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APPLICATION OF MATHEMATICAL APPARATUS OF FUZZY MULTIPLIERS FOR FORECASTING DISEASES ON THE EXAMPLE OF SUGAR DIABETES

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Анотація

Проаналізовано основні напрями застосування математичних методів у медичній діагностиці, сформульовано їх недоліки , принципи діагностики, засновані на нечітій логіці. Розроблено математичні моделі та алгоритми, що формалізують процес прийняття діагностичних рішень на основі нечіткої логіки при кількісних та якісних параметрах стану пацієнта; розробляються математичні моделі функцій членування, формалізуючи представлення кількісних і якісних параметрів стану пацієнтів у вигляді нечітких множин, що використовуються в моделях і алгоритмах діагностики і визначення діагнозу при діабетичному кетоацидозі.

Ключові слова: *інформаційно-експертна система, контроль-метод нечітких множин, датчики, медична діагностика, діабетичний кетоацидоз.*

Abstract

Main directions of the application of the mathematical methods in medical diagnosis are analyzed, their drawbacks are evaluated , principles of diagnosis, based on fuzzy logic are formulated. Mathematical models and algorithms, formalizing the process of diagnostic decisions making on the base of fuzzy logic at quantitative and qualitative parameters of the patient state are developed; mathematical models of the membership functions, formalizing the presentation of quantitative and qualitative parameters of the patients state in the form of the fuzzy sets, used in the models and algorithms of diagnosis and determining the diagnosis in case of diabetic ketoacidosis are developed.

Aim of the study is realization of the computer-based expert system for the solution of the problems, dealing with medical diagnosis on the base of fuzzy logic in case of Diabetic Ketoacidosis.

Key words: *information expert system, control-method of fuzzy sets, sensors, medical diagnostics, diabetic ketoacidosis.*

Introduction

Diabetes – is one of the growing problems of the public health service in XXI century. According to the data of the 9th edition of the Diabetes Altas of IDF (The International Diabetes Federation) for a year 2019 the amount of diabetic patients among the adult population in the world is on average 9.3 % (from 6 to 11 % in different regions). In absolute terms this is approximately 463 million persons, among them more than 1.1 million of diabetes cases of the first type is among children.

Diabetic ketoacidosis(DKA) is an acute decompensation of the diabetes as a result of poor control of glycemia, that is characterized by the sharp increase of the glucose level and Ketone bodies in the blood, emergence of the ketone bodies in the urine and metabolic acidosis, that may cause death as a result of brain edema [1, 2]. Acute complication of diabetes results in considerable financial loading both on the health care system and the patient. The amount of expenses may reach approximately 26566 USD per patient for the period of the hospitalization in the USA [3]. Main standard approach to the stratification of the patient by the degree of Diabetic Ketoacidosis severity is the assessment and distribution according to the level of blood pH (for the arterial blood DKA I 7.21 - 7.34, DKA II 7.10 - 7.20, DKA III<7.1) [4, 5, 6]. Additional criteria of the severity assessment in some countries are level of bicarbonates and beta-y-hydroxybutyrate [7, 8].

Aim and tasks of the research

Aim of the research is the realization of the automated expert system for the solution of the problems of medical diagnostics, on the base of fuzzy logic in case of Diabetic Ketoacidosis.

The given paper analyses main directions of the application of the mathematic methods in medical diagnostics, the drawbacks of these method are analyzed, principles of diagnostics, based on fuzzy logic are formulated, mathematical models and algorithms, which formalize the diagnostic decisions making process on the base of fuzzy logic at quantitative and qualitative parameters of the patient`s state are developed, mathematical models of the membership functions, formalizing the presentation of quantitative parameters of the patient`s state in the form of fuzzy sets, used in the models and algorithms of Diabetic Ketoacidosis diagnostics are elaborated.

Usage of mathematic tools of fuzzy logic for the processing of the diagnostic information

In the given study such laboratory indices of the arterial blood were determined, blood pH, partial pressure of carbon dioxide - pCO_2, total content of carbon dioxide in the blood - tCO_2 and partial pressure of oxygen - pO_2. All the patients were taken blood tests regarding the gas composition and indices of acid-base balance. Blood sample was taken mainly from the radial artery of the nondominant hand in the place of the palpatory determination of the best pulsation of the vessel in the heparinized syringe of 2 ml of volume during the hospitalization. Prior Allan's test was taken. Blood samples were taken to the laboratory during 1-2 min for the immediate laboratory study. If necessary, the corrective indices of Нв, body temperature, oxygen concentration in the mixture, taken by the patient were input into "Easy Blood Gas" (USA, 2008). Gas analysis of the blood was determined by the method of the potentiometric measurement, by means of ion-selective electrodes, using automatic analyzer "Easy Blood Gas" (USA, 2008).

Necessary range will correspond to this decision, this range indicates the degree of the severity level in case of Diabetic Ketoacidosis.

Practical realization of the medical expert system for the assessment of diabetic ketoacidosis severity

For the realization of the operation of the blocks of adjustment, membership functions storage, fuzzy processing and output of the expert system principles of obtaining the valid diagnosis on the base of fuzzy logic were provided as the basis.

