

Медицинская и биологическая кибернетика

DOI: [https:// 10.15407/kvt195.01.064](https://10.15407/kvt195.01.064)

UDC 617.7-073.178: 004

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THE SYSTEM OF INTRAOCULAR PRESSURE ASSESSMENT USING INTERFERENCE EYE PICTURES

Introduction. According to the World Health Organization (WHO), glaucoma accounts for 4–5% of the total ocular pathology, making it one of the most common eye diseases in the world. The first sign of the disease is a constant or periodic increase in intraocular pressure, which leads to the development of visual field defects, optic nerve atrophy, and dystrophic changes in eye tissues. Detection of glaucoma and ocular hypertension is done by measuring the intraocular pressure, which is the standard procedure for diagnosis of the condition of eyes in all patients over 40 years of age. Patients with a diagnosis of "glaucoma" should constantly measure the intraocular pressure, which is necessary to control the effectiveness of treatment, its correction and evaluation of the effectiveness of drugs.

The purpose of the article is to develop the system for assessing the intraocular pressure level using the interference pictures parameters observed on the eye cornea in the polarized light.

Results. The proposed system of two-level classification of the intraocular pressure level, which contains a pair of complementary fuzzy models, formalized in the form of logical rules and sets of numerical parameters of functions (membership and conclusion), and additional decisive rules that consist of a regression equation and a classification criterion.

Such a hybrid system adequately reflects the general communication of adjusted interference picture parameters with a measured value of intraocular pressure by classical Goldman tonometry, which allowed offering it to practical use as a basis for intraocular pressure express assessment.

Conclusion. Using the developed software module evaluation of intraocular pressure, based on the proposed concept of express assessment of intraocular pressure, integrates fuzzy models and decisive rules allowing to improve the results of glaucoma treatment at early detection of high level of intraocular pressure.

Keywords: intraocular pressure, central eye cornea thickness, interference pictures, express assessment.

INTRODUCTION

According to the WHO, glaucoma accounts for 4–5% of the total onset of the pathology, making it one of the most common eye diseases in the world. About 3% of the total population of the Earth suffer from glaucoma (in particular, from 0.5 to 2% comprise people younger 40 years old, and 7% of the world population by the age of 80) [1–5]. In the world, there are more than 8 million people who got blinded because of this disease, among them 7 million people lost sight of both eyes. Glaucoma takes the second place after cataract as to the frequency of blindness, with a clear tendency to increase the rate of morbidity of glaucoma [6–9].

The first sign of the disease is a constant or periodic increase in intraocular pressure (hereinafter — IOP), which leads to the development of defects in the vision fields, the optic nerve atrophy, dystrophic changes in the eye tissues. The earlier this pathology will be detected, the more effective the treatment and prevention of changes in the visual system will be [10]. Detection of glaucoma and ocular hypertension is carried out by measuring the IOP, which is the standard procedure for diagnosis of the eyes condition in all patients over 40 years of age. Patients with a diagnosis of "glaucoma" should constantly measure the IOP, which is necessary to control the effectiveness of treatment, its correction and evaluation of the effectiveness of drugs [10]. This requires a permanent visit to the hospital, that is difficult in many cases, for example, in rural areas.

THE PROBLEM SETTING

For the IOP express estimation using interference pictures (hereinafter — IP) observed on the eye cornea in polarized light, there was proposed the telemedicine system creation, developed the IP parametrization method, and implemented in the working software [11].

The interference pictures parameters of each eye consist of axial segments (OK, OH, OP, OR) drawn from the center of the cornea to the isochrome points located on the vertical and horizontal corneal diameters, as well as diagonal segments (OB1, OB2, OB3, OB4) that are held at an angle of 45° to the axial straight lines from the center of the cornea to certain points of the isochrome. The lengths of all the segments after their definition are automatically

normalized by the software on the average diameter of the cornea (by dividing) and are dimensionless values.

According to many studies, the thickness of the cornea has a definite effect on the IOP values obtained using appanatomic tonometry; therefore, at present, corrections are made to the measured values of the IOP, depending on the central corneal thickness [12–16]. Based on physical representations that the thickness of the cornea has a definite influence on the value and distribution of internal stresses in it, there is a need to consider it when using the IP parameters to determine the IOP. The eye cornea has a complex geometric shape, which is manifested by a change in its thickness from the center to periphery and affects the shape of IP [17].

The value of the eye cornea thickness in its center differs in different patients. In addition, studies have shown that it may be different for the right and left eyes in one patient [16] which should also be taken into account when evaluating IOP.

Determining the level of IOP by IP parameters is the next step in the development of the telemedicine system. To do this, it is necessary to develop a system for assessing the level of IOP using the IP parameters.

The object and methods of research. To develop the system of IOP level assessment using the IP parameters, we determined the IP parameters of 100 eyes with different levels of IOP, 70 of which were used as a training sample and 30 of them were used for checking the system. Since it is known that the IOP value has a certain effect on the eye cornea thickness, we determined its value using the method of parathyroidism in all patients.

The purpose of the article is to develop the system for assessing the intraocular pressure level using the interference pictures parameters observed on the eye cornea in the polarized light.

DEVELOPMENT OF THE SYSTEM OF ASSESSING THE INTRAOCULAR PRESSURE LEVEL USING THE INTERFERENCE PICTURES PARAMETERS

The process of developing models and solving the problems of the system for assessing the IOP level using IP parameters observed on the eye cornea in polarized light is shown in Fig.1. The interference pictures obtained from the patients are processed (parameterized) using previously developed software [11].

