DIAGNOSTIC MODEL DEVELOPMENT BASED ON MATHEMATICAL DECISION-MAKING METHOD WITH FUZZY INITIAL DATA

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Abstract- The use of modern information technologies is becoming a critical factor in the development of most branches of knowledge and areas of practical activity; therefore, the development and implementation of information systems in medicine is one of the most urgent tasks. This article aims to improve the efficiency of diagnosis of enteral and pancreatic insufficiency, by developing a diagnostic model based on the mathematical method of making decisions with fuzzy initial data. With the help of the developed diagnostic model described in the article, the drawbacks of diagnosing with poorly formalized diagnostic signs eliminated. In addition, the quality of diagnosis of enteral and pancreatic insufficiency is improved, and errors associated with subjective factors minimized.

Keywords- IT in medicine, diagnostic model, mathematical decision making method.

At the present stage of development of medicine, the importance of using modern information technology in healthcare to diagnose various diseases is increasing. Some problems of control processes in living organisms are similar to control in technical devices and described mathematically. The mathematical methods used in the technique used to study biological and medical processes.

The mathematical approach to solving the problems of diagnosing diseases in medicine is very fruitful and is associated with the development of mathematical models that underlie diagnostic information systems, using the accumulated knowledge about the disease. The database, most of all, is a qualitative description. From a mathematical point of view, the complexity of diagnosing diseases lies in the fact that the initial data (diagnostic signs) are incomplete, of a different type. The use of the mathematical decision-making method with qualitative uncertainty (Bellman R., Zade L.) is very justified. In medicine, to diagnose diseases, one has to rely on poorly formalized databases (diagnostic signs). In this regard, the use of the mathematical method of decision making with fuzzy source data is promising, as shown in [1-4].

Presenting a medical knowledge base for diagnosing diseases is a very complex process. Medical indicators can be either quantitative analogue or binary (a sign is present / absent), as well as vague diagnostic signs (insignificant / significant, for example, blood loss). We studied the possibilities of various mathematical approaches for solving diagnostic problems, based on very complex, ambiguous medical data using the apparatus of probability theory, mathematical statistics, the theory of fuzzy sets, etc. Clinical history, clinical laboratory and other data presented in the form of so-called linguistic variables. The coverage of all types of diagnostic signs gives a more reliable diagnosis.

In medicine, the application of the theory of fuzzy sets is associated with solving a number of problems of an applied nature, such as diagnosing diseases based on poorly formalized databases (diagnostic signs). A mathematical approach to solving diagnostic problems provides a more objective diagnosis and eliminates to some extent the subjectivity present during the initial examination of the patient.

The mathematical theory of fuzzy sets and fuzzy logic are a generalization of classical set theory and classical formal logic. The development of the mathematical apparatus of the theory of fuzzy sets is devoted to the work of L. Zade, E. Mamdani, R. Bellman and others. In medicine, for diagnosing diseases, it is necessary to be based on a database (diagnostic features) represented by linguistic parameters and, therefore, we apply the mathematical decision-making method with qualitative uncertainty. The creation of information technology systems that automate various aspects of the medical personnel's activities, as well as the development of a model for diagnosing diseases based on mathematical methods, is one way to solve the problems posed. Decision support system can help doctors during the initial examination; contribute to a more objective diagnosis.

The aim of this work is to develop a mathematical model for diagnosing diseases of enteric and pancreatic insufficiency, based on decision-making methods with fuzzy initial data (poorly formalized diagnostic signs).

To develop a mathematical model for the differential diagnosis of enteric and pancreatic insufficiency, we use the diagnostic table (A.N. Okorokov, 2005). It is convenient to present the

utility matrix of enteric and pancreatic insufficiency based on the diagnostic table in the form:

	X 1	X2 (А)	X2 (Б)	X 3	X 4	X5 (А)	X5 (Б)	X6 (А)	X6 (Б)
А 1	НХ	Х	НХ	НХ	НЧ	Х	НХ	Х	НХ
А 2	ОЧ	НХ	Х	Ч	Ч	НХ	Х	НХ	Х

	X 7	X8(А)	X8(Б)	X 9	X 10	X 11	X12(А)	X12 (Б)
А 1	НХ	Х	НХ	Ч	Ч	Х	Х	НХ
А 2	Ч	НХ	Х	НЧ	НЧ	НХ	Х	НХ

In the table of alternatives, which are enteric and pancreatic insufficiency, A1 and A2 are indicated, and the criteria (symptoms) are X1, X2, ..X12.

