

Personal Data Protection with Smart Cards Using Eye-Ground Image Recognition Technique

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Abstract. This work analyzes the methods and computer tools for recognition of diabetes-affected eye-ground images and offers the theoretical grounds for methods and computer aids fit for recognition of eye-ground images in case of diabetes. The methods, algorithms and architecture of software and hardware tools for eye-ground pathology identification have been developed and demonstrate the capability of the cryptographic methods in smart-card functionality; such methods are to ensure confidentiality and integrity of patients' and doctors' data within an eye-ground pathology identification computer system. The eye-ground image recognition is based on automatic tracing of an individual blood vessel. The described in the paper process generates a sequence of parameters which characterize the condition of the vascular system and can be used for pathology assessment and authentication process as well. The use of eye-ground image (which is unique enough for every individual) for authentication allows to reduce risks of data breaches in health sector.

Keywords: image recognition, eye-ground image, authentication, ocular pathology identification, multiprocessor solutions, graphics processing units (GPUs), smart card, personal data protection.

1 Introduction

Diabetes-induced pathologies are among the major causes, worldwide, of poor sight and blindness and are nowadays the least identifiable and treatable diseases. The resultant severe pathological changes entail persistent loss of visuality functions in patients over 50 [1,2,3,4]. In recent years, such pathologies tend to become “younger”. Actually,

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early manifestations of diabetes-triggered eye-ground pathological changes are ophthalmoscopied even at the age of 12 to 20 years [5]. It is noteworthy that a significant rise of morbidity rate is observed among the able-bodied categories of the population, inasmuch as the longevity of older people has increased, thereby increasing their share in the overall population [6]. In the USA, eye-ground pathologies hold the second place, after diabetes, among the causes of blindness. In Ukraine, the situation, as to the extent of diabetes-induced eye-ground pathologies, is worsening all the time [7]. For instance, for the last 20 years, the annual quantity of the first-revealed sight-disabled patients suffering from such pathology has increased 2.5 times [6].

The public health industry makes an intensive use of automated systems which allow to store data electronically. Such systems enhance the data exchange efficiency between health institutions, enable a remote access to health data systems, simplify and speed up patients' check-in procedure with the use of an electronic reception desk. Therefore, we can assert that health electronic information serves as a basis for many processes in the present-day health industry [8,9,10].

However, the major shortcoming of the modern computer systems lies in the fact that the access to a patient's case record for entering, modifying or deleting any information there is granted without the knowledge of the patient. As a result, such systems are not safe, inasmuch as they cannot ensure confidentiality and integrity of information. The systems that handle such important data as information about human health should be well secured [11,12,].

The main attention should be focused on ensuring safe access to information, protection of the data being transmitted and usage of electronic signatures. The solution to such problems consists in using doctor's and patient's smart cards for definite identification of a doctor and a patient in a unified base of electronic medical cards (records). The use of such smart cards in computer systems would ensure a safe access to information and safe storage of confidential data of a patient. The safety of such information resources is provided with cryptographic methods [13,14].

The objective of this work consists in upgrading of diabetes-induced eye-ground pathology recognition method and software tools, usable for pathology identification, and to demonstrate its possibility of person authentication to ensure confidentiality and integrity of the corresponding medical data system [15,16] and reduce risks of data breaches.

2 Development of Diabetes-Induced Eye-Ground Pathology Computer Recognition Method

Early diagnosis automated system is an expert system used to forecast the evolution and to assess the treatment efficacy of diabetes-induced vascular diseases. The image processing engines (modules) are based on well-known algorithms. The user shell runs in the MS Windows XP operating system environment. This shell has been developed with the use of Borland Delphi 5 tools. The system database accommodates a set of reference samples and the patients' details. The information about patients includes a list of patients; a list of patients' visits to a doctor; eye-ground images taken in the

course of each visit; and per-visit image processing results [14, 17]. While processing the images, the vascular areas are selected and the processing results are tabulated. Moreover, while doing so, it is possible to classify such results into several user-defined groups of vessels. The graphic user interface allows, at a time, to view, on the screen, such things as the image under analysis (with zoom-in/out feature) (Fig. 1), the patient's details and diagnostic parameter values to be assessed, as well as the blood vessel gauge variation diagram for the given area [14,18,19].