Analytical expressions of the functions $\mu^j(x_1)$ from the value X_1 (pHARTERIA), if $PH = \overline{6{,}9;\,7{,}45}$ [8]

$$\tilde{\mu}^{L}(X_1)=\begin{cases}\dfrac{3{,}575-0{,}5x_1}{0{,}12}, x_1\in[6{,}9;7{,}03]\\ \dfrac{3{,}725-0{,}5x_1}{0{,}42}, x_1\in[7{,}03;7{,}45]\end{cases};\quad \tilde{\mu}^{LA}(X_1)=\begin{cases}\dfrac{0{,}5x_1-3{,}385}{0{,}13}, x_1\in[6{,}9;7{,}03]\\ \dfrac{3{,}655-0{,}5x_1}{0{,}14}, x_1\in[7{,}03;7{,}17]\\ \dfrac{3{,}725-0{,}5x_1}{0{,}28}, x_1\in[7{,}17;7{,}45]\end{cases};$$

$$\tilde{\mu}^{A}(X_1)=\begin{cases}\dfrac{x_1-6{,}9}{0{,}27}, x_1\in[6{,}9;7{,}17]\\ \dfrac{7{,}45-x_1}{0{,}28}, x_1\in[7{,}17;7{,}45]\end{cases};\quad \tilde{\mu}^{HA}(X_1)=\begin{cases}\dfrac{0{,}5x_1-3{,}45}{0{,}27}, x_1\in[6{,}9;7{,}17]\\ \dfrac{0{,}5x_1-3{,}515}{0{,}14}, x_1\in[7{,}17;7{,}31]\\ \dfrac{3{,}795-0{,}5x_1}{0{,}14}, x_1\in[7{,}31;7{,}45]\end{cases};$$

$$\tilde{\mu}^{H}(X_1)=\begin{cases}\dfrac{0{,}5x_1-3{,}45}{0{,}4}, x_1\in[6{,}9;7{,}31]\\ \dfrac{0{,}5x_1-3{,}58}{0{,}14}, x_1\in[7{,}31;7{,}45]\end{cases}.$$

$$\tilde{\mu}^{H}(X_2)=\begin{cases}\dfrac{0{,}5x_2-5}{37{,}5}, x_2\in[10;47{,}5]\\ \dfrac{30-0{,}5x_2}{12{,}5}, x_2\in[47{,}5;60]\end{cases}$$

Basic ideology of the information medical expert system operation for the assessment of the Diabetic Ketoacidosis severity, on the base of the introduction of fuzzy logic blocks for the assessment of the severity stage in case of Diabetic Ketoacidosis is shown in Fig. 1 (to improve the reliability of the assessment it is planned to perform the assessment by the venous component).

The result of realization of the given blocks was the developed programming shell, in this case, the user is proposed after the launching of the program to introduce the value of the low and upper scale of values, that is in the data base of certain pathology, in our case, we introduce the values which are basic for the determination [8].

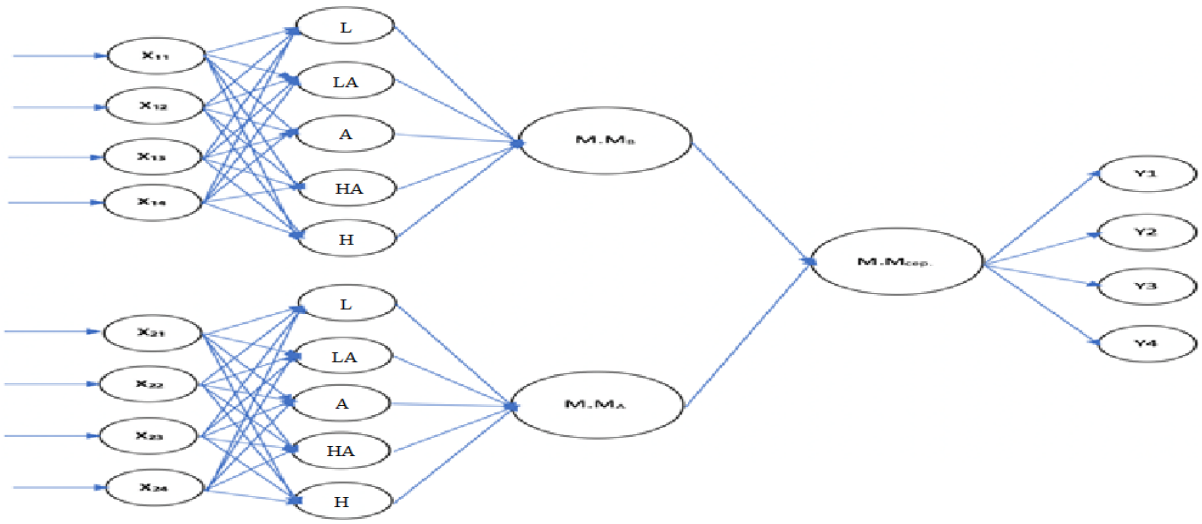

Fig 1. Fuzzy logic blocks for the assessment of the severity stage

Conclusions

Method of the application of fuzzy sets for the realization of the information expert system for the solution of the problems of medical diagnostics, in particular for Diabetic Ketoacidosis diagnosis was further developed.

Main directions of mathematic methods application in medical diagnostics were analyzed, their drawbacks were evaluated, principles of diagnostics, based on fuzzy logic were formulated.

Basic scientific results: mathematical models and algorithms, formalizing the process of diagnostic decisions making on the base of fuzzy logic, taking into account quantitative and qualitative parameters of patient`s state were developed; mathematical models of the membership functions, formalizing the presentation of the quantitative and quantitative parameters of the patient`s state in the form of fuzzy sets, used in the models and algorithms of diagnostics and determining the diagnosis in case of Diabetic Ketoacidosis were developed.

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

Practical value of the research is the possibility of the application of the automated expert system for the solution of the problems of medical diagnostics on the base of fuzzy logic for the classification of the severity

degree of Diabetic Ketoacidosis. Program shell on the base of fuzzy expert system is created. This shell can be used as a tool for the design of the object-oriented systems, necessary for the intelligent support of diagnostic decisions in different branches of medicine, including clinical practice and doctors training. Characteristic feature of the shell is that it enables to create expert diagnostic systems without special training in the sphere of programming and fuzzy sets.

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