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EXPERT FUZZY SYSTEMS FOR EVALUATION OF INTENSITY OF REACTIVE EDEMA OF SOFT TISSUES IN PATIENTS WITH DIABETES

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Abstract. *The paper analyzes the main areas of application of mathematical methods in medical diagnostics, formulates principles of diagnostics based on fuzzy logic; developed mathematical models and algorithms that formalize the process of making diagnostic decisions based on fuzzy logic with quantitative and qualitative parameters of the patient's condition; developed mathematical models of membership function. Mathematical models and algorithms have been developed that formalize the process of making diagnostic decisions based on fuzzy logic with quantitative and qualitative parameters of the patient's condition; developed mathematical models of membership functions, formalizing the representation of quantitative and qualitative parameters of the patient's condition in the form of fuzzy sets, used in models and algorithms for diagnosis and finding a diagnosis of assessing the intensity of reactive postoperative edema in patients of all study groups. An expert system was implemented for solving the problems of medical diagnosis based on fuzzy logic when assessing the intensity of reactive swelling of soft tissues, which develops in the postoperative period in patients of all study groups against the background of diabetes. The paper analyzes the main areas of application of mathematical methods in medical diagnostics, formulates the principles of diagnostics based on fuzzy logic.*

Key words: information expert system, control, method of fuzzy sets, medical diagnostics, diabetes, dentistry

EKSPERCKIE SYSTEMY ROZMYTE DO OCENY INTENSYWNOŚCI REAKTYWNEGO OBRZĘKU TKANEK MIĘKKICH U PACJENTÓW Z CUKRZYCĄ

Streszczenie*. W pracy analizowane są główne kierunki zastosowania metod matematycznych w diagnostyce medycznej, formułowane są zasady diagnostyki opartej na logice rozmytej; opracowywane są modele matematyczne i algorytmy formalizujące proces podejmowania decyzji diagnostycznych w oparciu o logikę rozmytą z ilościowymi i jakościowymi parametrami stanu pacjenta; opracowywane są modele matematyczne funkcji przynależności. Opracowano modele matematyczne i algorytmy formalizujące proces podejmowania decyzji diagnostycznych w oparciu o logikę rozmytą z ilościowymi i jakościowymi parametrami stanu pacjenta; opracowano modele matematyczne funkcji przynależności formalizujące reprezentację ilościowych i jakościowych parametrów stanu pacjenta w postaci zbiorów rozmytych wykorzystywanych w modelach i algorytmach diagnozowania i znajdowania rozpoznania nasilenia reaktywnego obrzęku pooperacyjnego u pacjentów wszystkich grup badawczych. Wdrożono system ekspercki do rozwiązywania problemów diagnostyki medycznej oparty na logice rozmytej w ocenie nasilenia reaktywnego obrzęku tkanek miękkich, który rozwija się w okresie pooperacyjnym u pacjentów wszystkich grup badawczych z cukrzycą. W artykule przeanalizowano cechy zastosowania metod matematycznych w diagnostyce medycznej, sformułowano zasady diagnostyki opartej na logice rozmytej.*

Słowa kluczowe: informacyjny system ekspercki, sterowanie, metoda zbiorów rozmytych, diagnostyka medyczna, cukrzyca, stomatologia

Introduction

The development of methods and strategies for the implementation of diagnostic functions in expert systems is becoming more and more important nowadays. Structurally, it contains a number of subsystems: language processor (interface subsystem), information-reference, information-diagnostic (machine for drawing conclusions), information-analytical subsystems, and the actual information base – a database and knowledge base. The interface subsystem provides topic-oriented communication with the system of its users, who can belong to one of two main groups: the actual users (patients) and the owner (owner) of the system, who can act both in the role of an expert (source of knowledge) and in the role of an administrator information resources [6, 13].