As noted earlier, the thickness of the cornea is different for different individuals, and varies from the center of the cornea to its periphery. This led to the need to develop measures taking into account the thickness of the cornea of a particular eye by correction of the length of all measured segments of parametrized IP. For this purpose, the central thickness of the cornea was determined in all patients by the method of optical pachymetry. Next, for the whole sample, the median value was determined and the correction coefficient of the IP parameters for each eye was calculated using the following formula:

$$k_{cor}^i = \frac{t_{cornea}^i}{M_e^{cornea}},$$

where k_{cor}^i is correction coefficient of IP parameters, t_{cornea}^i — is measured thickness of the cornea, M_e^{cornea} — is median thickness of the cornea, i — is ordinal index of the eye.

The correction of the IP parameters values was carried out by dividing the length of the segments by the corresponding correction coefficient. These measures allowed to bring all the IP parameters to a single scale.

After registration of patients IP photos, were performed IOP measurements using Goldman tonometer. The obtained IOP values were conventionally divided into classes according to the following rule: IOP up to 24 mm Hg (inclusively) were treated as acceptable with code 1; larger IOP values were considered to be high-pressured with code 2:

$$PC = \begin{cases} 1, IOP \leq 24 \text{ mmHg} \\ 2, IOP > 24 \text{ mmHg} \end{cases}$$

where PC — conditional indication of the intraocular pressure class.

Since the pressure class is presented as a real number in the range of 0 to 3 at the output of the fuzzy inference system, then there was a need for additional solving rules, by which one can uniquely determine the discrete code of each class. In addition, the models M1 and M2 mutually complement each other, that is, erroneously determined PC with the help of one model will be clearly defined by another model, and vice versa. The rules for obtaining a discrete PC code are the form of a linear regression equation derived from the initial data of models and a priori values of PC in conjunction with a simple rule:

$$PC_{M1, M2} = a \cdot PC_{M1} + b \cdot PC_{M2}$$

$$PC = \begin{cases} 1, PC_{M1, M2} \leq 1,5 \\ 2, PC_{M1, M2} > 1,5 \end{cases}$$

where PC is the discrete value of PC, $PC_{M1, M2}$ is the PC of the total result of the models M1 and M2, PC_{M1} is a separate result of the fuzzy output of the model M1, PC_{M2} is a separate result of the fuzzy output of the model M2, a, b are coefficients of the regression equation.

To construct the model for the IOP class determining, a Takagi–Sugeno fuzzy inference system [18] was used, which is executed on the following odd basis:

$$(x_1 = \tilde{a}_{1j} \Theta_j \ x_2 = \tilde{a}_{2j} \Theta_j \ \dots \ x_n = \tilde{a}_{nj}) \Rightarrow y_j = b_{j0} + \sum_{i=1, n} b_{ji} x_i,$$

where \tilde{a}_{nj} is the fuzzy term, which evaluates the input variable x_n in the j -M rule; n is the number of rules in the base; Θ_j is logical operation, which combines fragments of the rule j -th (logical operation "AND", "OR"); \Rightarrow is a fuzzy implication; b_{ji} are coefficients of the linear function (products) represented by some real numbers.

