Model of the monitoring process for early diagnosis of patients' health

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Abstract

This research paper presents an approach for resolving the monitoring task for early diagnosis process of patient's health. The problem of the monitoring task for different sphere of life is considered. The model of the monitoring process has been developed in the form of an activity diagram. The analysis of existing medical information system for clinical monitoring is conducted. The analytical review of mathematical methods for resolving the monitoring task in medicine has been made. The BPMN-model of the monitoring for early diagnosis process has been formalized. Experimental studies were carried out on the example of determining the presence or absence of diabetes mellitus in a patient. The list of risk factors and set of symptoms of type 2 of diabetes mellitus have formed. The quality criteria have been chosen. The integral quality factor is proposed. The assessment process of the quality of the monitoring task for early diagnosis process indicates that developed method would determine the improving of the medical decision process.

Keywords 1

Monitoring task, early diagnosis of diseases, fuzzy logic, quality of monitoring process

1. Introduction

Monitoring is the process of observing an object or phenomenon in order to collect, store and process information about the object of research to support decision-making. There are many cases of using the monitoring process for different domain areas:

- environmental monitoring: it allows to assess the state of environmental pollution in order to identify factors and sources of anthropogenic impact on the environment [1];
- social monitoring or monitoring of public opinion: it allows to highlight the most acute problems of the population, to receive feedback and from the initiatives of the authorities, to evaluate the activities of any object based on the opinion of the target audience [2];
- monitoring for nuclear power plants: it is needed to prevent emergencies [3];
- business monitoring: it is a systematic observation of the state of the market in order to assess it, study trends and competitors [4];
- medical monitoring: it is used to assess the quality of the work of medical institutions, to assess the effectiveness of the medical services and medical information systems (MIS), to prove hypotheses in evidence based medicine [5].

Usually medical monitoring is used for continuous monitoring of the patient's health based on an assessment of the system of diagnostic indicators in order to identify deviations from the standard in the course of treatment. This is clinical monitoring. It is exploited for inpatients and outpatients, the

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elderly people and pregnant women, and chronic patients. There is a large number of successful implementations of MIS for clinical monitoring and diagnosis of critical states in medicine based on the results obtained from instrumental-computer studies [6-8]. Such studies can be carried out using special hardware and software systems. They can register, store and process the patient's biological signals using various medical devices: infrared non-contact thermometer, pulse oximeter, glucose meter, blood pressure monitors, etc. There are many scientific researches dedicated to medical monitoring process [9-11]. Many works have appeared related to monitoring the health status of patients with COVID-19 in connection with the coronavirus pandemic [12, 13]. A separate area of research is the development of various mobile applications for monitoring the health status of patients [14, 15]. For instance, the platform [15] contains information about a huge number of mobile applications for medical purposes with the ability to search of the required application by category: Bones and Muscles; Breathing and Lungs; Heart, Circulation and Blood etc. Mobile apps can differ according to platform (Android, Apple, Blackberry, Nokia, and Windows) and interface's language. Certain apps are part of the National Health Service, which means they are used by government health services. For example, the My Inhealthcare application developed by Inhealthcare is used on the state level in the UK. Registered patients of the app can send information about their health status directly to their therapist, receive feedback from the doctor, and analyze their health indicators over time, set various reminders, for example, about taking medications or about the need to upload information to the application. Despite on such a wide range of MIS for solving the monitoring task and existing research, the problem of early diagnosis of the patient in dynamics remains not completely solved.

Thus, the purpose of this study is to improve the quality of the monitoring process of patients' health with solving the early diagnosis task.

2. Formal problem statement

Let's consider the medical monitoring task for early diagnosis process of concrete disease. Every disease is characterize of set of chosen indicators $Y = \{y_1, \dots y_n\}$. Let designate $X = \{x_1, \dots x_m\}$ as a set of possible states of patients for concrete disease. Then the task of the monitoring process for early diagnosis of patients' health is a mapping of one set to another $f: Y \rightarrow X$.

The given issue can be divided to following subtasks:

- formalize monitoring process;
- develop the model of the early diagnosis process;
- conduct review of approaches for resolving the monitoring task;
- choose suitable method for given domain area;
- assess the quality of the monitoring process of patient's health.

3. An analytical review of existing mathematical methods

To solve the issue of monitoring and predicting the patient's health state according to medical indicators, the various mathematical methods can be applied. Each method has advantages and disadvantages. Let's take a look at some of them.

An example of numbered list is as following.