However, it is often impossible to strictly adhere to such requirements in practice – due to both objective and subjective circumstances: the real world transfers our vision of things to the so-called fuzzy information environment. Today, it can be confidently asserted that the intelligence embedded in modern information technologies is largely based on the theory of fuzzy mathematics and the results of its numerous applications, mostly for the creation of so-called fuzzy software systems. However, the reorientation of components of intelligent systems to fuzzy mathematical support is a difficult problem from both a theoretical and a technological point of view. In the first case, the focus is on fuzzy output methods, in the second, on fuzzy database and knowledge structures, control methods, and fuzzy interfaces.

The problems of fuzzy expert systems are now intensively researched by specialists all over the world, almost half of them concern the class of fuzzy systems, in particular, a significant part of them is devoted to the problems of creating diagnostic technologies [6, 13, 14].

1. Statement of the problem

World and domestic dentistry has unique fundamental information about the physiology of the dental pulp and hardware tools for painless lifelong monitoring of the state of both the intact pulp and its various pathological conditions. However, despite the digital methods of medical diagnostics, the dentist often does not have the opportunity to establish an accurate diagnosis of the state of the dental pulp, since all existing basic and additional diagnostic methods are relative and have a number of disadvantages [5, 13, 14]. The need to develop new methods is dictated by the inconsistency of the results obtained from clinical data using various diagnostic methods and tooth plaster [5, 11, 14].

To date, the world uses the ICD-10 classification (1997) to systematize pulp diseases. In the section "Diseases of the dental pulp" K04.00 Initial pulpitis, K04.01 Acute pulpitis, K04.02 Purulent pulpitis, K04.02 – K04.05 Chronic forms of pulpitis are distinguished. When making a diagnosis, the dentist mainly focuses on his own interpretation of clinical data, based on complaints, the patient's pain history and clinical examination indicators. Thus, without objective data on the condition of the tooth pulp, the choice of treatment method is usually determined empirically. The analysis of numerous subjective and objective data during the clinical examination allows the doctor to establish a diagnosis [12].

In order to objectify information about the state of the dental pulp, specialists from around the world have developed and improved special diagnostic methods, such as reodontography, photoplethysmography, ultrasound Doppler, laser Doppler flowmetry, etc. [4, 11, 12]. For the first time, F. Liebman and F. Cosenza (1962) [11] applied to the study of the pulp by the rheography method. The developed method made it possible to study some issues of the physiology of the blood circulation of the tooth pulp, however, this method turned out to be unsuitable in practice, since it was hindered by the high electrical resistance of the hard tissues of the tooth.

In this work, we propose to expand the range of indicators for assessing the intensity of edema in patients of all groups of the study in patients with diabetes. The results are presented regarding the further development of the method based on fuzzy sets and an automated expert system for solving problems of medical diagnostics based on fuzzy logic. This method is an interconnected set of mathematical models, algorithms and software for evaluating the intensity of edema in patients with diabetes at given values of the parameters of his condition.

2. The purpose and objectives of the research

The purpose of the study is to implement an expert system for solving medical diagnostic problems based on fuzzy logic in assessing the intensity of reactive edema of soft tissues, which develops in the postoperative period in patients of all study groups against the background of diabetes [2, 7].

The paper analyzes the main areas of application of mathematical methods in medical diagnostics, formulates principles of diagnostics based on fuzzy logic; developed mathematical models and algorithms that formalize the process of making diagnostic decisions based on fuzzy logic with quantitative and qualitative parameters of the patient's condition; developed mathematical models of membership functions, formalizing the representation of quantitative parameters of the patient's condition in the form of fuzzy sets, used in models and algorithms for diagnosis and assessment of the intensity of reactive postoperative edema in patients of all study groups.

3. Using a mathematical apparatus of fuzzy logic for processing diagnostic information

Taking into account the fact that during clinical research it is quite often necessary to use not only clear digital criteria, but also certain linguistic characteristics of changes in indicators (terms), we analyzed some of them using a mathematical apparatus of fuzzy logic. Thus, using the principles of fuzzy logic, we will present the ranges of change of each of the indicators of face size presented in the table in qualitative fuzzy terms, which consist of the levels: L – low, LA – lower that average, A – average, HA – higher than average, H – (table 2).