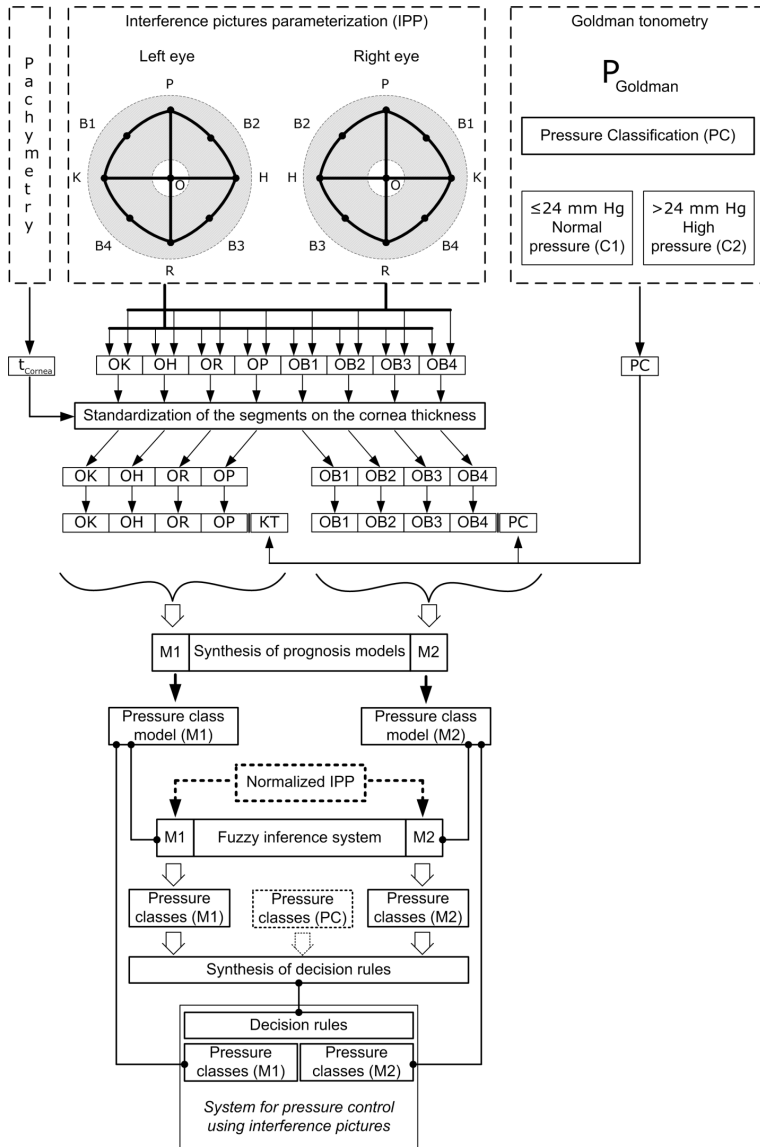


Fig. 1. The process of developing the system for assessing the IOP level

Fuzzy rules are synthesized based on clustering results. For this purpose, for each cluster, one fuzzy rule is put into conformity: "IF $x = x'$, then $y = y'$ ", where x is the input value of the parameter, y is the output value of the parameter, x' , y' are fuzzy terms "CLOSE TO x ", "CLOSE TO y ". The coordinates of the maxims of the functions of affiliation (hereinafter – AF) are taken equal to the centers of the obtained clusters. AF of these fuzzy terms are given by Gaussian function [18]:

$$\mu^i(x) = \begin{cases} e^{-\frac{(x-b)^2}{2c^2}}, & x \neq b, \\ 1, & x = b \end{cases}$$

where $\mu'(x)$ is AF of variable x to the term t ; b is AF parameter, corresponding to the maximum coordinate (in this case to the coordinate of the cluster center); C is parameter of AF compression-stretching.

The algorithm for the synthesis of models for determining the IOP class is shown in Fig. 2. Uploaded from the database matrix with the prepared data, they are first subjected to subtractive clusterization (under the mountain algorithm) [19]. Next, each of the received clusters corresponds to one fuzzy rule, and the coordinates of its center are the points of the AF maximum (for the Gaussian function, parameter b) [18]. Further, coefficients of linear functions of the conclusions used in the Sugeno fuzzy deducing system are calculated. The set of logical rules and sets of AF parameters and conclusions form the fuzzy model for determining the IOP class. After that, a fuzzy logical conclusion is made using the Sugeno fuzzy excursion. According to its results and the a priori value of PC, the value of the mean square error pressure classification error (hereinafter — SPCE) is calculated.

Next, the configuration of the model is made. For this purpose, we cyclically change the AF parameters (for the Gaussian function parameter c) and the coefficients of the conclusion functions and repeat the conclusion and the calculation of the values of the SPCE to obtain its minimum value. Since the number of cycles required to set the model is not known in advance, then the restriction is introduced for this operation: the cycle is interrupted if for each subsequent cycle of the setting the value of the SPCE decreases by less than 1% of the value obtained in the previous cycle. To reduce the dimensionality of the model and reduce the probability of its re-training it is optimized. To do this, the cycle changes the parameters of the clustering algorithm (acceptance and rejection coefficients), with subsequent repetition of all subsequent operations (clustering, matching and model setting). This cycle is repeated until the number of clusters becomes minimal, provided that the accuracy of the model determined by the SPCE does not decrease by more than 1%.

To confirm that the resulting model not only corresponds to the training data, but also adequately reflects the general relationship of the IP parameters with the measured IOP value, an additional verification is carried out. To do this, one line is extracted from the input matrix, the corresponding IP parameters and PC set of one patient, and the synthesis of the model is performed again. If the values of SPCE then do not change by more than 1% (when deleting any data row) then such a model is considered adequate if all lines are checked.

According to the study samples consisting of 50 photos of patients eyes IP with glaucoma with different levels of IOP and 20 IPs of healthy people (70 eyes on the whole), we obtained 2 fuzzy models for determining the class of the IOP. They consist of 6 fuzzy logic equations, 6 AF fuzzy rules (estimate the corresponding input variable) approximated by the Gaussian function and 6 linear functions in the conclusions of fuzzy rules, the definition of the IOP class.