1. Neural networks (NN)

Neural networks are widely used in medical research to solve the problems of diagnosing diseases, processing medical images, monitoring the health of patients, predicting the results of using different methods of treatment, predicting the state of health of patients, evaluating the effectiveness of treatment methods [16-17]. Neural networks needs to be trained on a special dataset. Usually, the larger the dataset, the better results the NN shows in solving a particular problem. However, it is difficult to create datasets with medical data of the required volume, with the necessary characteristics. Only medical professionals have access to such data, since they belong to the category of personal data of a person and are protected by the laws of all countries of the world, and are also medical secrets. Moreover, the physiology of people is different, so it is difficult to train a NN to distinguish between normal and abnormal data. It means that some patients have such normal values of medical indicators that are abnormal for healthy people. Nevertheless, there is a huge amount of research of the usage of NN that show high efficiency in solving various medical problems.

2. Computational Logic

The mathematical apparatus of predicate and propositional logic can also be used to solve medical issues [18, 19]. Researched medical objects should be represent in the form of a set of n-place predicates. For example, the indicator of patient's health "elevated body temperature" can be represent by the double predicate . It means in natural language, "the patient's body temperature is greater than 36.6". Alternatively, the double predicate in natural language means "the average volume of red blood cells is 83.9". Any case can be described with such predicates. Then the values of these predicates are compared with the values of a set of n-place predicates representing the researched object. The comparison findings can show the presence of a certain disease, determine the choice of a particular treatment plan, etc. The values of predicates are 1 or 0, so they can be linked by logical operations, the generality quantifier and the existential quantifier. However, the logic of predicates has such drawbacks as an excessive level of formalization of knowledge representation, difficulty of reading them, and not very good performance of computer processing.

3. Fuzzy logic

A more effective mathematical approach for solving medical issue is the apparatus of fuzzy logic, since a decision is made in the face of uncertainty often. On the one hand, sometimes the patient cannot clearly describe own symptoms, on the other hand, the medical expert can interpret the information received from the patient in different ways. There are such situations when a certain set of symptoms describes several diseases, or the course of the illness is atypical, or some disease is disguised as another etc. Therefore, the advantages of this method are the similarity with human decision making and the ability to use fuzzy data for decision making. The basis of the fuzzy logic is the base of fuzzy expert rules, where each rule defines a cause-and-effect pattern in the form of "if-then". The fuzzy inference would determine belonging of researched object to a particular class. Each rule is associated with the values of the membership function of the corresponding linguistic terms. Various membership functions can be used, for example, the Gaussian function. The logical conclusion is made using some special algorithm of logic inference [20, 21]. Comparing the aforementioned methods, one can conclude that the fuzzy logic can be used for tracking the patient's health.

4. Monitoring model for early diagnosis

The monitoring task in general terms is to observation of the object of research based on the set of selected indicators for checking the achievement of the given goals. The aims in its capacity as the following tasks: assessing the state of the object of research, monitoring and managing the behavior of the object, early warning of possible situations, modeling and predicting behavior of the object, studying both individual properties of the object and the whole one. It is possible to assess the degree of achievement of the goal based on the selected criteria. Thus, the monitoring model of the research object is presented in the form of the following scheme (Fig. 1).

The first stage is the analysis of the domain area. The obtained results is a base for the selection a system of indicators that allow assessing whether the goal has been achieved or not. The second stage provides data collection and evaluation or diagnostics of the current state of domain. These findings are compared with standard, which can be collected from various sources: special literature, previous research, knowledge bases about the subject area etc. The comparison results are the framework for decision making at the fourth stage. They allow forming a set of management decisions. Depending on the degree of achievement of the given goal, the monitoring process can continue with insufficient data or a final report of the research is formed.

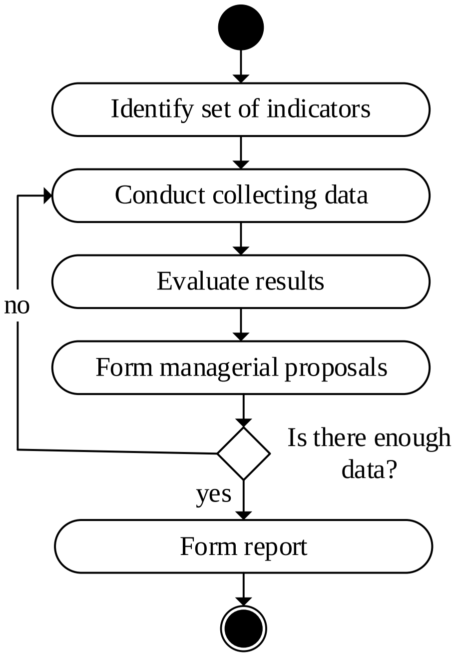

Figure 1: Monitoring process model

The monitoring process may differ depending on the subject area. Let's consider the monitoring in solving the issue of early diagnosis of patient's health. This task is a systematic diagnosis of the patient's state with a certain frequency based on the use of a system of chosen indicators (Fig. 2).

