If we consider Fig. 2, the boundaries between the area of glass and background are poorly expressed. In fact, the above figure presents one of the significant drawbacks of existing methods of obtaining initial data: in most of them they provide the formation of low-contrast images. Therefore, the main purpose of the enhancement methods is to convert the image to a look that makes them more contrasting and therefore more informative[2]. Often, the image contains distortions in certain local surroundings caused by light diffraction, optical system defects, or defocusing. This leads to the need to perform local transformations on the image. In other words, this adaptive approach makes it possible to separate the information areas in the image and to process them accordingly. The stated requirements meet the methods of adaptive conversion of local contrast[3]. Methods of this class can be represented by a generalized block diagram (Fig. 5), which uses the following symbols:

$L(i,j)$ – the original image and its element with coordinates, (i,j)respectively;

$C(i,j)$C(i,j) – contrast of the image element with the coordinates(i,j);

$F(C(i,j))$F(C(i,j)) – converted contrast value$C(i,j)$;

ε, σ, H_s ε , σ , H$_s$ – local neighborhood characteristics (ε ε – entropy, σ – root mean square deviation, H_s – histogram length function);

$L^*(i,j)$L*(i,j) – element of the processed image with coordinates(i,j).

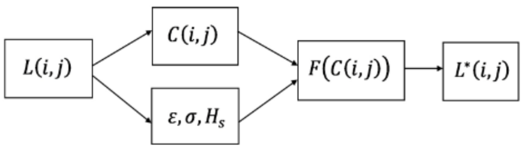


Fig. 5. Generalized block diagram of image enhancement methods using adaptive conversion of local contrasts.

[1] URL : http://matlab.exponenta.ru/imageprocess/book2/14.php (accessed 29 May 2019).

[2] *Dhawan A. P.* Enhancement of mammographic features by optimal adaptive №eighbourhvod image processing / A.P. Dhawan, G. Buelloni, R. Gordon. iEEE Trans. Med. imaging, 1986. 5. P. 8–15.

[3] *Bowyer K. W.* State of the Art in Digital Mammographic image Analysis / K. W. Bowyer, S. Astley. World Scientific Publishing Co. Pte. Ltd, 1994.

For each element of the image $L(i,j)$, calculate the local contrast $C(i,j)$ values in a neighborhood W centered in the coordinate element(i,j) and then calculate the local sliding circle statistics W. The next step is to transform (contrast) the local contrast$C(i,j)$, using nonlinear functions and taking into account the local sliding circle statistics For the conversion of local contrasts use nonlinear monotonic functions, and to form an adaptive function for the transformation of local contrast, choose power function and set the minimumα_{min} and maximumα_{max} $\alpha_{\max}$ values of the degreeα α. Adaptation is to form an additional operand to α_{min} by determining it based on local statistics in the sliding neighborhood. The parameters that will characterize the sliding circles are the histogram length functionH_s,, entropyε and the standard deviationσ of the brightness values of the sliding element elements. Therefore, depending on the task, the methods of this class may differ in the function of local contrast transformation and the characteristics of the sliding circle. Finally, the last step in implementing the structural diagram is to restore the brightness of the image$L^*(i,j)$ with enhanced contrast.

The implementation of the above algorithm using the features of the Image Processing Toolbox application package is possible using one of the ways to improve the contrast of color images – the transformation of color spaces, which change the values of color components. One such transformation is the change of the color space RGB to L * a * b *, its implementation is represented by a fragment of the program code in Fig. 6.

```
        Input_Image_contrast = Input_Image;

    srgb2lab=makecform('srgb2lab');
    lab2srgb=makecform('lab2srgb');
    shadow_lab=applycform(Input_Image_contrast, srgb2lab);
```

Fig. 6. Color space conversion code snippet.

The next step in the program is to change the image quality using the standard image processing feature of the Image Processing Toolbox, which is based on the action of the adapthisteq local contrastive adaptive conversion algorithm described above. In addition, comparative analysis used the image contrast enhancement function by changing the imadjust source image range and the histeq histogram[1]. equalization operation. Part of the program code for the application of these functions and the results of image processing using them are presented in Fig. 7 and fig. 8. All three functions give a satisfactory result for further processing of the image to locate the area of optical properties of the transparent medium as part of the

[1] URL : http://matlab.exponenta.ru/imageprocess/book2/29.php (accessed 29.05.2019.

image recognition task. But as you can see in Fig. 8, the boundary between the separation of the observation area and the surrounding background becomes sufficiently blurred. This problem would be important if the authors were interested not only in the space occupied by the sample, but also in the direct form of the object. The latter, at this stage of the program implementation, is not significant, since for the determination of the optical properties, in the case of a homogeneous medium, the clarity of the shape of the object under study is not particularly important.

```
% Значение интенсивности из диапазона от 0 до 100, преобразуется в диапазон
% [0 1] (преобразования выполняются в формате double)
% и далее применяются некоторые методы повышения контрастности

max_luminosity=420;
L=shadow_lab(:, :, 1)/max_luminosity;

shadow_imadjust=shadow_lab;
shadow_imadjust(: ,: , 1)=imadjust(L)*max_luminosity;
shadow_imadjust=applycform(shadow_imadjust, lab2srgb);
% shadow_histeq=shadow_lab;
% shadow_histeq(: ,: , 1)=histeq(L)*max_luminosity;
% shadow_histeq=applycform(shadow_histeq, lab2srgb);
% shadow_adapthisteq=shadow_lab;
% shadow_adapthisteq(: ,: , 1)=adapthisteq(L)*max_luminosity;
% shadow_adapthisteq=applycform(shadow_adapthisteq, lab2srgb);

figure, imshow(shadow_imadjust);
title('Imadjust');
```

Fig. 7. Snippet of classic image contrast enhancement application code for MATLAB Numerical Analysis Application Pack

Fig. 8. Example of image processing result using standard contrast enhancement features from MATLAB numerical analysis application suite.