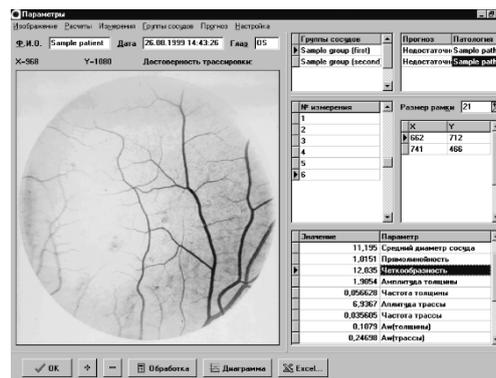


Fig. 1. Diagnostic mode graphic interface

The task of pathology recognition consists in the following. Automatic tracing of an individual blood vessel is carried out from a user-set starting point to an end point in the direction of the blood vessel as found out in the current point. The width of a blood vessel is defined as a quantity of non-zero counts on a line which is perpendicular to the direction of the blood vessel. After the width has determined, the starting point is shifted by a certain user-set tracing increment in the direction, which is found out from among the pre-computed directions as the one most close to the direct line towards the end point. Such tracing process generates a sequence of parameters which characterize the condition of the vascular system and can be used for pathology assessment [20,21].

See the diabetes-induced eye-ground pathology biomedical image analysis flow chart in Fig. 2 below.

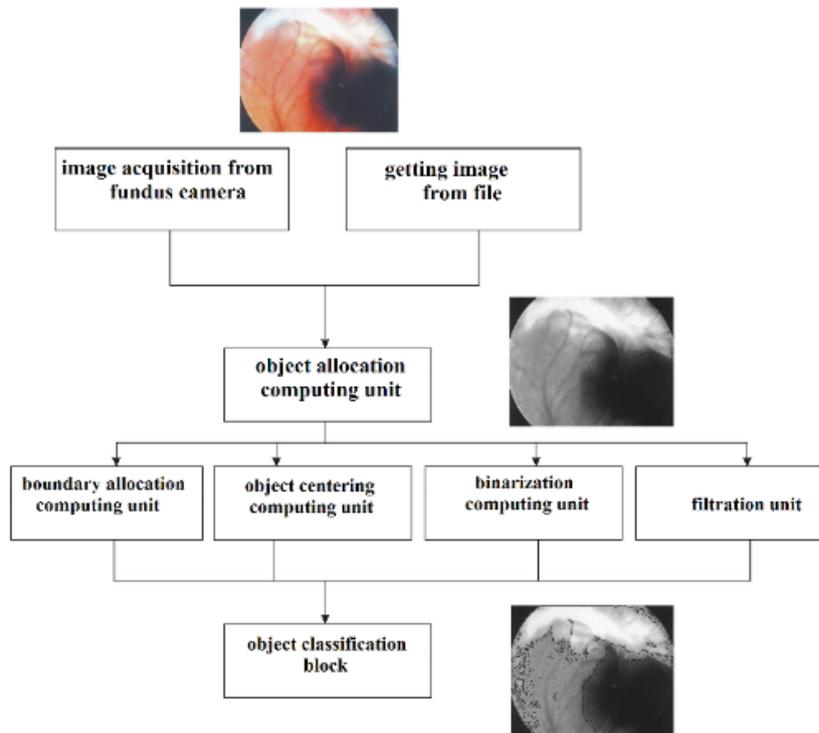


Fig. 2. Diabetes-induced eye-ground pathology biomedical image analysis flow chart

3 Development of Computer System Architecture

The computer system is a combination of two major components: the hardware and the software. The hardware component includes graphic processing units (GPU) and an external eye-ground image acquisition device (fundus camera). The software consists of the image enhancement unit (IEU), image analysis unit (IAU) data unit (DU). See the computer system architecture, as developed by the authors hereof, in Fig. 3 below. The computer system is implemented in Borland's DELPHI environment. In terms of hardware, the system must incorporate a graphics adapter with a pixel-shading feature. This computer system (Fig. 3) is intended for ascertaining the location and the area of a pathology, as well as for clusterization and diagnosing of eye-ground pathologies. It has been decided to use, for the hardware platform, an nVidia video card based on the GeForce 250 chipset, which is an affordable and fairly efficient solution.