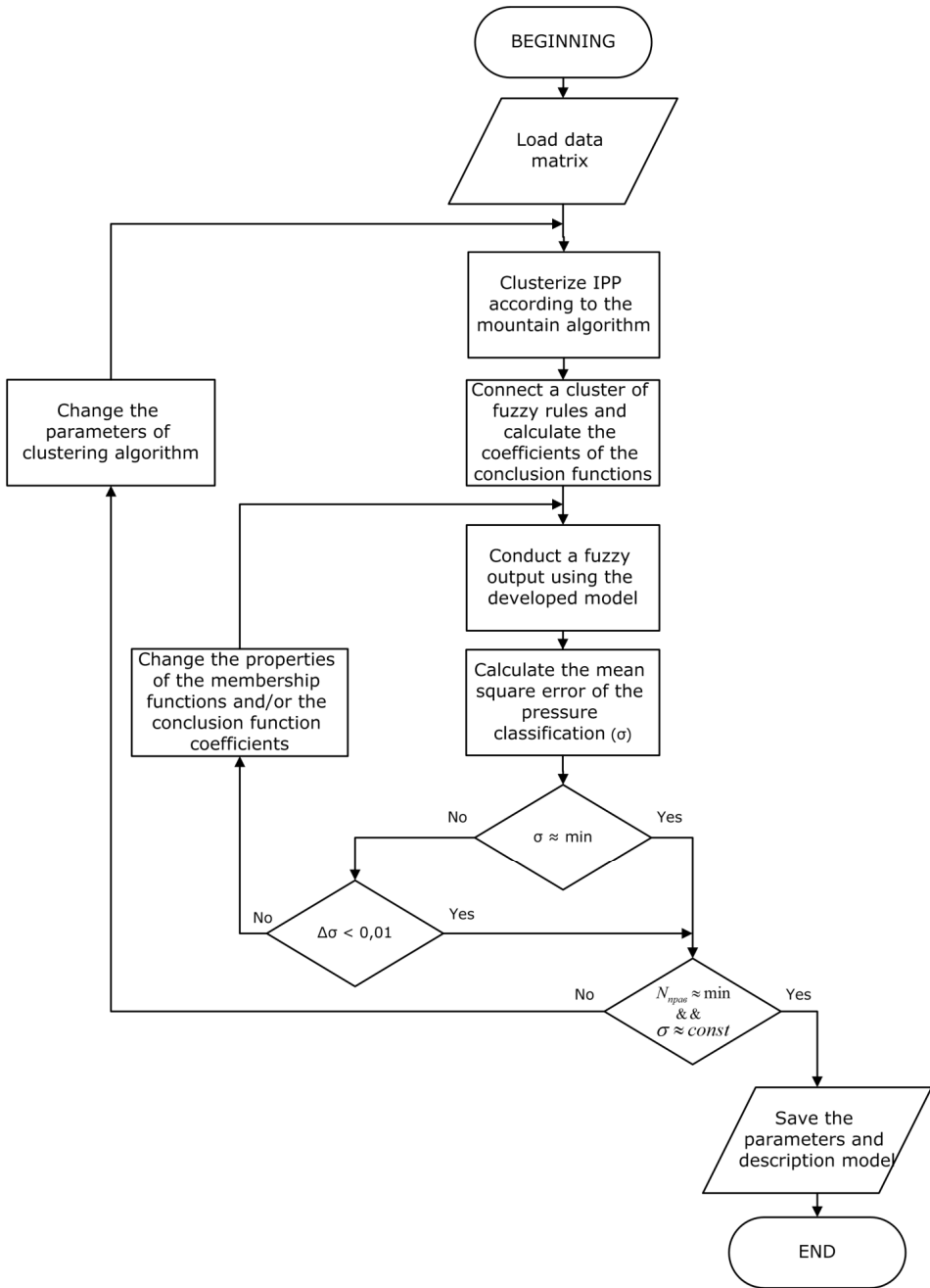


Fig. 2. Algorithm for the synthesis of IOP classification models

The knowledge database rules of the M1 model correspond to the system of fuzzy logic equations:

$$\mu_{PC}^1(X) = \mu_{OK}^1(x_{OK}) \wedge \mu_{OH}^1(x_{OH}) \wedge \mu_{OR}^1(x_{OR}) \wedge \mu_{OP}^1(x_{OP})$$

$$\mu_{PC}^2(X) = \mu_{OK}^2(x_{OK}) \wedge \mu_{OH}^2(x_{OH}) \wedge \mu_{OR}^2(x_{OR}) \wedge \mu_{OP}^2(x_{OP})$$

$$\mu_{PC}^3(X) = \mu_{OK}^3(x_{OK}) \wedge \mu_{OH}^3(x_{OH}) \wedge \mu_{OR}^3(x_{OR}) \wedge \mu_{OP}^3(x_{OP})$$

$$\mu_{PC}^4(X) = \mu_{OK}^4(x_{OK}) \wedge \mu_{OH}^4(x_{OH}) \wedge \mu_{OR}^4(x_{OR}) \wedge \mu_{OP}^4(x_{OP})$$

$$\mu_{PC}^5(X) = \mu_{OK}^5(x_{OK}) \wedge \mu_{OH}^5(x_{OH}) \wedge \mu_{OR}^5(x_{OR}) \wedge \mu_{OP}^5(x_{OP}),$$

where $\mu_{PC}^n(X)$ is the degree to which the fuzzy knowledge base rules are executed for the input vector of the indices $X = \{x_{OK}, x_{OH}, x_{OR}, x_{OP}\}$ $\mu_{OK}^n(x_{OK}), \mu_{OH}^n(x_{OH}), \mu_{OR}^n(x_{OR}), \mu_{OP}^n(x_{OP})$ is AF of the corrected normalized length of the axial segments of the fuzzy term of the knowledge database, n is the serial number of the fuzzy rule.

Table 1 shows the AF parameters of the fuzzy rules of the model M1 approximated by the Gaussian function (parameters of maximum and compression-stretching).

Table 2 shows the coefficients of linear functions in the derivation of fuzzy rules of the model M1.

Table 1. Parameters of the membership function of the model M1 fuzzy rules

Rule number	AF paramaters	Values of Parameters			
		OK	OH	OR	OP
1	b_1	0,36918	0,41677	0,37697	0,37844
	c_1	0,03991	0,03997	0,02856	0,02180
2	b_2	0,41500	0,46013	0,44946	0,38566
	c_2	0,03699	0,05173	0,04774	0,04744
3	b_3	0,40862	0,44621	0,42220	0,38232
	c_3	0,04007	0,02737	0,01566	0,04982
4	b_4	0,38057	0,36672	0,34821	0,35697
	c_4	0,02576	0,04400	0,03318	0,03718
5	b_5	0,42269	0,50764	0,45839	0,43533
	c_5	0,03299	0,04585	0,02240	0,04389

Table 2. Coefficients of linear functions in the derivation of the model M1fuzzy rules