After receiving an image that has undergone a contrast enhancement procedure, it is converted to black and white (binary) to facilitate further noise-related processing (see Figure 9).

The next step in the program is a mechanism for detecting and delineating the boundary of the separation of two environments: background and glass. In addition, by presenting the original and processed images in the form of matrices, it is possible to delineate the space of the study area to further determine the values of the optical characteristics of transparent objects (Fig. 10).

```
    Input_Image_Gray      = rgb2gray(shadow_imadjust);
    threshold             = graythresh(Input_Image_Gray);
    Black_White           = imbinarize(Input_Image_Gray, threshold);

                  figure, imshow(Black_White), title('Черно-белое изображение');

% устраним объекты, которые не являются объектами нашего интереса, т.е. шум
% удаление всех объектов, содержащих меньше чем 30 пикселей

    Black_White       = bwareaopen(Black_White,10000);

% заполнение пустот

    se                = strel('disk', 2);
    Black_White       = imclose(Black_White, se);
    Black_White       = imfill(Black_White,'holes');

                  figure, imshow(Black_White), title('Заполненое изображение');
```

Fig. 9. The code snippet of the program responsible for implementing the image conversion to binary and noise elimination.

```
[B_W, L] = bwboundaries(Black_White, 'noholes');

% отображение матрицы меток и извлечение границ

            figure, imshow(L), title('Разделение границей изображения и фона');
                    hold on

                for k=1:length(B_W)
                    boundary=B_W(k);
                    plot(boundary(:, 2), boundary(:, 1), 'r', 'LineWidth', 1)
                end

% создание выходной маски

    Black_White_1 = im2uint8(Black_White);

        Temp_1 = cat(3,Black_White_1,Black_White_1,Black_White_1);

%наложение маски на исходное изображение

    Output_Image                = Input_Image;
    Output_Image_backward       = Input_Image_backward;

    Output_Image(Temp_1==0)          = 0;
    Output_Image_backward(Temp_1==0) = 0;
          figure, imshow(Output_Image), title('Исходное изображение с маской');
          figure, imshow(Output_Image_backward), title('Исходное изображение фона с маской');

          imwrite(Output_Image, 'E:\MATLAB\bin\WORK\1971\1.jpg', 'jpg');
          imwrite(Output_Image_backward, 'E:\MATLAB\bin\WORK\1971\2.jpg', 'jpg')
```

Fig. 10. A snippet of the program code that is responsible for identifying the boundary between the background and the study area and the immediate restriction of research area.

Fig. 11 presents the results of the program to identify the boundary of the separation of two media and limit the area of direct study after using algorithms for image enhancement. Although, as you can see, the boundary between the separation of the background and the study area is sufficiently blurred, within the scope of the task to determine the values of the optical characteristics of transparent objects, as common features in identifying trace evidence research in whole, such accuracy was enough.

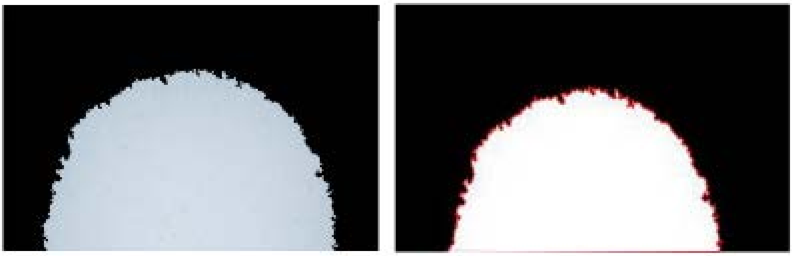


Fig. 11. The results of the program to identify the boundary of the separation of two environments (right) and the limitation of the study area (left).

In more detail, issues related to reducing the error of detection of borders, as well as ways of recognizing transparent objects by their optical characteristics will be discussed in the following works of the authors.

Conclusions. Thus, the paper provides an overview of modern algorithmic circuits of image recognition and image quality improvement by segmentation and contrast correction. The proposed algorithms are implemented in a computer program developed by the authors at the Sumy Research Institute of the Ministry of Internal Affairs of Ukraine based on the mathematical software MATLAB, which allows an automatic comparative analysis of the studied samples based on their digital images. The questions posed to the authors for further development of this topic are outlined.

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АВТОМАТИЗАЦІЯ РОЗПІЗНАВАННЯ ОБЛАСТІ ДОСЛІДЖЕННЯ ПРИ СЛАБКО КОНТРАСТНИХ МЕЖАХ НА ЗОБРАЖЕННІ ПРОЗОРИХ ОБ'ЄКТІВ

При створенні систем автоматичного розпізнавання об'єктів виникають проблеми виявлення межі переходу сусідніх областей розділеного простору при слабкій контрастності зображення, що призводить до необхідності проведення додаткової обробки зображення. В роботі проведено огляд сучасних алгоритмічних схем розпізнавання і підвищення якості зображення шляхом сегментації та корекції контрастності. Дані алгоритми реалізовані в розробленій авторами комп'ютерній програмі, яка дозволяє проводити автоматичний аналіз досліджуваних зразків для подальшого визначення значень оптичних характеристик прозорих об'єктів, як загальних ознак при ідентифікаційних трасологічних дослідженях цілого по частинах.

Ключеві слова: розпізнавання зображень; ідентифікація трасологічних досліджень цілого по частинах; сегментація; корекція контрастності; градієнт яскравості

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