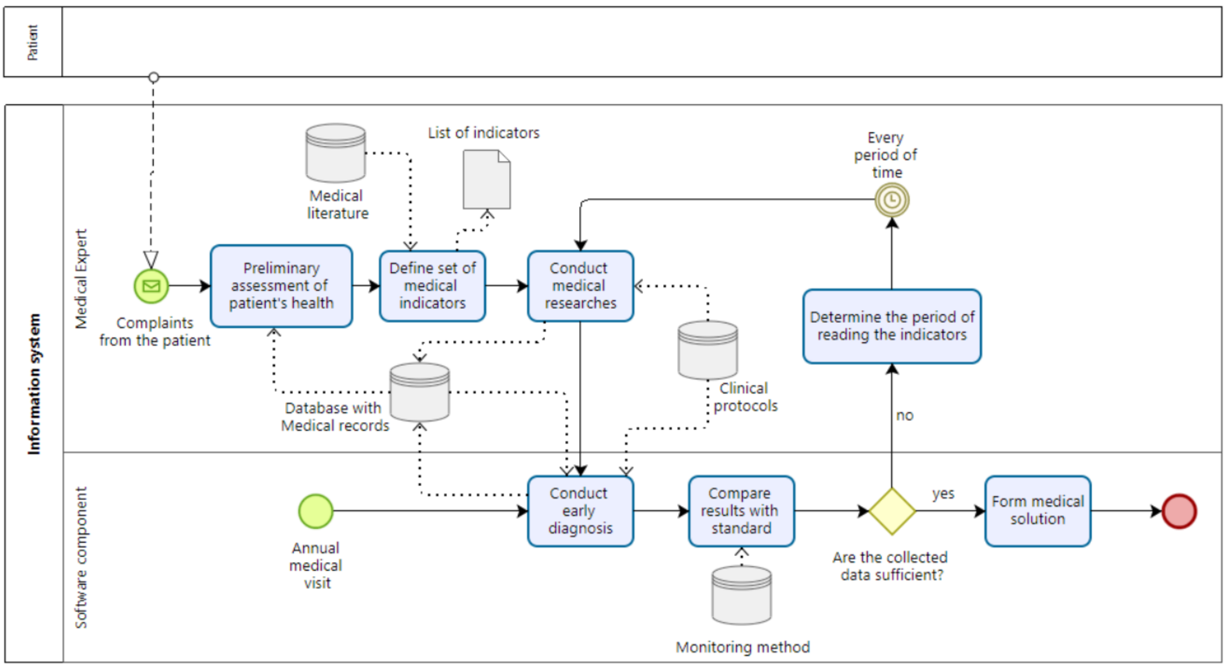

Figure 2: BPMN-model of the early diagnosis process

There are two events, which can initiate monitoring process: a patient attendance with certain complaints or an annual medical examination. In the first case, a preliminary assessment of the patient's health is carried out on the basis of the initial examination, history and existing complaints. Next, the doctor determines a set of indicators and markers for monitoring. The next stage provides conducting of the medical procedures in accordance with medical protocols of treatment and diagnostics [22]. These procedures would determine the values of the selected indicators. Further, the task of early diagnosis of the patient's health is solved. The findings are compared with standard. The standard on the first cycle of evaluating of patient's data is based on average data for particular indicators. On subsequent cycles of checking the medical values, the data are compared not only with the average values, but also with the results of previous examination. The period of medical research depends on the complexity of the case, on the magnitude of the discrepancy with the standard, etc. The doctor in each case determines this rate separately. When the period of observation expires, the doctor draws up a conclusion about patient's health.

The second reason for starting the monitoring process is the annual physical examination. The patient can come by himself or at the request of the HR-department. In this situation, the patient has a certain list of examinations according to medical protocols [22]. Then the doctor forms a conclusion about the confirmation of the health group. If the results of the examination revealed critical or questionable values of some indicators, then after a while the patient is sent for repeated examinations to clarify the diagnosis.