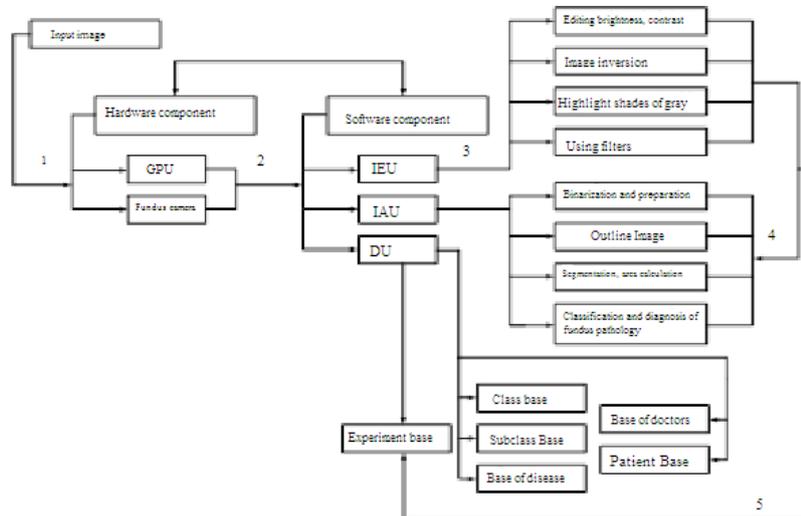


Fig. 3. Computer system architecture

4 Personal Data Protection with Smart Cards in Eye-Ground Pathology Identification Computer Systems

A smart card is a plastic card which looks exactly like a medical insurance policy card. It has a built-in chip which accommodates an autonomous memory space and a cryptoprocessor (a microcomputer built in a plastic card). The chip's memory contains a unique user certificate and other personified data (e.g. the patient's profile and health data). The cryptoprocessor provides the operating logic for the card, including generation of key pairs and an e-signature.

To start using a computer system which contains electronic case records, a user has to connect his/her smart card to the card reader and enter a PIN code. Three consecutive processes occur thereafter:

1. identification (a procedure of user recognition according to his/her identifier);
2. authentication (a procedure of user's identity proving);
3. authorization (a procedure of granting the user a certain right of access to the system resources).

There are two types of cards: a patient card and a doctor card. The patient card has an open memory domain and a closed memory domain. The open memory domain contains the basic data (the patient's surname and name, date of birth, blood group, name of insurance company, etc.). Such data should be readily available to any medical

officer for delivery of urgent aid to the patient. However, such information should be safeguarded against any unauthorized changes.

The protected memory area contains the data which are required for the patient's identification, as well as the public key certificate of the doctor who has signed the card. The protected area is accessible only for the medical officers who use their smart cards. Other information about the patient's health status (the case record) is stored on the medical institution server and is available only to a relevant health officer.

The other type of smart cards is a doctor card (or specialist's card). This card contains the surname and name of the health officer (specialist), the name of the health institution where he/she is employed, the field of specialization, the personal number and the e-signature. The doctor smart card gives access to the protected information stored both on the patient card and on the health institution servers. However, the health officer (specialist) can get access only to the information, which he/she is entitled to according to the field of his/her specialization.

A doctor smart card must contain an identifier and a key pair (the e-signature key and the e-signature verification key). So, such card must have the protected memory areas intended for safe storage of the key data. Apart from authentication, such doctor smart card is used for signing up electronic personal health records.

An eye-ground pathology identification computer system makes use of both types of smart cards; it consists of two elements, viz. a PC and a fundus camera and functions as follows. Upon a successful identification and authentication of the doctor and the patient with the use of the smart card, the image received from the fundus camera or from another external eye-ground image acquisition device (EEGIAD) goes over to the image processor (graphics processing unit - GPU), consisting of several units, such as image enhancement unit (IEU), image analysis unit (IAU), data unit (DU) and base of experiments.

Having received an eye-ground image, the IEU performs the biomedical image quality improving operations, such as:

1. brightness and contrast editing;
2. image inversion;
3. grayscale discrimination;
4. application of different filters (Sobel, Canny, etc.).

Having performed the image quality enhancing and pre-processing operations, it is necessary to analyze the parameters of the image in the IAU. This unit carries out operations on image binarization, image contour detection, image segmentation, delineation of individual elements in the image and computation of the area thereof.

Sorting out of the results within the above-said unit is given over to the GPU-level. Such solution has immensely reduced the size of the output arrays (64 to 256 times depending on the size of the rank area).

Having delineated the contours of the image items of interest (entities), we arrive at a respective eye-ground outline picture (EGOP). After such contour delineating operation, we have the following parameters of image items:

- item center coordinates;

- item color;
- description.

Such data will be further used for pathology clustering analysis. After normalization, it is necessary to perform clustering and diagnosing of eye-ground pathologies. Having conducted all research required, it is necessary to make a diagnosis for a patient.

The data unit incorporates:

- a built-in base of main pathology classes;
- a base of auxiliary subclasses;
- a base of known diseases;
- a base of patients (a doctor smart card is to be used).

The base of experiments incorporates:

- a list of patients (patient smart cards are to be used);
- a list of examinations (date and time of the examination, patient's reference number/code, diagnosis);
- patient's eye-ground image;
- an eye-ground outline picture (EGOP);
- examination reports.

The output of the graphics cards is connected to the data display device to visualize examination reports.

To start working with the system, one has to undergo a doctor's or patient's identification and authentication procedure with the use of a relevant smart card (Fig. 4).

