Selection of the logical model of the intellectual algorithm for dynamic processing of medical data (obtained through portable medical devices)

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Abstract. Portable devices are one of the important emerging areas of modern medicine. This article presents the rationale for the selection of the logical model of the intellectual algorithm for dynamic processing of medical data obtained through portable medical devices. The description of the main criteria for the selection and application of the method of Saaty is provided. And the conclusion about the feasibility of using fuzzy logic as a logical model for the investigated subject area is made.

1. Introduction

Portable medical devices are one of the actual fastest growing trends in modern medicine and are successfully used in solving problems such as the timely detection of patient's diseases symptoms, the time reduction for the hospitalization in medical institutions and the transition to the home treatment with the first improvement of health indicators [1].

Earlier in [2], an analysis of relevant research on the use of handheld devices in medicine was conducted. It allowed one to assess the current state and tendencies of development of modern technologies in this field.

During the research data on modern portable devices, they were classified according to two criteria:
- an approach to intellectual data processing (obtained through portable medical devices);
- an approach to the storage of medical data.

As the result, it was concluded that the operation of most modern information technologies in the field of medicine is aimed to extract quantitative data describing the basic parameters of the patient's health. After receiving them, the patient tries to detect the characteristic symptoms of the disease and to interpret the data as the primary diagnostic hypothesis.

In reallity, the detection of the characteristic symptoms of a tentative disease is not always enough for the desease identification. This can be explained by the nessesity for basing the diagnostic decision on symptom shades and disease distinction [3, 4].

That is why, when somebody approaches a health care facility, the doctor's task is focused on characteristic distinction of tentative disease detection, on the one hand, and searching for signs, which deny other diseases, on the other. That is to say, facts that confirm or deny diseases are used. They are also ranged by priority. One strong argument can change medical desision despite some less strong arguments. Obviously, the doctor uses his intuition, his own medical experience and professional education to set a provisional diagnosis.

However, the fact that methods of treatment are based on doctor knowledge and experience does not make it impossible to describe them using formal logic means. Medical data received through medical devices can be not only quantitative. They can also include qualitative characteristics. Those characteristics lessen the role of probability in disease diagnostics and add argumentativeness to decisions made by a patient himself or with the doctor [5, 6].

Overall, to increase the efficiency of portable medical devices, mining the received data, is needed early on. It will estimate and range the level of aberration. This will allow patients to make the healthcare decisions related to the early case by themselves.

In this paper, we propose to define one of the main components of the system, by choosing a logical model class for the intellectual algorithm for dynamic processing of medical data obtained through portable medical devices. This algorithm will be the basis of the developing an expert system, which will allow patients (users) to predict and prevent the clinical symptoms of various diseases at an early stage.

2. Methods

Development of the intellectual algorithm for dynamic processing of medical data involves the selection of a logical model among the variety of options, which are actively implemented in the system of decision support in medical organizations. [7].

To solve this problem, it was proposed to access the methods and models of system analysis, namely to assess the methodology of logical analysis of systems that are primarily used at the early stages of design and development of complex systems [8]. Logical analysis focuses on finding causal relationships between problems and their causes, between the goals and ways of achieving them. It is based on the methodology of building an objectives tree.

One of such methods is the "hierarchy analysis method" proposed by Thomas Saaty [9, 10]. This method is used for the solutions selection of complex multifactor problems. It consists of the decomposition of the goal into simpler components and further evaluation of these components through pairwise comparison. As the result, the priority of thierarchy elements used for the selection of best alternatives of solving the problem is determined.

Usually, the hierarchy is built from the top (the global objective in terms of solving problems through intermediate levels, which determine the purpose) to the lowest level, which is usually a list of alternatives. The order of the following levels is []:
  • a global goal;
  • actors - a group of persons interested in solving the problem;
  • objectives of actors;
  • alternative scenarios.

The next step is the description of the usage of the hiererchy analysis method to select the logical model, which is the most appropriate for the developed information system.

3. Results

The main criteria for the selection of the model were the possibility of the logical conclusion construction. As a result, five most common logical concepts, appropriate to these criteria were selected. Let us present their brief description.

3.1. Predicate calculus

It is also known as the first-order predicate calculus. This is a collection of formal systems that allows the use of sentences that contain variables, fixed functions and predicates. It has such properties as completeness, consistency and compactness (if a set of the first-order sentences has a model, if and only if every finite subset of it has a model). It allows to strictly separate true and false statements and reason about their correlation.

3.2. Modal logic

Modal logic is a type of formal logic that extends classical propositional and predicate logic to include operators expressing modality. Modalities such as "possible", " necessary", "contingent", "impossible" and another are standard. This logic can be used as a base for generation logical systems which are meant to fomalize statements with quantitative and qualitative characteristics describing some statement estimate.