To improve the quality of monitoring for solving the problem of early diagnosis, the aforementioned model of the business process provides usage of mathematical methods of information processing. The review of the methods showed the feasibility of using the apparatus of fuzzy logic as a monitoring method in solving the early diagnosis task of patient's health.

To make decisions regarding the dynamics of changes in the patient's health state, it is necessary to form a base of fuzzy rules in the form: "if … , then …". It is proposed to convert input data to linguistic variables. A linguistic variable takes values from a variety of words or phrases in a natural or artificial language. Each linguistic variable is a term-set consisting of a set of fuzzy variables defined on the same range of variation as the linguistic variable itself. Let's consider the indicator "Sore throat". It is a qualitative indicator, which contain term set with different values: weak sore throat, moderate sore throat and strong sore throat. Every variable from term set has to be assessed with the help of chosen membership function. Membership functions show graphical view of the fuzzy set. The x axis represents the universe of discourse: the level of sore throat. The y axis represents the degrees of membership in the [0,1] interval. There are many different forms of membership functions. The most used functions are following: Gaussian, Triangular, Singleton, Trapezoidal etc. The linguistic variable "Sore throat" is shown below (Fig. 3).

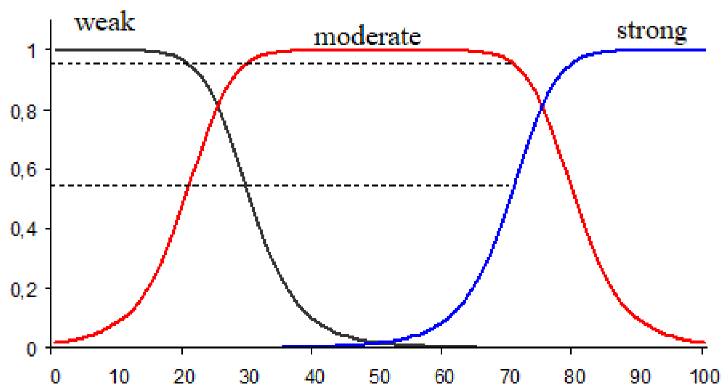

Figure 3: Defining of a linguistic variable

Next stage is selecting the method of fuzzy inference. The most common methods are the algorithms of Mamdani, Suggeno, Tsukamoto, Larson. The usage of the fuzzy rule base consists of the following steps: fuzzification (fuzziness introduction), inference, composition and defuzzification. A distinctive feature of inference methods is the use of different formulas for bringing to clarity.

5. Experimental part

Let's consider the usage of developed model for resolving the monitoring task on the example of the diabetes mellitus. According to the International Diabetes Federation (IDF), about 578 million people with diabetes will be registered in 2030, and 700 million people in 2045. The IDF report for 2019 indicates that the number of patients with diabetes in the world has reached 463 million people, and from 85 to 95% of patients suffer from type 2 diabetes mellitus and big number of the disease remains undiagnosed [23]. It means that the problem of medical monitoring of patients with a high risk of diabetes mellitus for the purpose of early diagnosis is an extremely urgent task. The first priority is to determine the patient's risk. Table 1 presents a list of risk factors for diabetes mellitus of type 2 over the next 10 years according to the Finnish Diabetes Risk Score (FINDRISC) [24].

Table 1
List of medical indicators for type 2 diabetes mellitus according to the Finnish Diabetes Risk Score

	Name of indicator	Term set of indicator
Y_1	age (years)	$\{y_1^1$ =less than 45, y_1^2 =from 45 to 54, y_1^3 =from 55 to 64, y_1^4 =more or equal 65$\}$
Y_2	body mass index, BMI (kg/m2)	$\{y_2^1$ =less than 25, y_2^2 =from 25 to 30, y_2^3 =more than 30$\}$
Y_3	sex	$\{y_3^1$ =female, y_3^2 =male$\}$
Y_4	waist circumference for women (cm)	$\{y_4^1$ =less than 80, y_4^2 =from 80 to 88, y_4^3 =more than 88$\}$
Y_5	waist circumference for men (cm)	$\{y_5^1$ =less than 94, y_5^2 =from 94 to 102, y_5^3 =more than 102$\}$
Y_6	daily consumption of vegetables, fruits, or berries	$\{y_6^1$ =yes, y_6^2 =no$\}$
Y_7	history of physical activity for 30 minutes every day or 3 hours during the week	$\{y_7^1$ =yes, y_7^2 =no$\}$
Y_8	use of blood pressure medications	$\{y_8^1$ =no, y_8^2 =yes$\}$
Y_9	history of high blood glucose	$\{y_9^1$ =no, y_9^2 =yes$\}$
Y_{10}	family history of type 1 diabetes	$\{y_{10}^1$ =no, y_{10}^2 =yes (grandparents, uncle/aunt, cousins), y_{10}^3 =yes (parents, sibling, child)$\}$
Y_{11}	family history of type 2 diabetes	$\{y_{11}^1$ =no, y_{11}^2 =yes (grandparents, uncle/aunt, cousins), y_{11}^3 =yes (parents, sibling, child)$\}$