The degree of belonging of the criteria, which are linguistic variables, is set qualitatively: characteristically, not characteristically, very often, often, etc. Qualitative signs presented in the table by letter designations: X - characteristically; НХ is not characteristically; ОЧ - very often; Ч-often; НЧ - not often. For the convenience of solving the problem, we introduce the following simplifications: the qualitative features presented in the form of НХ (not characteristically) and ОЧ (not often) replaced by one sign of Р (rarely), which, in our opinion, is advisable. Since the sign of ОЧ (very often) is close to the sign of X (characteristically), then we replace it.

Then the utility matrix of enteric and pancreatic insufficiency will take the form:

	X 1	X2 (А)	X2 (Б)	X 3	X 4	X5 (А)	X5 (Б)	X6 (А)	X6 (Б)
А 1	Р	Х	Р	Р	Р	Х	Р	Х	Р
А 2	Х	Р	Х	Ч	Ч	Р	Х	Р	Х

	X 7	X8(А)	X8(Б)	X 9	X 10	X 11	X12(А)	X12 (Б)
А 1	Р	Х	Р	Ч	Ч	Х	Х	Р
А 2	Ч	Р	Х	Р	Р	Р	Х	Р

To create a mathematical model for the differential diagnosis of enteric and pancreatic insufficiency, we use the utilities indicated in the table and the mathematical method of the theory of fuzzy sets (A.N. Borisov, O.A. Krumberg, I.P. Fedorov, 1999). The method allows you to work with data that is set qualitatively. Linguistic variables (characteristic, often, rarely) can be represented as subsets:

X= {0.5/9; 1.0/10}; Ч={0.5/7; 1.0/8;}; Р={0.5/2; 1.0/1;}

The expert sets the index, which accounts for the maximum degree of ownership.

To develop a diagnostic model, we take the symptoms (conditional patient). We believe that the patient has severe abdominal pain, having the nature of herpes zoster, vomiting, anemia, and there are diffuse changes in the pancreas,

Based on the data of the diagnostic table, a matrix is formed:

$$U = \begin{Vmatrix} u_{11} & \dots & u_{1in} \\ u_{21} & \dots & u_{2n} \\ & \dots & \\ u_{m1} & \dots & u_{mn} \end{Vmatrix}$$

$\tilde{U}_{ij} = \bigcup_k \mu_{u_{ij}}(u_k)/u_k$, where $u_k = \mu \sim (x_k)$,

representing a fuzzy set,

consist of fuzzy subsets defined:

$$\mu\sim_{u_i}(\tilde{u_k})/u_k) = [\mu(u_i)/\tilde{u_i}]/[\mu_{u_k}(u_i)/u_i].$$

Set $\tilde{u_i}$ simplify as follows:

$$\mu\sim_{u_i}(\tilde{u_k}) = \min[\mu_{\sim x}(\tilde{x_k}),\ \mu_{\sim u_{ik}}(u_i)]$$

Minimization reduces the risk of misdiagnosis.

Optimizing set $\tilde{U}_{io}$, which is like the intersection of sets U_{im} и U_i and $\mu_{\sim \varepsilon_{io}}(u_k) = \min\{\mu_{\sim \varepsilon_{im}}(u_k);\ \mu_{\sim \varepsilon_i}(u_k)\}$ allows you to calculate the best alternative, which means a probable disease with this complex of symptoms.

$$A^* = \mu_{\sim A_o}(a_o) = \max_{A_o} \mu_{\sim A_o}(a_i)$$

where $\mu_{A_o} \sim (a_i) = \max_{u_{io}} \mu_{\sim}(u_k)$

The patient's condition is recorded in a fuzzy set:

X= {0.5/X1; 0.6/X3; 0.7/X4; 0.3/X11; 0.8/X8(Б)}

Define fuzzy utility alternatives:

U~$_1$={0.5/P, 0.6/P, 0.7/P, 0.3/X, 0.8/P }

U~$_2$={0.5/X, 0.6/Ч, 0.7/Ч, 0.3/P, 0.8/X, }

Given that some element appears several times, we obtain:

U~$_1$={0.98/P, 0.3/X}. U~$_2$={0.9/X, 0.3/P, 0.88 /Ч},.

Then:

U~$_1$={0.98/P, 0.3/X} = {0.98/[0.5/2; 1.0/1]; 0.3/[0.5/9; 1.0/10] }.