3.3. Description logic
Description logic is a family of formal knowledge representation languages that allows one to describe the subject field in a formalized language. It combines full indicative possibilities, on the one hand, and good computational features such as tractability and low compuational properties of logical problems, on the other. It makes it possible to use this method on practice. Description logic can be considered as tractable parts of predicate logic, but it is also syntactically close to modal logics.

3.4. Bayesian network
This is a directed acyclic graph that represents graph nodes as a set of random variables and an arc of graphs as their conditional dependencies. Bayesian network is a full model for varibles and their relationships, it can be used to give answers to probabilistic questions. For example, the network can be used to gain some new knowledge about the variable subset condition by watching other variables.

3.5. Fuzzy logic
Fuzzy logic is a mathematical subdiscipline, generalizing classic logic and set theory, based on the defenition of a fuzzy set. The fuzzy logic method use allows one to build a computation system to minimize probability of making wrong decisions in a critical case. The main feature of the fuzzy logic is the probability of answering the question about some condition fulfillment or non-fulfillment not just with two ways "yes" or "no", but also with such options as "probably yes" or "probably no". The fuzzy logic methods differentiate from each other by the ways of determination of probability of positive and negative answer veracity .

The main task for the developing information system is to set up a level of medical grounds deviation from standard means. However, the notion of "standard" is individual for every person and can have different values, that is why the primary analysis results are very suppositive.

Knowledge uncertainty leads to incorrect result even in very simple cases. Besides the incorrect knowledge, incorrect or unreliable data of clinical case can lead to uncertainty. Not always, there is an opportunity to get needed data fast, especially when the situation needs to be solved as soon as possible.

This is why, it is very important to base on subject area features while choosing basic model as a base for developing information system. In our case, this feature is data uncertainty, obtained through portable medical devices.

It is very important for the system to be able to obtain incoming data, to process and interpret them in the apprehensible for system users form. In the mean time, the whole system working process has to take as little time as possible, without reducing the quality of resulted information.

This is why the following selection criteria for the most suitable logic model were chosen:
- the possibility of a logical output construction;
- the ability to work with incomplete, uncertain data;
- the possibility of implementing logical operations;
- intelligent data handling capabilities;
- the speed of data processing;
- the completeness of the system description;
- the possibility of creating a user-friendly interface.

A method offered by an American mathematician, Thomas Saaty, was used for the following model selection. This method is called an "analytic hierarchy process".

Saaty's method uses the relevance tree methodology and is intended for selection of solution tools for the complex multifactor problem. It consists of intentional decomposition into simpler parts and the following estimation of these parts by paired values. As a result, hierarchy elements are estimated numerically to choose the best result of the given problem. The hierarchy of objectives for the selection of the system logical model is shown in figure 1.
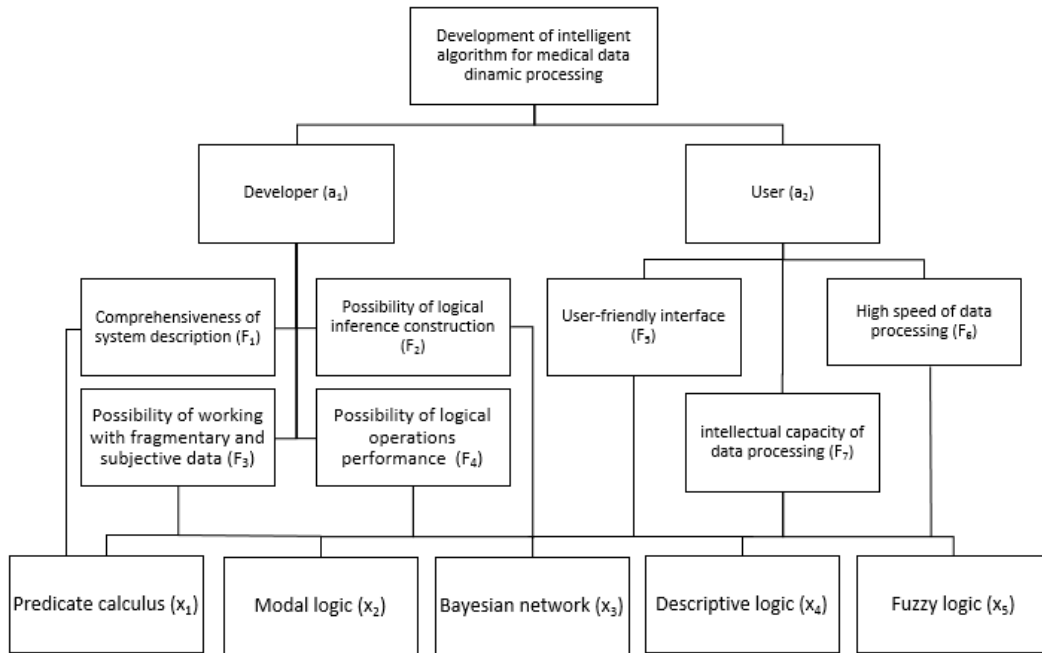

Figure 1. The hierarchy of objectives for the selection of the system logical model

The first level is represented by a global goal. The second level of the system is represented by actors - a group of interested people (in this case - medical staff). The third level is represented by actors wishes. The lower level is a list of alternatives, which make up possible logical models.