The fuzzy rule base was compiled based on the indicators in Table 1. Here are some examples of rules:

$$R_1: \ if\ Y_1 = y_1^1 \text{ and } Y_2 = y_2^1 \text{ and } Y_3 = y_3^1 \text{ and } Y_4 = y_4^1 \text{ and } Y_6 = y_6^1 \text{ and } Y_7 = y_7^1 \text{ and } Y_8 = y_8^1 \text{ and } Y_9 = y_9^1 \text{ and } Y_{10} = y_{10}^1 \text{ and } Y_{11} = y_{11}^1, \text{ then } x = S_1$$

$$R_2: \text{if } Y_1 = y_1^1 \text{ and } Y_2 = y_2^1 \text{ and } Y_3 = y_3^1 \text{ and } Y_4 = y_4^2 \text{ and } Y_6 = y_6^2 \text{ and } Y_7 = y_7^1 \text{ and } Y_8 = y_8^1 \text{ and } Y_9 = y_9^1 \text{ and } Y_{10} = y_{10}^2 \text{ and } Y_{11} = y_{11}^1, \text{ then } x = S_2$$

$$R_3: \text{if } Y_1 = y_1^3 \text{ and } Y_2 = y_2^2 \text{ and } Y_3 = y_3^2 \text{ and } Y_5 = y_5^2 \text{ and } Y_6 = y_6^2 \text{ and } Y_7 = y_7^1 \text{ and } Y_8 = y_8^1 \text{ and } Y_9 = y_9^1 \text{ and } Y_{10} = y_{10}^3 \text{ and } Y_{11} = y_{11}^1, \text{ then } x = S_3$$

$$R_4: \text{if } Y_1 = y_1^4 \text{ and } Y_2 = y_2^3 \text{ and } Y_3 = y_3^2 \text{ and } Y_5 = y_5^2 \text{ and } Y_6 = y_6^2 \text{ and } Y_7 = y_7^1 \text{ and } Y_8 = y_8^1 \text{ and } Y_9 = y_9^1 \text{ and } Y_{10} = y_{10}^3 \text{ and } Y_{11} = y_{11}^2, \text{ then } x = S_4$$

The values of the variable $x \in \{S_i\}, i = \overline{1,5}$ show the patient's risk of type 2 diabetes mellitus over the next 10 years, where S_1 means very low risk, S_2 – low risk, S_3 – moderate risk, S_4 – high risk, S_5 – very high risk.

Depending on the value of x obtained at the previous stage, the patient is provided with recommendations for further monitoring of health. Patients with very low and low risk are encouraged to monitor their blood glucose levels once every three years. Group of patients with moderate, high and very high risk is checked for symptoms of type 2 diabetes. Table 2 provides a list of informative signs of diabetes.

Table 2
Symptoms of diabetes mellitus

	Name of indicator	Term set of indicator
t_1	excessive thirst	$\{t_1^1$ =yes, t_1^2 =no$\}$
t_2	increased urination	$\{t_2^1$ =yes, t_2^2 =no$\}$
t_3	weight change	$\{t_3^1$ =yes, t_3^2 =no$\}$
t_4	sweating, especially after eating	$\{t_4^1$ =yes, t_4^2 =no$\}$
t_5	weakness, tiredness	$\{t_5^1$ =yes, t_5^2 =no$\}$
t_6	itching of skin	$\{t_6^1$ =yes, t_6^2 =no$\}$
t_7	nausea, vomiting	$\{t_7^1$ =yes, t_7^2 =no$\}$
t_8	slow-healing sores or cuts	$\{t_8^1$ =yes, t_8^2 =no$\}$
t_9	fasting blood glucose level	$\{t_9^1$ =more or equal 7 mmol/l, t_9^2 =more than 5 and less than 7 mmol/l, t_9^3 =less or equal 5 mmol/l$\}$
t_{10}	hyperinsulinemia	$\{t_{10}^1$ =yes, t_{10}^2 =no$\}$
t_{11}	compensatory hyperplasia of pancreatic b-cells	$\{t_{11}^1$ =yes, t_{11}^2 =no$\}$