Аутентифікація користувача

Логін:

Прізвище	Імя	Кваліфікація
Іванов	Петро	лікар
Рудюк	Ганна	офтальмолог

1/2

Пароль:

Ввійти

Fig. 1. Doctor's or patient's identification and authentication procedure

Upon a successful completion of the identification and authentication procedure, the program main working area comes up (Fig. 5).

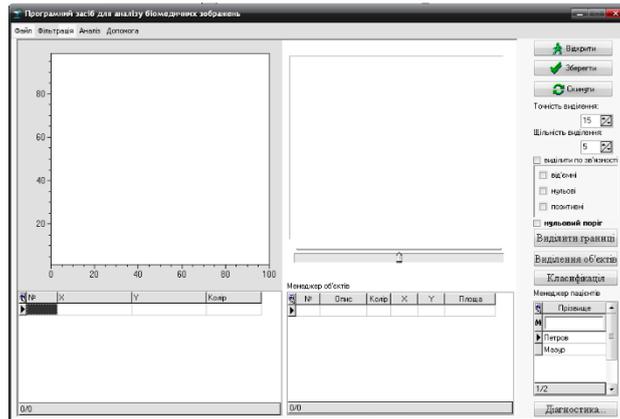


Fig. 2. Program main working area

Acquisition of Eye-Ground Image

There are two possible sources to obtain/retrieve an eye-ground image:

1. from an external device (fundus camera);
2. from a file.

The image acquisition operation can be initiated from the File menu or by pressing the Open button.

Biomedical Image Quality Enhancing Operations

Upon successful uploading of an eye-ground image, if required, it is possible to perform the biomedical image quality enhancing operations such as, such as:

1. brightness and contrast editing (using the slider under the image);
2. image inversion;
3. grayscale discrimination;
4. application of different filters (Sobel, Canny, etc.).

All these functions are available in the Filtration menu (Fig. 6).

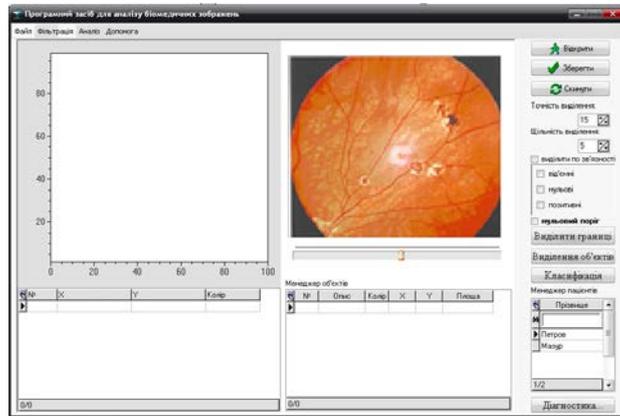


Fig. 3. Execution of biomedical image quality enhancing operations

4.1 Analysis of Image Parameters

Upon completion of the image quality enhancing and pre-processing operations, the image parameters are analyzed. The operations of image binarization, image contour detection, image segmentation, delineation of individual elements in the image and computation of the area thereof are initiated in the Analysis menu or with the Item Selection buttons. Using the Selection Accuracy and Selection Density features, it is possible to vary the quality (level) of processing and analyzing of the elements, as well as their subsequent classification. As soon as the operation on outlining the items is completed (Fig. 7), we get an eye-ground outline picture (EGOP) on the left.

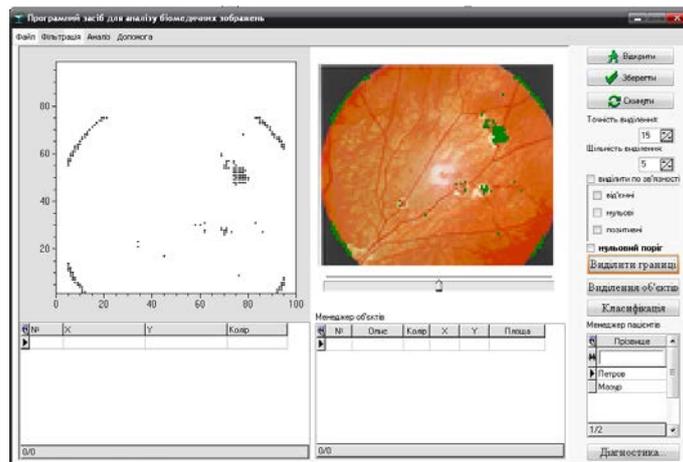


Fig. 4. Eye-ground outline picture

The next step is to analyze the image items. To do so, press the Outline button (Fig. 8).