Rule number	Values of Linear Functions				
	OK	OH	OR	OP	Residual Member
1	-12,27402	-25,87299	-24,12933	-20,15253	32,68096
2	17,54735	5,53546	-4,80440	-67,90470	19,38437
3	-6,60772	-65,54054	-55,83284	60,54832	34,55925
4	7,26108	-16,19525	-3,23262	12,52714	1,36121
5	20,66198	-48,97063	30,44241	-15,30205	12,22603

The rules of the knowledge database of the model M2 correspond to the system of fuzzy logic equations:

$$\begin{aligned} \mu_{PC}^1(X) &= \mu_{OB1}^1(x_{OB1}) \wedge \mu_{OB2}^1(x_{OB2}) \wedge \mu_{OB3}^1(x_{OB3}) \wedge \mu_{OB4}^1(x_{OB4}) \\ \mu_{PC}^2(X) &= \mu_{OB1}^2(x_{OB1}) \wedge \mu_{OB2}^2(x_{OB2}) \wedge \mu_{OB3}^2(x_{OB3}) \wedge \mu_{OB4}^2(x_{OB4}) \\ \mu_{PC}^3(X) &= \mu_{OB1}^3(x_{OB1}) \wedge \mu_{OB2}^3(x_{OB2}) \wedge \mu_{OB3}^3(x_{OB3}) \wedge \mu_{OB4}^3(x_{OB4}) \\ \mu_{PC}^4(X) &= \mu_{OB1}^4(x_{OB1}) \wedge \mu_{OB2}^4(x_{OB2}) \wedge \mu_{OB3}^4(x_{OB3}) \wedge \mu_{OB4}^4(x_{OB4}) \\ \mu_{PC}^5(X) &= \mu_{OB1}^5(x_{OB1}) \wedge \mu_{OB2}^5(x_{OB2}) \wedge \mu_{OB3}^5(x_{OB3}) \wedge \mu_{OB4}^5(x_{OB4}), \end{aligned}$$

where $\mu_{PC}^n(X)$ is the degree of execution of the fuzzy knowledge database rules for the input vector of indicators $X = \{x_{OB1}, x_{OB2}, x_{OB3}, x_{OB4}\}$; $\mu_{OB1}^n(x_{OB1}), \mu_{OB2}^n(x_{OB2}), \mu_{OB3}^n(x_{OB3}), \mu_{OB4}^n(x_{OB4})$ is AF of corrected normalized length of diagonal segments of the fuzzy term of knowledge database, n is the serial number of the fuzzy rule.

Table 3 shows the parameters of the AF fuzzy rules of the model M2 approximated by the Gaussian function (parameters of maximum and compression-stretching).

Table 4 shows the coefficients of linear functions in the derivation of fuzzy rules of the model M2.

Table 3. Parameters of the membership function of the model M2 fuzzy rules

Rule number	AF parameters	Values of Parameters			
		OB1	OB2	OB3	OB4
1	b_1	0,34248	0,34743	0,35303	0,31608
	c_1	0,03340	0,04569	0,11324	0,04307
2	b_2	0,37303	0,35059	0,35440	0,34852
	c_2	0,02613	0,03143	0,11114	0,04170
3	b_3	0,38751	0,39324	0,37913	0,36465
	c_3	0,04704	0,02782	0,11554	0,03125
4	b_4	0,42245	0,39006	0,41332	0,37167
	c_4	0,02453	0,04276	0,11587	0,04478
5	b_5	0,30514	0,27628	0,34245	0,30944
	c_5	0,03212	0,03403	0,11676	0,04423

Table 4. The coefficients of linear functions in the derivation of the model M2 fuzzy rules

Rule number	Linear function Parameters				
	OB1	OB2	OB3	OB4	Residual Member
1	-78,62481	-33,51865	-7,69473	-25,87150	47,59678
2	-72,83438	17,35565	-8,78933	-88,77824	58,90563
3	-102,65654	-11,93603	44,8187	-82,18424	57,16713
4	18,85960	-44,30061	-13,91040	-11,47781	25,42608
5	-5,80666	-54,26055	5,09097	78,50133	-7,18751

Decisive rules for obtaining a discrete PC code are obtained in the form of a linear regression equation derived from the data output models and a priori values of PC and simple rules:

$$PC_{M1,M2} = 0,60 \times PC_{M1} + 0,59 \times PC_{M2} - 0,26$$

$$PC = \begin{cases} 1, & PC_{M1,M2} \leq 1,45 \\ 2, & PC_{M1,M2} > 1,45 \end{cases}$$

where PC is the discrete value of PC, $PC_{M1,M2}$ is the class of PC total result of models M1 and M2, PC_{M1} is a separate result of the fuzzy output of the model M1, PC_{M2} is a separate result of the fuzzy output of the model M2.

THE SOFTWARE FOR THE SYSTEM OF ASSESSING THE INTRAOCULAR PRESSURE LEVEL USING THE INTERFERENCE PICTURES PARAMETERS

Initial data processing and analysis, as well as the development of IOP classification models, were conducted using the Scilab computer algebra system [20] and sciFLT's fuzzy logic package [21], which implements the Sugeno fuzzy logic output machine. The Scilab package was developed by the staff of the French National Institute of Computer Science and Automation (INRIA) and distributed free under the free CeCILL license. Formalized M1 and M2 models in the Scilab system are stored in the form of text files with the description of membership functions (the type of approximating function with tabulated parameters), the parameters of linear functions in the output of the rules and the type of the system of fuzzy output (Sugeno). In order to get the IOP class you have to input data of the vector of IP segments values in the Scilab command window. Then, with the help of commands, a file with the description of the model was downloaded and a fuzzy output procedure was launched (built into the sciFLT package), the results of which were the calculation of PC using decisive rules. Scilab's capabilities for the practical application of already developed models are redundant, and the need for working with the command interface makes it unsuitable for untrained user work.