The fuzzy rule base was compiled based on the indicators in Table 2. Here are some examples of rules:

R_{278}: if $t_1 = t_1^2$ and $t_2 = t_2^2$ and $t_3 = t_3^2$ and $t_4 = t_4^2$ and $t_5 = t_5^2$ and $t_6 = t_6^2$ and $t_7 = t_7^2$ and $t_8 = t_8^2$ and $t_9 = t_9^3$ and $t_{10} = t_{10}^2$ and $t_{11} = t_{11}^2$, then $z = D_1$

R_{279}: if $t_1 = t_1^2$ and $t_2 = t_2^2$ and $t_3 = t_3^1$ and $t_4 = t_4^2$ and $t_5 = t_5^2$ and $t_6 = t_6^2$ and $t_7 = t_7^2$ and $t_8 = t_8^2$ and $t_9 = t_9^3$ and $t_{10} = t_{10}^2$ and $t_{11} = t_{11}^2$, then $z = D_1$

R_{280}: if $t_1 = t_1^2$ and $t_2 = t_2^2$ and $t_3 = t_3^1$ and $t_4 = t_4^2$ and $t_5 = t_5^2$ and $t_6 = t_6^2$ and $t_7 = t_7^2$ and $t_8 = t_8^2$ and $t_9 = t_9^2$ and $t_{10} = t_{10}^2$ and $t_{11} = t_{11}^2$, then $z = D_2$

R_{281}: if $t_1 = t_1^2$ and $t_2 = t_2^2$ and $t_3 = t_3^2$ and $t_4 = t_4^2$ and $t_5 = t_5^2$ and $t_6 = t_6^2$ and $t_7 = t_7^2$ and $t_8 = t_8^2$ and $t_9 = t_9^2$ and $t_{10} = t_{10}^2$ and $t_{11} = t_{11}^2$, then $z = D_2$

R_{282}: if $t_1 = t_1^1$ and $t_2 = t_2^2$ and $t_3 = t_3^1$ and $t_4 = t_4^2$ and $t_5 = t_5^1$ and $t_6 = t_6^2$ and $t_7 = t_7^2$ and $t_8 = t_8^2$ and $t_9 = t_9^1$ and $t_{10} = t_{10}^2$ and $t_{11} = t_{11}^2$, then $z = D_3$

R_{283}: if $t_1 = t_1^1$ and $t_2 = t_2^1$ and $t_3 = t_3^1$ and $t_4 = t_4^1$ and $t_5 = t_5^1$ and $t_6 = t_6^2$ and $t_7 = t_7^2$ and $t_8 = t_8^2$ and $t_9 = t_9^1$ and $t_{10} = t_{10}^2$ and $t_{11} = t_{11}^2$, then $z = D_3$

R_{284}: if $t_1 = t_1^1$ and $t_2 = t_2^1$ and $t_3 = t_3^1$ and $t_4 = t_4^2$ and $t_5 = t_5^1$ and $t_6 = t_6^2$ and $t_7 = t_7^2$ and $t_8 = t_8^2$ and $t_9 = t_9^1$ and $t_{10} = t_{10}^2$ and $t_{11} = t_{11}^1$, then $z = D_3$

The values of the variable $z \in \{D_j\}, j = \overline{1,3}$ show the absence or presence of prediabetes or type 2 diabetes mellitus, where D_1 means patient doesn't have prediabetes or type 2 diabetes, D_2 means that patient has prediabetes, D_3 means that patient has type 2 diabetes.

6. Discussion

To assess the quality of the monitoring process of patient's health in dealing with the solving the problem of early diagnosis, it is necessary to form a set of criterion that help to determine the degree of achievement of certain goals. Analysis of domain area and experience of experts allow choosing the following criteria for quality measurement process:

- c_1 – time expenditure for processing of medical information;
- c_2 – level of complexity of medical data processing;
- c_3 – level of patient satisfaction;
- c_4 – level of emergency room visits;
- c_5 – level of readmissions.