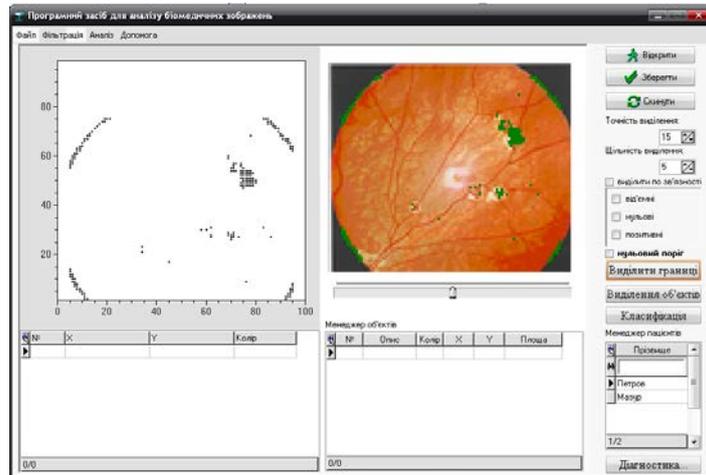


Fig. 5. Results of image items analysis

For convenience of visual perception, the red square boxes in the eye-ground outline picture highlight the centroids of the resultant items, while the items are shown in different colors. The Items Manager (Fig. 8) lists the parameters of the resultant items:

- item center coordinates;
- item color;
- description.

Such data will be further used for pathology clustering analysis.

4.2 Clustering and Diagnosing of Eye-Ground Pathologies

Basing on the results of normalization, one can perform clustering and diagnosing of eye-ground pathologies. To do so, press the Classification button (Fig. 9).

Нормовані дані		Кластерний аналіз			Протокол
1:5	Atm	1	C-2	C-3	
R-1	0	0.795	0.532	0.941	
R-2	0	0.950	0.884	0.486	
R-3	0	0.836	0.076	0.776	
R-4	0	0.324	0.311	0.689	
R-5	0	0.178	0.791	0.795	
R-6	0	0.256	0.808	0.159	
R-7	0	0.883	0.689	0.615	
R-8	0	0.822	0.493	0.029	

Fig. 6. Item clustering analysis window

The clustering analysis window incorporates the following tabs:

- the normalized data tab, which contain the data of the items;
- the clustering analysis tab, where a graph is drawn and where one can select the type of link and distance measurement (Fig. 10);
- the protocol tab, where the examination report is shown (Fig. 11).

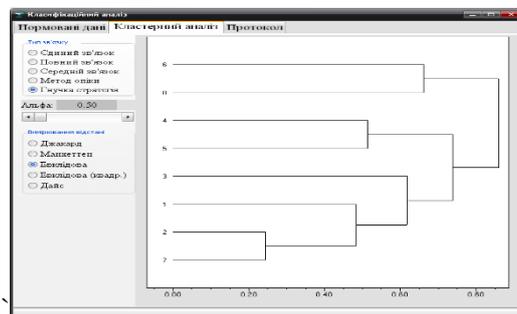


Fig. 7. Clustering analysis window

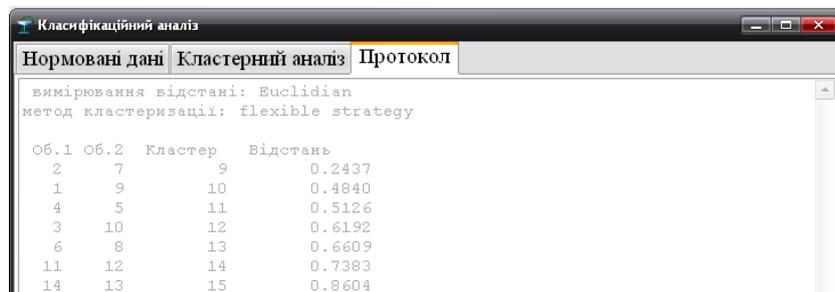


Fig. 8. Examination report window

4.3 Patient's Diagnosis

Having conducted all research required, we can receive a diagnosis. To do so, use the Diagnosing button (Fig. 12).

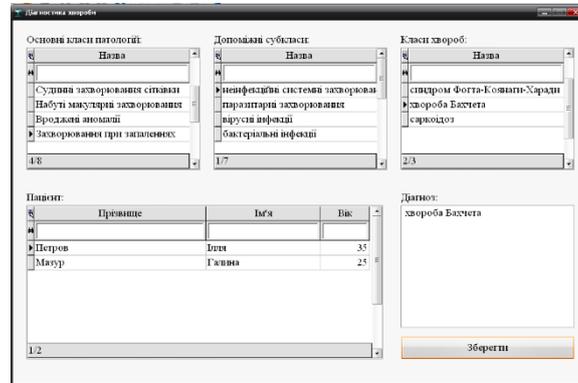


Fig. 9. Diagnosing window

This window accommodates:

- a built-in base of main pathology classes;
- a base of auxiliary subclasses;
- a base of known diseases;
- a base of patients.