Each of the specified terms represents a fuzzy set, which is described by membership functions defined on the interval [0;1].

Each of the specified terms is a fuzzy set, which is specified using special membership functions and can be represented by a certain interval, which has its digital degrees from 0 to 1. Absolute non-belonging to the set is indicated by 0, and absolute membership is indicated by 1.

The application of the mathematical apparatus of fuzzy logic can be important in cases where it is necessary to determine the probability of the relationship of pathological conditions that have different clinical characteristics [6, 13, 14].

In our case, the fuzzy logic apparatus is used to assess the intensity of reactive postoperative edema in patients of all study groups.

4. Research methodology

90 patients took part in the clinical study, who were divided into three groups: 1st group (comparison, 30 patients) – patients without diabetes, who underwent tooth extraction and the postoperative wound healed independently. The 2nd group (experimental, 30 patients) – patients suffering from diabetes, who underwent tooth extraction without the use of additional local treatment, the 3rd group (experimental, 30 patients) – patients suffering from diabetes, who underwent tooth extraction, photon therapy was used and Platelet-Rich Fibrin (PRF) was injected into the socket of the extracted tooth.

Patients were examined before surgery and on the 1st, 3rd, 5th, and 7th days after surgery, and the amount of tissue swelling in the area of the postoperative wound was determined using the method of determining the average size of the face by G. Arakeri (2013).

The patient was seated in a chair with his mouth closed and 5 segments were marked. The first – from the lateral corner of the eye to the corner of the jaw; the second – from the wing of the nose to the corner of the jaw; the third – from the corner of the mouth to the corner of the jaw; the fourth – from the chin to the corner of the jaw; the fifth – from the wing of the nose to the bridge of the ear.

With the help of a flexible centimeter tape, which could repeat the contour of the face, the length of each segment was measured, the sum of the lengths is considered the face size (FS). Using the formula:

$$(FS_{\text{after surgery}} - FS_{\text{before surgery}}) / FS_{\text{before surgery}} \times 100\%$$

where FS is the size of the face, the change in the size of the face was calculated as a percentage, which characterized the amount of edema.

On the first day after surgery, the size of the face increased in patients of all three groups. However, in the patients of the 1st group, the increase was insignificant (up to 57.28±0.87) and amounted to 0.06±0.01 cm. While in the patients of the 2nd and 3rd groups, a distinct increase in the average size of the face was observed (up to 62.45±0.99 cm and 61.92±1.17 cm, respectively), which was statistically significant compared to the preoperative level.

The absolute and relative increase in indicators in the 1st group on the first day after surgery were 0.06±0.01 cm and 0.10±0.09%, which is significantly less than the absolute – 4.67±0.09 cm and 3.91±0.60 cm and a relative 8.08±0.11% and 6.74±0.73% increase in average face sizes in the 2nd and 3rd groups, respectively.

A similar situation was observed on the third day after the operation. Thus, in the patients of the 1st group, the increase in the size of the face remained insignificant (up to 57.25±0.90) and amounted to 0.03±0.01 cm. In the patients of the 3rd group, the size of the face decreased slightly compared to the 1st day and approached its preoperative level (> 0.05). In the 2nd group, the absolute increase in the average face size was 4.8±0.17 cm, and the relative increase was 8.31±0.18%, which was statistically significant compared to the preoperative level.

On the first and third day after the operation, the dimensions of the face of the patients of the 1st group differed significantly from the dimensions of the 2nd and 3rd studied groups ($p < 0.001$). The indicators of the 2nd and 3rd studied groups during this period did not differ from each other ($p > 0.05$).

On the seventh day after the operation, the average facial dimensions of the patients of the first, second and third groups approached their preoperative level and were 57.21±0.88 cm, 59.21±0.85 cm and 58.83±0.97 cm, respectively.