For this study, experts have proposed to use for evaluation of each criterion a 5-point scale. Then the obtained values are normalized. The criterion can be positive, or it can make a negative contribution to the overall assessment. In the latter case, the reciprocal is taken [26]:

$$c_i^{norm} = \frac{c_i}{5} \text{ or } c_j^{norm} = 1 - \frac{c_j}{5}, \qquad i, j \in \overline{\{1,5\}}, i \neq j$$

where c_i – are positive criteria; c_j – are negative criteria.

Then the aggregation of particular criteria is performed according to the formula proposed in [25, 26]:

$$Q = \frac{\sum_{l=1}^{5} c_l^{norm} \, w_l}{\sum_{l=1}^{5} \, w_l}$$

where w_l – is the weight of c_l-th criterion.

In order to assess the dynamics of changes in the quality of the monitoring process for early diagnosis, the features of the process can be measured in two ways. First case is conducted in the classical way with the help of experts. Second way indicates how the developed model can help to resolve the monitoring task. Experts evaluate both ways according to the proposed scale (Table 3). The conducted researches have shown that the only c_3-rd criterion has positive influence onto overall value of the quality measurement. When the values of others criteria are increased, the quality of the monitoring process of patient’s health is decreased.

Table 3

The quality assessment

Number of criterion	Classical way	Proposed model	Weight of criterion	Results of assessment	
				Classical way	Proposed model
c_1	5	2	0,9	0,74	0,82
c_2	4	1	0,7	0,79	0,91
c_3	2	4	0,6	0,11	0,36
c_4	4	2	0,7	0,79	0,82
c_5	4	2	0,4	0,79	0,82
Q				0,65	0,75

The Table 3 demonstrates that the quality of the early diagnosis process for solving the monitoring problem has increased by 10%. It proved the feasibility of proposed approach for resolving the given task.

7. Conclusion

Solving the monitoring problem for early diagnosis improves not only the quality of patient care, but also the level of satisfaction of patients and doctors. The proposed approach showed that the use of fuzzy logic in decision-making generates additional medical information for the doctors. In addition, studies and analyses have showed the possibility of using of the proposed monitoring model in clinics to improve the management of medical decisions.

8. References

[1] M. Palinkas, L. Hufnagel, Distinctive patterns and signals at major environmental events and collapse zone boundaries. Environmental Monitoring and Assessment 193, 676 (2021). https://doi.org/10.1007/s10661-021-09463-7.

[2] Kochuieva Zoia, Natalia Borysova, Karina Melnyk and Dina Huliieva. (2021) “Usage of Sentiment Analysis to Tracking Public Opinion”, in Proceedings of the 5th International Conference on