Examination Log

Upon authentication with the use of his/her smart card, a doctor can select the required patient and enter the diagnostic data and/or his/her recommendations. After pressing the Save button, all examinations are recorded in the Examination Log (Fig. 13).

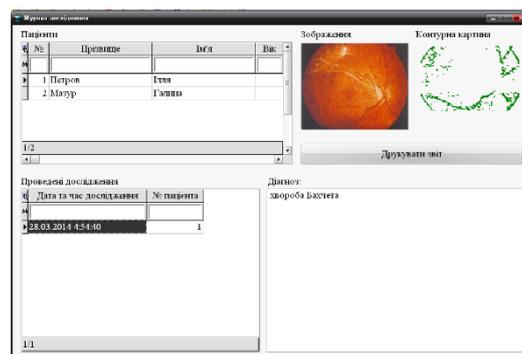


Fig. 10. Examination Log

This window accommodates: a list of patients; a list of examinations (date and time of an examination, patient's reference number/code, diagnosis); - patient's eye-ground image; an eye-ground outline picture (EGOP); a Print Report button.

4.4 Printing of Examination Reports

It is possible print out an examination report. To do so, press the Print Report button in the window (Fig. 12), and the report printing window comes up (Fig. 14).

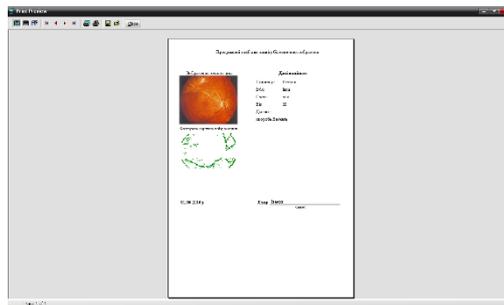


Fig. 11. Report printing window

The computer system is implemented in the Borland DELPHI environment. The system's hardware must include a graphics adapter with pixel shaders.

The computer system, suggested herein, is intended for locating and computing a pathology area, as well as for clustering and diagnosing eye-ground pathologies.

5 Results of Experimental Research into Pathology Localization and Pathology Area Assessment and Results of Experimental Research into in Clusterization of Eye-Ground Pathologies

The database for the experimental research was furnished by Filatov Eye Pathology and Tissue Therapy Research Institute of the Academy of Medical Science of Ukraine. It contains over 500 images obtained with the use of a ZEISS VISUCAM LITE fundus camera (Germany). Upon enhancing the quality and pre-processing of such image, it is necessary to analyze its parameters. Having delineated the contours of the image items of interest (entities), we arrive at the respective eye-ground outline pictures (EGOPs). The next step is to identify all items so outlined for existence of a pathology, if any, and for the area thereof.

In Table 1, below, see the results of identification of item-related parameters in the input test picture, as shown in Fig. 15.



Fig. 12. Input test picture

Table 1. Item-of-Interest-Related Parameter Identification Results in the Above Input Test Picture

Item	X Midpoint Coordinate	Y Midpoint Coordinate	Area, mm ²
1	46	25	28.4
2	48	15	5.5
3	63	7	10.7
4	66	22	19.3
5	72	13	19.6
6	76	9	3.1
7	87	23	26.4
Total area, mm ²			113.0

In Table 2, below, see the results of localization of pathology and assessment of the area thereof.

Table 2. Results of Experimental Research in Localization of Pathology and Assessment of the Area Thereof

Picture	Pathology Zone Area, mm ²	Total Area, mm ²	Pathology Percentage
1	2	3	4
1	154.3	6486.5	2.38
2	1398	5929	23.58
3	711.2	6404	11.11
4	1138.5	6446	17.66
5	1381.3	5632.5	24.52
6	1047	6445.5	16.24
7	703.4	6437	10.93
8	1490	6488	22.97
9	133.6	6471	2.06
10	113.0	6387.5	1.77

11	1184.7	6197.5	19.12
12	968.3	6261.5	15.46
13	1224.5	6397.5	14.45
14	864.8	6452	13.4
15	922	6392.5	14.42
16	694	5814.5	11.94
Average pathology percentage, %			13.88

The analysis of the results demonstrates that the bulk-information-based segmentation method, based on assessment of the quantity of information, as developed by the authors hereof, exceeds by 5 to 25% in terms of the FOM criterion, and is not much inferior, in terms of RMS criterion, to Roberts, Prewitt and Sobel operators.