In this regard, for the practical use of the results of work, was developed a software module, which integrated a fuzzy pull-out machine of Sugeno with models and decisive rules. It allows to form a fuzzy conclusion using M1 and M2 models, and to obtain an IOT class with the use of decisive rules with the help of normalized IP parameters and measured corneal thickness to automatically adjust the lengths of IP segments.

The program module is developed using the C# programming language from the Microsoft .NET Framework software platform and integrated into the software that performs the parameterization of the IP [11]. Fuzzy Logic Library for Microsoft .Net (fuzzynet) [22], which is provided by its author in the form of a dynamic library of executable codes or source codes in the C # programming language, is used to implement the fuzzy inference system. The diagram of the classes of the software module EyePressureClassifier is shown in Fig. 3.

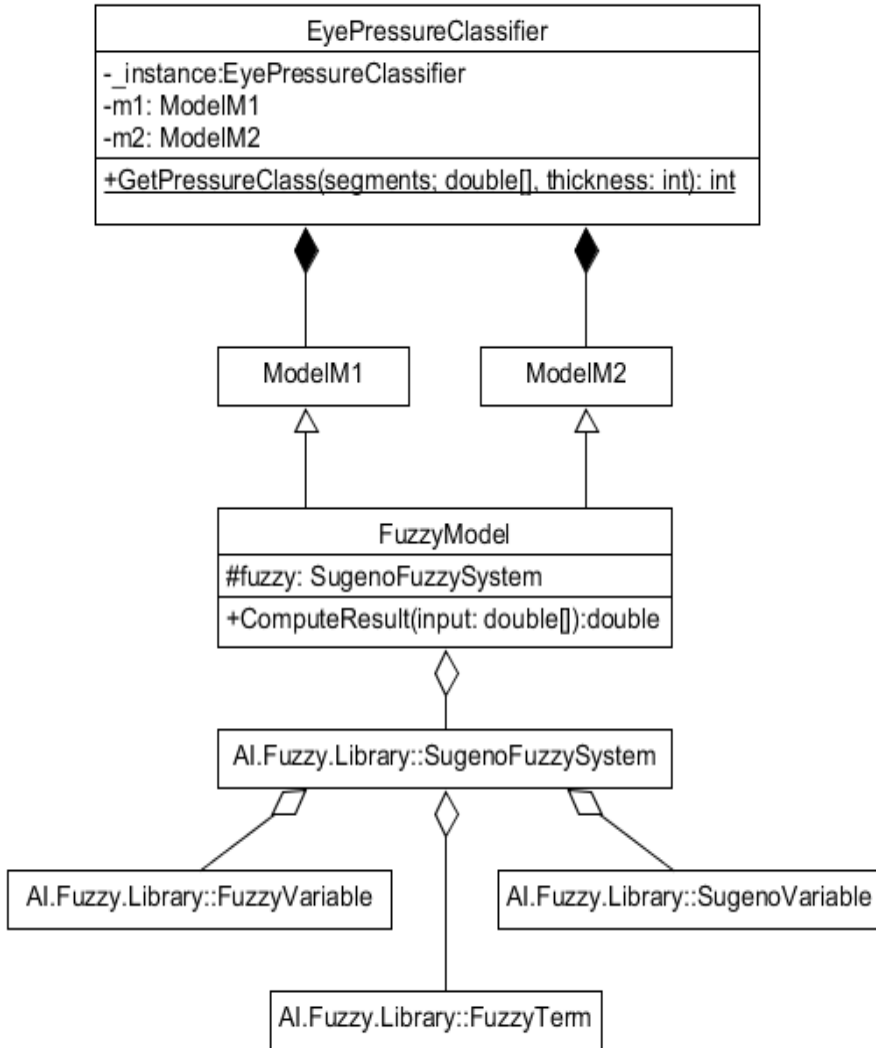


Fig. 3. The diagram of the classes of the software module EyePressureClassifier

The class of the program module implements the static method `GetPressureClass`, which is called from the program code of the application with the input parameters: an array of segments of type `double` with the normalized lengths of the IP parameter segments and the thickness of the `int` type. The result of the calculation will be represented by integer type `int`.

The algorithm of the `GetPressureClass` method is presented in Fig. 4.