After building a hierarchy, it is necessary to conduct the pairwise comparison of one level elements in relation to the parent elements. Below, there is a main measurement scale for the comparison of hierarchy elements, adopted in the analysis of hierarchies:

1 - equality of the compared elements in relation to the parent;

3 - preference;

5 - an expressed preference;

7 – a strong preference;

9 – an absolute preference;

2, 4, 6, 8 - intermediate values.

Figure 2 shows matrices of pairwise comparisons of elements a_1, a_2 и F_1, F_2, F_3, F_4, F_5, F_6, F_7.

	a_1	a_2
a_1	1	1/3
a_2	3	1

(a)

	F_1	F_2	F_3	F_4
F_1	1	2	1/4	3
F_2	1/2	1	1/3	2
F_3	4	3	1	5
F_4	1/3	1/2	1/5	1

(b)

	F_5	F_6	F_7
F_5	1	1/2	2
F_6	2	1	4
F_7	1/2	1/4	1

(c)

Figure 2. Matrices of pairwise comparisons of the second and third levels of the hierarchy

Next, we use the simplest algorithm for the calculation of normalized weights of alternatives based on the pairwise comparisons matrix . The algorithm consists of three steps (the example of the calculation of the 1st matrix is below):

1) calculuate the sum of the elements for each row of the matrix (i.e. for each alternative). Denote these amounts as S_1 and S_2:

$S_1 = 1+1/3 = 1.33$

$S_2 = 3+1 = 4$

2) calculate the total amount: $S = S_1+S_2 = 1.33+4 = 5.33$

3) calculate normalized weights: $W_1=S_1/S = 1.33/5.33 = 0.25$; $W_2=S_2/S = 4/5.33 = 0.75$.

The algorithm is generic, i.e. it is used for processing of the matrix of pairwise comparisons of any size and gives the result (the normalized weights of the compared objects) with accuracy 0,01.

As a result, following normalized priorities were received:

$a_1 = 0.25$; $a_2 = 0.75$;

$F_1 = 0.22$; $F_2 = 0.15$; $F_3 = 0.55$; $F_4 = 0.08$; $F_5 = 0.286$; $F_6 = 0.57$; $F_7 = 0.14$.

At the last stage of the analysis, local priorities were restated in relation to elements priority. The table shows data for the calculation of global priorities and the results of calculation.

Table 1. Calculation of global priorities

Global priorities guiding elements	Local scenarios priorities					
Element	A priority	Predicate calculus	Modal logic	Bayesian network	Description logic	Fuzzy logic
Completeness of the system description (F_1)	0.055	0.14	0.15	0.11	0.02	0,58
The possibility of constructing a logic output (F_2)	0.037	0.35	0.13	0.17	0.03	0,32
The ability to work with incomplete and subjective data (F_3)	0.138	0.16	0.19	0.15	0.06	0,44
The ability to implement logical operations (F_4)	0.02	0.1	0.14	0.18	0.07	0,51
User-friendly interface (F_5)	0.21	0.21	0.15	0.15	0.04	0,45
High speed data (F_6)	0.43	0.11	0.19	0.21	0.1	0,39
The ability of data mining (F_7)	0.11	0.15	0.22	0.13	0.13	0,37
Global scenarios priorities		0.15	0.18	0.173	0.079	0.418

Thus, according to the method of Saati, fuzzy logic has the highest global priority among other logical models.

4. Rationale

Thus the most appropriate logic model for the developed information system was chosen. Fuzzy logic will ensure the functioning of the algorithm for dynamic processing of medical data. It will be the basis of

an expert system for interpreting and predicting the results of measurements obtained through portable medical devices.

However, expert systems, besides computing operations performing, form certain conclusions based on the existing knowledge. The knowledge inside the system is presented in a special language and is kept separately from the actual program code, which generates conclusions. This component of the program is called knowledge database.

Thus, the next step is to choose the storage and transmission model for medical data (using methods similar to that presented in this article). The model should provide the interoperability of the system and the ability to adapt the system in case of interaction with other systems and products, which, in turn, will allow one to create a universal system for data evaluation (obtained through portable medical devices) and making decisions under conditions of uncertainty, regardless of the scope of diagnostics.

5. Conclusion

In conclusion, we can say that the development of intellectual algorithm for dynamic processing of medical data (obtained through portable medical devices) will allow patients and doctors to get not only quantitative data, but also quality parameters, which characterize main indicators of the patient's state of health.

Application of fuzzy logic will build a computing system that minimizes the probability of making wrong decisions in critical conditions. Thus, it will help doctors of various specialties and lead to the improvement of the quality of preventive and laboratory diagnostic work, especially in terms of mass service with the time deficit of qualified specialists.

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