The average facial sizes of patients in the three studied groups on the seventh day after surgery did not differ. However, when comparing the indicators of absolute and relative increase in facial sizes in pairs, group No. 1 – group No. 3 and group No. 2 – group No. 3, a significant difference was established between them ($p < 0.001$). While the difference between the indicators of groups No. 1 and No. 2 was not statistically significant ($p > 0.05$).

During the period from the 3rd to the 10th day after the operation, the average size of the face decreased only in patients of the third group (from 63.45±1.23 to 60.05±1.21 cm, ($p < 0.001$).

5. Formation of databases for the implementation of an expert decision-making system

Table 1 shows the database of studies evaluating the intensity of edema in patients of all study groups in patients with diabetes.

Table 1. Indicators of intensity of reactive swelling of soft tissues in patients with diabetes

	M±m, (sm)			The significance of the difference between indicators (p)		
Indicators face size	1 group (n = 30)	2 group (n = 30)	3 group (n = 30)	1–2 groups	1–3 groups	2–3 groups
Before the surgery	57.22± 0.91	57.78± 0.91	58.01± 1.09	> 0.05	> 0.05	> 0.05
1st day	57.28± 0.87	62.45± 0.99***	61.92± 1.17*	< 0.001	< 0.01	> 0.05
3rd day	57.25± 0.90	62.58± 0.81***	60.15± 1.01	< 0.001	< 0.05	> 0.05
7th day	57.21± 0.88	59.21± 0.85•††	58.83± 0.97•	> 0.05	> 0.05	> 0.05
Growth indicators	1 group (n = 30)	2 group (n = 30)	3 group (n = 30)	1–2 groups	1–3 groups	2–3 groups
Δ 1st day	0.06± 0.01	4.67± 0.09	3.91± 0.60	< 0.001	< 0.001	> 0.05
% 1st day	0.10± 0.09	8.08± 0.11	6.74± 0.73	< 0.001	< 0.001	> 0.05
Δ 3rd day	0.03± 0.01‡	4.8± 0.17	2.14± 0.54‡	< 0.001	< 0.001	< 0.001
% 3rd day	0.05± 0.03‡	8.31± 0.18	3.69± 0.69‡	< 0.001	< 0.001	< 0.001
Δ 7th day	-0.01± 0.01‡‡‡	1.43± 0.12‡‡‡	0.82± 0.11‡‡‡	< 0.001	< 0.001	< 0.001
% 7th day	-0.02± 0.01‡‡‡	2.47± 0.12‡‡‡	1.41± 0.24‡‡‡	< 0.001	< 0.001	< 0.001

Notes:
1. The significance of the difference between the indicators before the operation and on the 1st/3rd/7th day after the operation: * -p < 0.05, ** -p < 0.01, *** -p < 0.001.
2. Significance of the difference between indicators on the 1st and 3rd/7th day after surgery: • -p < 0.05, •• -p < 0.01, ••• -p < 0.001.
3. Significance of the difference between indicators on the 3rd and 7th day after surgery: † -p < 0.05, †† -p < 0.01, ††† -p < 0.001.
4. Significance of the difference between growth indicators on the 1st/3rd/7th day after surgery: ‡ -p < 0.05, ‡‡ -p < 0.01, ‡‡‡ -p < 0.001.

Based on Table 1, a database based on fuzzy terms is formed to assess the intensity of edema in patients by study group by group (table 2).

Table 2. A database for evaluating the intensity of edema in patients

Diagnosis	Before the surgery (X_1)	1st day (X_2)	3rd day (X_3)	7th day (X_4)
I group (d_{1a})	L	L	L	L
	L	LA	L	LA
	LA	L	LA	L
II group (d_{2a})	L	HA	H	LA
	LA	H	H	LA
	LA	H	H	A
III group (d_{3a})	L	HA	A	LA
	LA	H	A	LA
	LA	H	A	A

Corresponding membership functions are determined for each indicator from the databases in order to formalize the indicators.