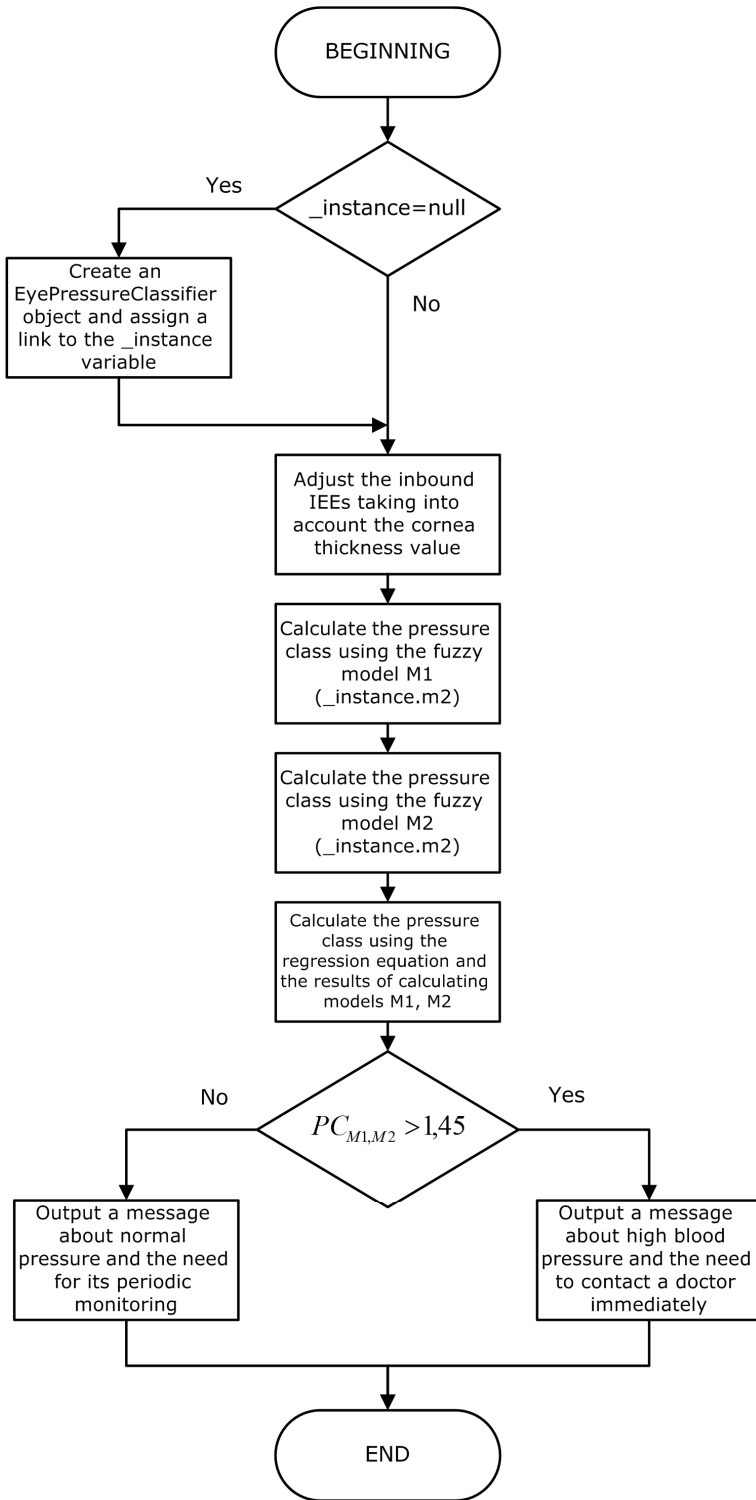


Fig. 4. Algorithm of the GetPressureClass method

Since the EyePressureClassifier class implements the Singleton software template and if the GetPressureClass method is called for the first time, an application object called EyePressureClassifier is created in the program memory and the link to it is stored in the `_instance` variable. Further, the values of the normalized IP segments transmitted into the form of an array of segments are adjusted to take into account of the cornea thickness (parameter thickness) and followed by a fuzzy conclusion using the models M1 and M2 carried out by calling the method Calculate objects `_instance.m1` and `_instance.m2` objects ModelM1 ModelM2 type, respectively. After that, the calculation of the pressure class is carried out using the regression equation. If this value is $PC_{M1, M2}$ is less than or equal to 1.45 there appears an IOP message on the screen showing the normal range (Fig. 5). If the value of $PC_{M1, M2}$ exceeds 1.45 there is a message about high IOP (Fig. 6) and recommendations to follow up.

Calling the GetPressureClass method in the IP parameterization software application is performed automatically when selecting the "Calculate PC" menu item (Fig. 7).

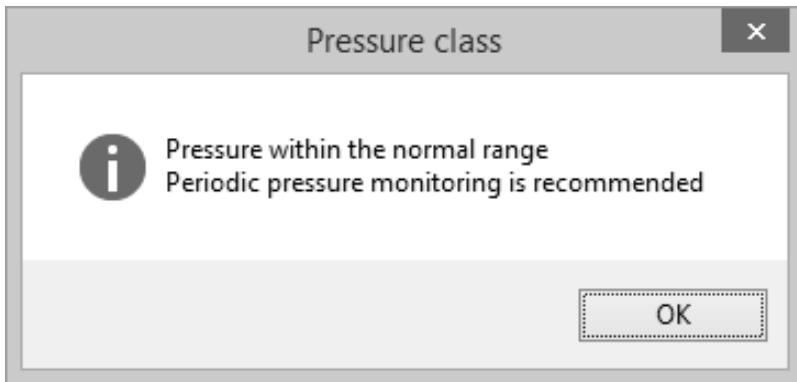


Fig. 5. Message about IOP within the normal range (class 1)

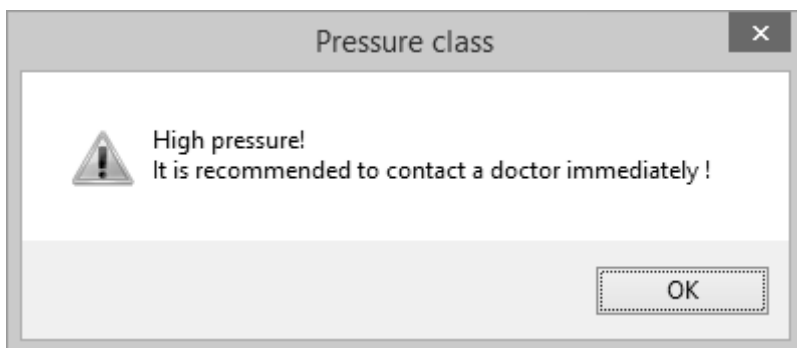


Fig. 6. Message about high IOP (class 2)