Upon outlining of the image items of interest (entities), acquisition of EGOP, localization and assessment of the area of pathologies, it is necessary to perform clustering and diagnosing of such eye-ground pathologies. In practical ophthalmology, the following parameters are deemed to be clinical implications of pathology:

- location of an item in question (post-equatorial location, equatorial location, location within the disk of optic nerve, etc.);
- color (black, pigment-free, pink etc.);
- size (diameter, height).

Proceeding from Table 1, above, let us sum up data in a tabular form for pathology cluster analysis (Table 3).

Table 3. Input data for Pathology Cluster Analysis

Item of interest	Item Location	Color	Size, mm
1	Equatorial	Yellow	6,0
2	post-equatorial	White	2,6
3	post-equatorial	White	3,7
4	post-equatorial	White	4,9
5	post-equatorial	Yellow	4,9
6	post-equatorial	Yellow	1,9
7	post-equatorial	Black	5,8

To reduce the measurement error, let us use normalization. This will yield atypicality in terms of all equal-weight factors which is required for optimal clusterization of pathologies (Table 4).

Table 4. Normalized Data for Pathology Cluster Analysis

Item of interest	Item Location	Color	Size, mm
1	1	0.39	1

2	0.6	0.01	0.43
3	0.28	0.01	0.62
4	0.88	0.01	0.82
5	0.52	0.01	0.82
6	0.36	0.01	0.32
7	0.92	0.99	0.97

See the results diabetes-induced eye-ground pathology clusterization in Table 5, below.

Table 5. Results of Experimental Research into Eye-Ground Pathology Clusterization with the Full-Bond Method

Item 1	Item 2	New Cluster	Distance
2	6	8	0.0697
3	5	9	0.0976
1	4	10	0.1912
9	8	11	0.2756
10	7	12	0.9845
11	12	13	1.6965

To assess the efficiency of the fuzzy logic-based method, a dispersion criterion is used exhibiting the sum of distances from the items of interest to the cluster midpoints at a certain degree of membership [20].

$$J = \sum_{i=1}^c \sum_{j=1}^n (m_{ij})^w \text{dist}(v_i d_j), \quad (1)$$

where $\text{dist}(v_i d_j)$ is the Euclidian distance between j-th item $d_j=(d_{j1}, d_{j2}, \dots, d_{jm})$ and i-th cluster midpoint $v_j=(v_{j1}, v_{j2}, \dots, v_{jc})$;

$w \in (1, \infty)$ is the exponential weight which determines fuzziness or blurriness of clusters.

$$V = \begin{matrix} v_{11} & v_{12} & \dots & v_{1m} \\ v_{21} & v_{22} & \dots & v_{2m} \\ \dots & \dots & \dots & \dots \\ v_{c1} & v_{c2} & \dots & v_{cm} \end{matrix} \quad (2)$$

and $c \times m$ is the matrix of cluster midpoint coordinates, where the elements of such matrix are found according to the formula below:

$$v_{ik} = \frac{\sum_{j=1}^n (m_{ij})^w d_{jk}}{\sum_{j=1}^n (m_{ij})^w}, k = \overline{1, m}. \quad (3)$$

Having found the dispersion criterion J, we can assess the efficiency of the fuzzy logic-based method for diabetes-induced eye-ground pathology clusterization (see Table 6 below).

Table 6. Experimental Research Estimated Results as to Eye-Ground Pathology Clusterization

Method	Estimated Dispersion		Estimated Dispersion of Pre-set Number of Clusters (w/o Linguistic Parameters)	Estimated Dispersion of Pre-set Number of Clusters (with Linguistic Parameters)	Mean Estimated Value
Kohonen method	0.639		0.831	0.841	0.770
k-means	-		0.742	-	0.247
c-means	1.000		0.989	1.000	0.996

6 Conclusions

The pathology average percentage is 13.88 %. In the course of the above-said research, the clusterization method has demonstrated the best result (0.996 %), which testifies to the applicability of such method for biomedical image recognition, as well as to its adaptability for other fields of application, such as person authentication using the stored in smart card eye-ground image.

The improved recognition method, as unique person's feature, allows to decrease risks of data breaches compared with traditional thumbprint method, which can be replicated using, for example, a modern 3D printing. The vascular system of eye-ground is more complex, not accessed for unauthorized scanning, has much longer total length and does not have a regular structure, which significantly improves a person authentication and decrease probability of the structure fitting.