U~$_2$={0.9/X, 0.3/P, 0.88 /Ч},= {0.9/[0.5/9; 1.0/10]; 0.3/[0.5/2; 1.0/1]; 0.88/[0.5/7; 1.0/8]}

Minimize:
U~$_1$={0.5/2; 0.98/1; 0.3/9; 0.3/10}, U~$_2$={0.5/9; 0.9/10; 0.3/2; 0.3/1; 0.5/7; 0.88/8}

u_{max}=sup Y, где Y=S(U $_1$)$\bigcup$ S(U $_2$) = {1,2,7,8,9,10}; u_{max}=10;
Using u_{max} , we are going to find Max from:
U~$_1$={2:10/2; 1:10/1; 9:10/9; 10:10/10},
U~$_2$={9:10/9; 10:10/10; 2:10/2; 1:10/1; 7:10/7; 8:10/8}
U~$_1$={0.2/2; 0.1/1; 0.9/9; 1/10},
U~$_2$={0.9/9; 1/10; 0.2/2; 0.1/1; 0.7/7; 0.8/8}
Then the optimizing sets:
U~$_1$={min(0.5,0.2)/2; min(0.98,0.1)/1; min(0.3,0.9)/9; min(0.3,1)/10}={0.2/2;,0.1/1; 0.3/9;0.3/10}
U~$_2$={0.5/9; 0.9/10; 0.2/2; 0.1/1; 0.5/7; 0.8/8}
From here we define:

μ ~(A1)= max (0.2, 0.1, 0.3, 0.3)=0.3; μ ~(A2)= 0.9,

Finally, A(*)= max (0.3, 0.9) = 0.9 (A2).
Therefore, with the above symptoms, the most likely disease: pancreatic insufficiency, which coincides with the findings of experts.

The main advantage of making a diagnosis using a mathematical model is its objectivity, which can eliminate the over diagnosis that occurs most often during the initial examination. The correspondence of the obtained results with the results of diagnosing by other methods, in particular by the Bayes method, indicates the applicability of this method for the diagnosis of the disease. Moreover, this method has an advantage, since it takes into account the severity of symptoms, which makes it possible in the future to use this fact to predict diseases. We pose the problem of diagnosing (enteric and pancreatic insufficiency) by the mathematical method of projection of gradients [5]. We use the utility matrix proposed above for this nosological class of diseases and, taking into account the patient's condition {X=0.5/X1; 0.6/X3; 0.7/X4; 0.3/XII; 0.8/X8(Б)}, form a matrix A:

$$A = \begin{vmatrix} a_{11}a_{13}a_{14}a_{111}a_{18Б} \\ a_{21}a_{23}a_{24}a_{211}a_{28Б} \end{vmatrix} = \begin{bmatrix} Р & Р & Р & Х & Р \\ Х & Ч & Ч & Р & Х \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 1 & 1 & 10 & 1 \\ 10 & 8 & 8 & 1 & 10 \end{bmatrix}$$

Since the condition of the patient is given by a fuzzy set and values (0.5; 0.6; 0.7; 0.3; 0.8), indicating the severity of symptoms in this patient, represent in the form of a matrix C:

$$\vec{C} = \begin{Bmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{Bmatrix} = \begin{Bmatrix} C_1 = 0.5 \\ C_2 = 0.6 \\ C_3 = 0.7 \\ C_4 = 0.3 \\ C_5 = 0.8 \end{Bmatrix}$$

We find: $\vec{X} = A * \vec{C}$

$$\vec{X} = \begin{vmatrix} a_{11}a_{13}a_{14}a_{111}a_{18Б} \\ a_{21}a_{23}a_{24}a_{211}a_{28Б} \end{vmatrix} * \begin{Bmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{Bmatrix}$$

Then:
A1=
$(a_{11} * C_1 + a_{13} * C_2 + a_{14} * C_3 + a_{111} * C_4 + a_{18Б} * C_5) = 5.6$
A2=26.4
then $\mu(A_0) = \max(5.6;\ 26.4)$

Consequently: A (*)= $\mu(A_0) = 26.4$
The best alternative is a disease is A2.
So, we conclude that for a given symptom complex and the patient's condition, a disease is observed - pancreatic insufficiency, which coincides with the diagnosis made by the decision-making method above with qualitative uncertainty and expert conclusions.

The results of the studies allow us to conclude that the developed model for diagnosing enteric and pancreatic insufficiency based on the mathematical method using qualitatively given initial data has several advantages. The model takes into account not only the presence of certain symptoms in the patient, set qualitatively, but also their severity. The mathematical model of diagnosis allows you to increase the objectivity of decisions. Using the developed diagnostic model, the disadvantages of making a diagnosis with poorly formalized diagnostic features are eliminated, the quality of diagnosis is improved, and errors associated with subjective factors are minimized. One of the advantages of the proposed model is the possibility of its technical implementation by creating an automated system that will significantly expand the doctor's capabilities in the differential diagnosis of enteric and pancreatic insufficiency with fuzzy initial data. The use of such programs in healthcare will allow monitoring of these diseases, as well as the implementation of such programs in the educational process. The possibility of using, along with instrumental, which are modern diagnostic devices, mathematical methods of decision-making are clearly demonstrated.

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