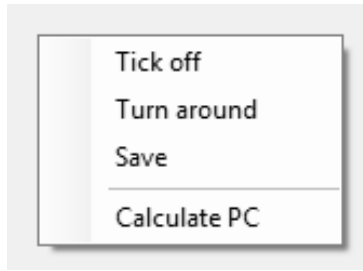


Fig. 7. Menu item "Calculate PC" application for IP parameterization

Thus, the development of the telemedicine system of the IOP express assessment was developed by the introduction of an additional integrated software module, which enables the automatic interactive mode to process IP images and determine the IOP level.

CONCLUSION

The cornea thickness differs in different people, as well as in one eye depending on the position relative to the cornea center. To take into account these features of the cornea during determining the level of intraocular pressure we introduced the correction factor for the parameters of interference patterns for each eye, which was determined by the ratio of the measured central corneal thickness of a particular patient to its median, calculated on the basis of the obtained indicators of 70 people. Correction of the parameters values of parametrized interference pictures was carried out by dividing them into an appropriate correction factor, which made it possible to bring all measured parameters of interference pictures to a single scale.

A proposed system of two-level classification of intraocular pressure contains a pair of complementary fuzzy models, formalized in the form of logical rules and sets of numerical parameters of functions (membership and conclusion), and additional decisive rules that consist of a regression equation and a simple criterion. Such a hybrid system adequately reflects the overall correlation between the corrected parameters of interference pictures with the measured values of intraocular pressure using the classic Goldman's tonometry, which allowed offering it for practical use as a basis for the express assessment of intraocular pressure.

The use of the developed software module for assessing the level of intraocular pressure, based on the proposed concept of express assessment of intraocular pressure and integrating fuzzy models and decisive rules provides an opportunity to improve the results of glaucoma treatment due to the timely detection of high intraocular pressure.

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Received 03.12.2018

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Отримано 03.12.2018

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СИСТЕМА ОЦІНЮВАННЯ РІВНЯ ВНУТРІШНЬООЧНОГО ТИСКУ ЗА ІНТЕРФЕРЕНЦІЙНИМИ КАРТИНАМИ ОКА

Вступ. За даними ВООЗ глаукома складає 4–5% всієї очної патології, що робить її одним з найпоширеніших очних захворювань у світі. Першою ознакою захворювання є постійне або періодичне підвищення внутрішньоочного тиску (ВОТ), що призводить до розвитку дефектів полів зору, атрофії зорового нерва, дистрофічних змін тканин ока. Виявлення глаукоми та очної гіпертензії здійснюють шляхом виміру ВОТ, що є стандартною процедурою під час проведення діагностики стану очей у всіх пацієнтів старше за 40 років. Хворі з встановленим діагнозом “глаукома” повинні постійно вимірювати ВОТ, що необхідно для контролю ефективності лікування, його корекції та оцінювання ефективності дії ліків.

Мета роботи — розроблення системи оцінювання рівня внутрішньоочного тиску за параметрами інтерференційних картин, спостережених на рогівці ока у поляризованому світлі.

Результати. Запропоновано систему дворівневої класифікації рівня внутрішньоочного тиску, яка містить, окрім пари взаємодоповнювальних нечітких моделей, формалізованих у вигляді логічних правил і наборів числових параметрів функцій (приналежності та висновку), додаткові вирішувальні правила, які складаються з регресійного рівняння та класифікаційного критерію.

Така гібридна система адекватно відображає загальний зв'язок скоригованих параметрів інтерференційних картин з вимірним значенням внутрішньоочного тиску за класичною гольдманівською тонометрією, що дало змогу запропонувати її для практичного використання як бази для експрес-оцінювання внутрішньоочного тиску.

Висновки. Використання розробленого програмного модулю оцінювання рівня внутрішньоочного тиску, який базується на запропонованій концепції експрес-

оцінювання внутрішньоочного тиску і інтегрує нечіткі моделі і вирішувальні правила, надає можливість покращити результати лікування глаукоми за рахунок своєчасного виявлення підвищеного рівня внутрішньоочного тиску.

Ключові слова: внутрішньоочний тиск, центральна товщина рогівки, інтерференційні картини, експрес-оцінювання.

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СИСТЕМА ОЦЕНКИ ВНУТРИГЛАЗНОГО ДАВЛЕНИЯ ПО ИНТЕРФЕРЕНЦИОННЫМ КАРТИНАМ ГЛАЗА

Представлена система двухуровневой классификации внутриглазного давления, которая содержит пару взаимодополняющих нечетких моделей, формализованных в виде логических правил и наборов числовых параметров функций (принадлежности и заключений), и дополнительные решающие правила, состоящие из регрессионного уравнения и простого критерия. Такая гибридная система классификации адекватно отражает связь скорректированных параметров интерференционных картин глаз со значениями внутриглазного давления, измеренного с помощью тонометра Гольдмана, что позволяет использовать ее в качестве базы для экспресс-оценки внутриглазного давления. Использование разработанного программного модуля оценки уровня внутриглазного давления позволяет улучшить результаты лечения глаукомы за счет своевременного выявления его повышенного уровня.

Ключевые слова: внутриглазное давление, центральная толщина роговицы, интерференционные картины, экспресс-оценка.