References

1. Starr C.E. Age-related macular degeneration. Can we stem this worldwide public health crisis? / C.E. Starr, D.R. Guyer, L.A. Yannuzzi // *Postgrad. Med.* – 1998. – Vol. 103, N 5. – P. 153-156, 161-164.
2. Dougherty, G.: *Image analysis in medical imaging: recent advances in selected examples.* *Biomed. Imaging Interv. J.* 6(3), e32 (2010).
3. Beutel, J., Kundel, H.L., Van Metter, R.L.: *Handbook of Medical Imaging*, vol. 1. SPIE, Bellingham, Washington (2000).
4. Rangayyan, R.M.: *Biomedical Image Analysis.* CRC, Boca Raton, FL (2005).
5. Meyer-Base, A.: *Pattern Recognition for Medical Imaging.* Elsevier Academic, San Diego, CA (2004).
6. Dougherty, G.: *Digital Image Processing for Medical Applications.* Cambridge University Press, Cambridge (2009).
7. . Sanniti di baja G., Thiel E. Computing and comparing distancedriven skeleton // *Proc. of 2nd international workshop on visual form.* – Italy, 1994. – P. 475-486.

8. Identification of retinal vessels by color image analysis / V. Rakotomalala, L. Macaire, J.-G. Postaire, M. Valette // *Machine graphics & vision*. – 1998. – V. 7. – № 4. – P. 725-743.
9. Image manipulation using M-filters in a Pyramidal computer model / M.E. Montiel, A.S. Agueado, M.A. Garza-Jinich et al. // *IEEE trans. on pattern analysis and machine intelligence*. – 1995. – V. 17, 111. – P. 1110-1115.
10. J.Soaes, J.Leandro, R.Cesar Jr., H.Jelinek, M.Cree. Retinal Vessel Segmentation Using the 2-D Gabor Wavelet and Supervised Classification // *IEEE Transactions of Medical Imaging*, Vol. 25, No. 9, 2006, pp. 1214–1222.
11. M.Welk, M.Breub, O.Vogel. Differential Equations for Morphological Amoebas // *Lecture Notes in Computer Science*, Vol. 5720/2009, 2009, pp. 104–114.
12. G.D.Joshi, J.Sivaswamy. Colour Retinal Image Enhancement based on Domain Knowledge // *Sixth Indian Conference on Computer Vision, Graphics and Image Processing (ICVGIP'08)*, 2008, pp. 591–598.
13. 22. S. Nagashima, K. Ito, T. Aoki, H. Ishii, K. Kobayashi High Accuracy Estimation of Image Rotation using 1D Phase-Only Correlation // *IEICE Trans.Fund. v. E92-A*, p. 235-243, 2009.
14. 26. Ritter G.X., Wilson J.N. *Handbook of Computer Vision Algorithms in Image Algebra*. – CRC Press, Boca Raton, Florida, USA, 1996. – 357 p.
15. 28. Development of the electronic service system of a municipal clinic (based on the analysis of foreign webresources) /A.V. Lantsberg, Klaus G. Troitzch, T.I. Buldakova // *Automatic Documentation and Mathematical Linguistics*. 2011. N. 2. V. 45. P. 74-80.
16. 29. Llinás G., Rodríguez-Iñesta D. et al. Comparison of Websites from Spanish, American and British Hospitals // *Methods of Information in Medicine*. 2008. Vol. 47; Issue 2. P. 124-130.
17. 31 Kuhlisch R., Kraufmann B., Restel H. Electronic Case Records in a Box: Integrating Patient Data in Healthcare Networks // *Computer*. 2012. Vol. 45, No. 11. Pp. 34-40.
18. 32. Aleman J.L.F., Senor Carrion I., Toval A. Personal Health Records: New Means to Safely Handle Health Data? // *Computer*. 2012. Vol. 45, No. 11. Pp. 27-33.
19. 33. Ritter G.X., Wilson J.N. *Handbook of Computer Vision Algorithms in Image Algebra*. – CRC Press, Boca Raton, Florida, USA, 1996. – 357 p.
20. S.V. Pavlov, T.A. Martianova, L.V. Zagoruiko, Y.R. Saldan, Y.I. Saldan, O.Yu. Pinaieva, Z. Omiotek K. Dassibekov. *Methods and computer tools for identifying diabetes-induced fundus pathology // Information Technology in Medical Diagnostics II*, 2019 Taylor & Francis Group, London, UK, ISBN 978-0-367-17769-0. □ P. 87-99.
21. Yosyp R. Saldan, Sergii V. Pavlov, Dina V. Vovkotrub, Waldemar Wójcik, and etc. Efficiency of optical-electronic systems: methods application for the analysis of structural changes in the process of eye grounds diagnosis // *Proc. SPIE 10445, Photonics Applications in Astronomy, Communications, Industry, and High Energy Physics Experiments 2017*, 104450S.