Therefore, mathematical models for assessing the intensity of edema in patients with diabetes have the following form (1-3):

$$\mu^{d1}(X_1, X_2, X_3, X_4) = \mu^{L}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{L}(X_3)\cdot\mu^{L}(X_4)\cdot\cup \\ \mu^{L}(X_1)\cdot\mu^{LA}(X_2)\cdot\mu^{L}(X_3)\cdot\mu^{LA}(X_4) \\ \cup\,\mu^{LA}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{LA}(X_3)\cdot\mu^{L}(X_4); \quad (1)$$

$$\mu^{d2}(X_1, X_2, X_3, X_4) = \mu^{L}(X_1)\cdot\mu^{HA}(X_2)\cdot\mu^{H}(X_3)\cdot\mu^{LA}(X_4)\cdot \\ \cup\,\mu^{LA}(X_1)\cdot\mu^{H}(X_2)\cdot\mu^{H}(X_3)\cdot\mu^{LA}(X_4)\cup \\ \mu^{LA}(X_1)\cdot\mu^{H}(X_2)\cdot\mu^{H}(X_3)\cdot\mu^{A}(X_4); \quad (2)$$

$$\mu^{d3}(X_1, X_2, X_3, X_4) = \mu^{L}(X_1)\cdot\mu^{HA}(X_2)\cdot\mu^{A}(X_3)\cdot\mu^{LA}(X_4)\cdot \\ \cup\,\mu^{LA}(X_1)\cdot\mu^{H}(X_2)\cdot\mu^{A}(X_3)\cdot\mu^{LA}(X_4)\cup \\ \mu^{LA}(X_1)\cdot\mu^{H}(X_2)\cdot\mu^{A}(X_3)\cdot\mu^{A}(X_4); \quad (3)$$

Graphic form of the membership functions is shown in Fig. 1. The selection of the similar curves is stipulated by the fact that they are piecewise linear approximations of the expert membership functions $\mu^{j}(x_i)$, obtained for the factors $x_1 \div x_4$ by the method of paired comparisons [3, 9, 10].

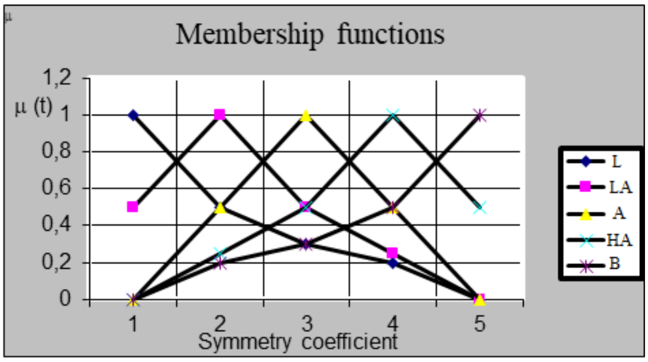

Fig. 1. Membership functions of fuzzy terms

Transition from $\tilde{\mu}^{j}(u)$ function to the required functions $\mu^{j}(x_i)$ is realized in the following way:

$$u_i = 4\frac{x_n - \underline{x}_n}{\overline{x}_n - \underline{x}_n},\ \mu^{j}(u_n) = \mu^{j}(x_n) \quad (4)$$

Analytical expressions of the functions $\mu^{j}(x_1 \div x_4)$:

$$\tilde{\mu}^{L}(X_1 \div X_4) = \begin{cases} 16.82 - 0.28x,\ x_1 \in [56.31; 58.09] \\ 5.93 - 0.09x,\ x_1 \in [58.09; 63.44] \end{cases}$$

$$\tilde{\mu}^{LA}(X_1 \div X_4) = \begin{cases} 0.28x - 15.31,\ x_1 \in [56.31; 58.09] \\ 17.31 - 0.28x,\ x_1 \in [58.09; 59.87] \\ 8.89 - 0.14x,\ x_1 \in [59.87; 63.44] \end{cases}$$

$$\tilde{\mu}^{A}(X_1 \div X_4) = \begin{cases} 0.28x - 15.82,\ x_1 \in [56.31; 59.87] \\ 17.77 - 0.28x,\ x_1 \in [59.87; 63.44] \end{cases}$$