Computational Linguistics and Intelligent Systems (COLINS-2021): 272–285. URL: http://ceur-ws.org/Vol-2870/paper23.pdf.
[3] P. H. Bianchi, B. D. Baptista F., Monitoring and Operational Support on Nuclear Power Plants using an Artificial Intelligence System, in: Proceedings of the 8th Latin-American congress on electricity generation and transmission, CLAGTEE, Ubatuba, Brazil, 2019. https://inis.iaea.org/collection/NCLCollectionStore/_Public/42/079/42079669.pdf
[4] Wayne W. Eckerson, Business Monitoring Systems: Using Machine Learning to Analyze Business Metrics, 2020. URL: https://www.yellowfinbi.com/campaign/business-monitoring-systems.
[5] Ogilvie, David, Jean Adams, Adrian Bauman, Edward W. Gregg, Jenna Panter, Karen R. Siegel, Nicholas J. Wareham, Martin White "Using natural experimental studies to guide public health action: turning the evidence-based medicine paradigm on its head." Epidemiol Community Health Journal 74 (2020) : 203–208.
[6] Central patient monitoring systems. URL: https://www.usa.philips.com/healthcare/solutions/patient-monitoring/central-monitoring-systems.
[7] Remote Patient Monitoring Systems: Components, Types, Vendors, and Implementation Steps, 2020. URL: https://www.altexsoft.com/blog/remote-patient-monitoring-systems/.
[8] Software for telemedicine IDIS2GO. URL: https://idismed.com.ua/.
[9] A. Athira, T. D. Devika, K. R. Varsha and S. S. Bose S., Design and Development of IOT Based Multi-Parameter Patient Monitoring System, in Proceedings of the 6th International Conference on Advanced Computing and Communication Systems (ICACCS), 2020: 862-866, doi: 10.1109/ICACCS48705.2020.9074293.
[10] Jorge Gomez, Byron Oviedo, Emilio Zhuma, Patient Monitoring System Based on Internet of Things, Procedia Computer Science, 83 (2016): 90-97. URL: https://doi.org/10.1016/j.procs.2016.04.103.
[11] Ben Hassen, H., Dghais, W. & Hamdi, B, An E-health system for monitoring elderly health based on Internet of Things and Fog computing. Health Information Science and Systems 7, 24 (2019). https://doi.org/10.1007/s13755-019-0087-z.
[12] I. D. Sabukunze, D. B. Setyohadi and M. Sulistyoningsih, Designing An Iot Based Smart Monitoring and Emergency Alert System for Covid19 Patients, in Proceedings of the 6th International Conference for Convergence in Technology (I2CT), 2021: 1-5. doi: 10.1109/I2CT51068.2021.9418078.
[13] A. Chrysler, H. Warnars, W. Utomo, Mobile application to track people in covid19 monitoring and patients under covid19 supervision, in Proceedings of the International Conference on Biospheric Harmony Advanced Research (ICOBAR 2020) 729 (2020):12-32, Jakarta, Indonesia doi :10.1088/1755-1315/729/1/012032.
[14] ASpine app. URL: https://aspineapp.ru/
[15] My health apps. Tried and tested by people like you. URL: https://myhealthapps.net/
[16] Chia-Ming Chang, Tzu-Kang Lin, Chih-Wei Chang, Applications of neural network models for structural health monitoring based on derived modal properties, Measurement, 129 (2018): 457-470, URL: https://doi.org/10.1016/j.measurement.2018.07.051.
[17] N. Axak, Development of multi-agent system of neural network diagnostics and remote monitoring of patient, Eastern-European Journal of Enterprise Technologies 82 (2016): 4-9. doi: 10.15587/1729-4061.2016.75690.
[18] K. Melnyk, Modeliuvannia protsesu intelektualnoi obrobky medychnykh danykh. [Modeling of the process of intelligent medical treatment of medical data.] Systemy obrobky informatsii [Information Processing Systems] 4, 150 (2017): 237–244. [in Ukrainian]
[19] Terrance Swift, Computational Logic for Healthcare Informatics: an Informal Survey, 2010. URL: https://www3.cs.stonybrook.edu/~tswift/webtalks/jhu10.pdf.
[20] O.A. Khorozovn, I.V. Krak, A.I. Kulias, V.S. Kasianiuk, W. Wójcik, A. Tergeusizova, Monitoring vital signs using fuzzy logic rules, in: Information Technology in Medical Diagnostics II, 1st ed., CRC Press, 2019.
[21] Mrozek D., Milik M., Małysiak-Mrozek B., Tokarz K., Duszenko A., Kozielski S., Fuzzy Intelligence in Monitoring Older Adults with Wearables. In: Krzhizhanovskaya V.V. et al. (eds) Computational Science – ICCS 2020. Lecture Notes in Computer Science, 12141. Springer, Cham, 2020. https://doi.org/10.1007/978-3-030-50426-7_22

[22] "Unifikovanyi klinichnyi protokol pervynnoi ta vtorynnoi (spetsializovanoi) medychnoi dopomohy. Tsukrovyi diabet 2 typu." ["Unified clinical protocol of primary and secondary (specialized) medical care. Type 2 diabetes."] URL: https://www.dec.gov.ua/wp-content/uploads/2019/11/2012_1118ykpmd.pdf [in Ukrainian]

[23] "International Diabets Federation. Worldwide toll of diabetes." URL: https://www.diabetesatlas.org/en/sections/worldwide-toll-of-diabetes.html

[24] Lindstrom Jaana and Jaakko Tuomilehto. (2003) "The Diabetes Risk Score. A practical tool to predict type 2 diabetes risk." Diabetes Care 26 (3):725–731.

[25] K. V. Melnyk, N. V. Borysova, V. I. Melnyk, Information system development for teaching staff performance evaluation, in: S.V. Kotlik (Ed.), Informatsiini tekhnolohii ta avtomatyzatsiia, Astroprynt, Odesa, 2020, pp. 46-54.

[26] Melnyk K. Towards Designing of Recommendation System for Recruiting of Software Development Teams/ Karina Melnyk, Natalia Borysova, Zoia Kochuieva and Dina Huliieva // Proceedings of the 4th International Workshop on Computer Modeling and Intelligent Systems, April 27, 2021, Zaporizhzia, Ukraine. – P. 226-237 http://ceur-ws.org/Vol-2864/paper20.pdf