$$\tilde{\mu}^{HA}(X_1 \div X_4) = \begin{cases} 0.14x - 7.91,\ x_1 \in [56.31; 59.87] \\ 0.28x - 16.31,\ x_1 \in [59.87; 61.65] \\ 18.22 - 0.28x,\ x_1 \in [61.65; 63.44] \end{cases}$$

$$\tilde{\mu}^{H}(X_1 \div X_4) = \begin{cases} 0.09x - 5.21,\ x_1 \in [56.31; 61.65] \\ 0.28x - 16.72,\ x_1 \in [61.65; 63.44] \end{cases}$$

Decision-making in assessing the intensity of edema in patients with diabetes can be done by making a decision (5)

$$\mu^{d_0}(x_1, x_2, \ldots x_n) = \max[\mu^{d_n}(x_1, x_2, \ldots x_n)] \quad (5)$$

This solution will correspond to the necessary range, which indicates the intensity group of reactive swelling of soft tissues in patients with diabetes.

6. Practical implementation of the information medical expert system for assessing the intensity of edema in patients with diabetes

The principles of obtaining a reliable diagnosis based on fuzzy sets were used to implement the operation of the tuning blocks, storage of membership functions and fuzzy processing and derivation of the expert system [1, 8].

The basic ideology of the information medical expert system for assessing the intensity of reactive postoperative edema in patients of all study groups in patients with diabetes based on the introduction of fuzzy logic blocks is shown in Fig. 2.

As a result of the implementation of these blocks, a software shell has been developed, while the user is asked to enter the values of the upper and lower scale of values that are in the database for a certain pathology after starting the program, in our case, we enter the values that are basic in the determination [1, 6].

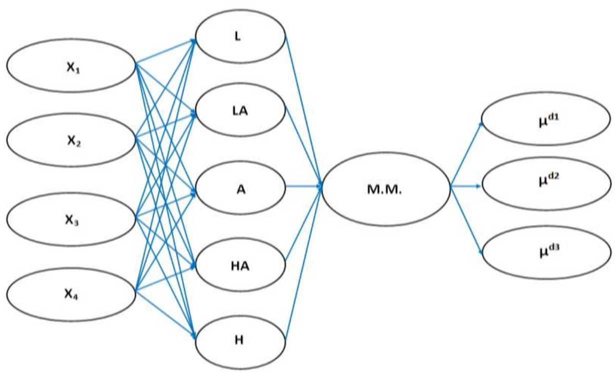

Fig. 2. Medical expert system for evaluating the intensity of reactive postoperative edema in patients with diabetes

The result of the implementation of these blocks was a software shell that works as follows.

1) After starting the program, the user is asked to enter the values of the upper and lower scale of values that are in the database on a certain basis based on the face size indicators, in our case we enter the values that are the main ones when determining
2) To continue working with the program, after filling in all the fields, click "save", to restore previous data that was entered earlier, the user needs to click "retire".

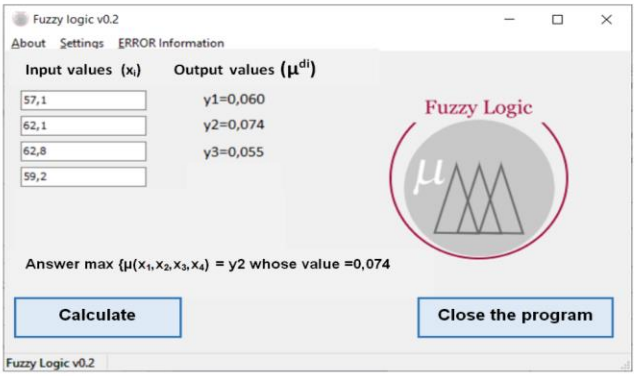

Fig. 3. An example of a dialog window of a program for evaluating the intensity of a reactive postoperative edema in patients with diabetes

Based on the data, a program was developed for assessing the intensity of reactive postoperative edema in patients with diabetes. An example of a dialog box is shown in Fig. 3.

7. Conclusions

The method of using fuzzy sets in the implementation of an information expert system for solving the problems of medical diagnostics, in particular, in assessing the intensity of reactive edema of soft tissues, which develops in the postoperative period in patients of all groups of the study against the background of diabetes, has gained further development.

The paper analyzes the main areas of application of mathematical methods in medical diagnostics, formulates the principles of diagnostics based on fuzzy logic.

Main scientific results: mathematical models and algorithms were developed that formalize the process of making diagnostic decisions based on fuzzy logic with quantitative and qualitative parameters of the patient's condition; developed mathematical models of membership functions, formalizing the representation of quantitative and qualitative parameters of the patient's condition in the form of fuzzy sets, used in models and algorithms for estimating the intensity of edema in patients with diabetes

The developed models and algorithms of medical diagnostics are based on the ideas and principles of artificial intelligence and knowledge engineering, the theory of experiment planning, the theory of fuzzy sets and linguistic variables. The expert system was validated on real data.

The practical value of the work lies in the possibility of using an automated expert system to solve the problems of medical diagnosis based on fuzzy logic when assessing the intensity of reactive swelling of soft tissues, which develops in the postoperative period in patients of all study groups against the background of diabetes.

References

[1] Abdikerimova G. B. et al.: The analysis of textural images on the basis of orthogonal transformations. Journal of Theoretical and Applied Information Technologythis link is disabled 97(1), 2019, 15–22.
[2] Arakeri G. et al.: A randomized clinical trial to compare the efficacy of submucosal Aprotinin injection and intravenous Dexamethasone in reducing pain and swelling after third molar surgery: A prospective study. Journal of Maxillofacial and Oral Surgery 12(1), 2013, 71–75.
[3] Azarova A., Zhytkevych O.: Mathematical methods of identification of ukrainian enterprises competitiveness level by fuzzy logic using. Economic Annals-XXI 9–10(2), 2013, 59–62.
[4] Clinical guidelines for the management of pulpal diseases, approved by Decree 15 of the Council of Public Association "Russian Dental Association". Dated August 2, 2018.
[5] Nizhynska-Astapenko Z. et al.: Information medical fuzzy-expert system for the assessment of the diabetic ketoacidosis severity on the base of the blood gases indices. Proc. SPIE 12126, 2021, 1212626.
[6] Rotshtein A.: Design and Tuning of Fussy IF – THEN Vuly for Medical Didicol Diagnosis. Fuzzy and Neuro-Fuzzy Systems in Medicine. CRC-Press, 1998, 235–295.
[7] Serkova V. K. et al.: Medical expert system for assessment of coronary heart disease destabilization based on the analysis of the level of soluble vascular adhesion molecules. Proc. SPIE 10445, 2017, 104453O.
[8] Taubayev G. et al.: Machine learning algorithms and classification of textures. Journal of Theoretical and Applied Information Technologythis 98(23), 2020, 3854–3866.
[9] Vasilevskyi O. et al.: Method of evaluating the level of confidence based on metrological risks for determining the coverage factor in the concept of uncertainty. Proc. SPIE 10808, 2018, 108082C.
[10] Vassilenko V. et al.: Automated features analysis of patients with spinal diseases using medical thermal images. Proc. SPIE 11456, 2020, 114560L.
[11] Vavilova T. P. et al.: Dental pulp responsiveness. Moscow State University of Medicine and Dentistry, 2017.
[12] Volgin M. A. et al.: Comparative analysis of IL-1. COX-2 and type II collagenase gene expression profile in acute inflammed pulps. Endodontics today 4, 2016, 16–20.
[13] Wójcik W. et al.: Information Technology in Medical Diagnostics II. Taylor & Francis Group. CRC Press, Balkema Book. London 2019.
[14] Wójcik W. et al.: Information Technology in Medical Diagnostics. CRC Press. 2017.


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