ass. Natalia Melnikova
dr tech. sc. Natalya Shakhovska

Department of Information systems and technologies
Institute of Business and Innovative Technologies
National University "Lviv Polytechnic"

Analysis of decision-making methods in patients' treatment

An analysis of the decision-making methods used in solving difficult – formalized problems of medical diagnostics and treatment was undertaken. A proposal was made as to a formal model of medical expert system, whose task is the selection of procedures in medical pharmaceutical programs.

The most important task at any stage of a medical evaluation is to determine the general condition of the patient, as well as the complexity of the pathological process and the immediate control of the effectiveness of treatment for timely correction. These problems can be attributed to a large group of practical problems that are classed as decision-making tasks.

The problem of evaluating the general condition of the patient is relevant specifically for medical diagnosis and treatment, which is based on a number of parameters to determine the type of disease or to find an alternative treatment. Since decision making is the result of the processing of certain information about the patient and is based on the usagee of knowledge, we can expect that computer artificial intelligence and the expert system (ES) can help the doctor to address the challenges of diagnosis and the choice of the appropriate methods of treatment.

During biomedical research it is necessary to conduct data analysis of pathological conditions as well as process diagnostic medical information[1]. Different methods of conducting these tasks are employed, among them Bayes' rule, Apriori algorithm, cluster analysis methods, reverse output method, artificial neural network models, etc.[2] The interpretation of the results from the survey is the primary and most important task of any research. The formal nature of methods of medical data analysis can limit and complicate their use in many cases.

The following problems may arise when considering and resolving problems in the analysis of medical data:

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[1] С.В. Павлов, *Неінвазивні оптико-електронні прилади та системи діагностики мікроциркуляції периферійного кровообігу*: автореф. дис. канд. техн. наук: спец. 05.11.17 «Біологічні та медичні прилади і системи» Він. Нац. техн. ун-т. – В., 2008. – 46 с.

[2] А.В. Мисник, *Аналіз одновимірних та двовимірних діагностичних даних методами штучних нейронних мереж*: дис... канд. фіз.-мат. наук: 03.00.02 Київський національний ун-т ім. Тараса Шевченка. – К., 2004. – С. 147–155.

- fuzzy knowledge may be represented;
- assessment of the degree of reliability may result in conclusions based on fuzzy background information and information that comes from dialogue with the user;
- problems in the selection and creation of classification data sets;
- the study of conceptual schemes for grouping objects.

THE EXPERT SYSTEMS

It is often difficult to make diagnostic and therapeutic decisions especially when the doctor has to do so in situations relevant to related medical specializations. Such problems can be solved by means of special software packages, i.e. ES. The purpose of the ES is to solve the problems of informal choices which are difficult using traditional methods of mathematical analysis and traditional programming methods[3] Logical structural and probabilistic mathematical models can be used as the main mechanism for searching for a solution. Therefore it is important to develop a therapeutic support system that integrates the benefits of traditional methods of presentation with the expert knowledge.

The article focuses on the analysis of treatment decision support systems in the area of medical diagnostics and treatment. It is common knowledge that the ES possess some basic components, such as[4]:

- a knowledge base
- an output mechanism.

The basic process is to apply the mechanism to the terminal output of knowledge in order to obtain the resulting knowledge that is of interest to guide the ES. In addition to these ES components there are additional subsystems that provide: communication with the user, the transfer of expert knowledge in a computer program and an explanation and rationalization of results, etc.[5]

This description of the ES features calls for presenting a formal model of medical expert system (MES). For formalized representation the MES, which has the task of selecting the optimal mechanism of therapeutic pharmaceutical scheme, we take as a base, the structural model of productive ES (PES), which is usually used to solve this class of problems.

Knowledge according to the block diagram of the ES lies in the selection of a set of rules P[6]:

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[3] И.Г. Черноруцкий, *Методы оптимизации и теории управления*. СПб.: Питер, 2004. – 380 с.

[4] Т.А. Гаврилова, *Базы знаний интеллектуальных систем*. СПб.: Питер, 2000. – 520 с.

[5] А.В. Алексеев, *Интеллектуальные системы принятия проектных решений*. – Рига: Зинатне, 1986. – 438 с.

[6] И.Г. Черноруцкий, *Методы принятия решений*. СПб.: БХВ – Петербург, 2005. – 416 с.

$$P = \{P_1, \ldots\ldots, P_n\}$$

where a product

$$P_i = s_{i1} \wedge s_{i2} \wedge \ldots\ldots \wedge s_{ik} \to s_j$$

and a finite array of facts S:

$$S = \{s_1, \ldots\ldots, s_m\}$$

All rules, according to the mechanism of productive expert systems, can be displayed as sub-sets of rules:

$$P : \Psi \to \Omega$$

where:

$$\Psi = \Psi(s_i),\ s_i \in S,\ \Omega = \Omega(s_j),\ s_j \in S$$

With the proposed formal model Les argue that Les – cortege of data:

$$LS = \langle S, A, P, Z, G, gf, ge, F \rangle$$

where:

Z – a set of all possible outputs
G – a finite set of states of the dialogue system
gf – the initial state of the system where
ge – the final state of the system where
F – a set of decision-making procedures
A – a set of precise parameters
S – a set of fuzzy data which can be divided into two subsets: S1 and S0:

$$S = S_0 \cup S_1,\ S0 \cap S1 = \varnothing,$$

S1 where we assume a set of stated parameters and S0 – a set of the unsung parameters. At the beginning of the ES set S1 contains parameters that during the further implementation of replenished items set S0:

$$S_0 = S_{0use} \cup S_{0unse}$$

Rules $\Psi \to \Omega$ are interpreted by the model:

IF Ψ THEN Ω

Therefore, the output mechanism follows the succeeding sequence: performed usually by the left portion of which Ψ is compared with the existing parameters in the set S1 and that becomes truth. As a result, a set S1 is replenished by the facts ascertained in the right portion of any product Ω. This creates chain conclusions interim and final decisions[7]. At any step of this output there may be more applicable rules and then the output becomes a generated tree that defines the set of circuits[8].

Presentation of the approach by Bayes. This method is based on Bayes theorem, through which one can collect information from a variety of sources in order to confirm or not confirm a hypothesis (an appropriate treatment regimen).

[7] *Ibidem.*
[8] И.Г. Черноруцкий, *Методы принятия решений…*

Example 1

Suppose, there is some hypothesis H that the patient has a diagnosis of diabetes. It can be considered, in accordance with statistical data known as a priori probability P (X) that in this area, patients are suffering from this disease. Let Y mean that the patient agents, who are sick with diabetes are treated with insulin. Using Bayes' formula, we get P (X / Y) (the likelihood that diabetes patients are treated with insulin). We can use the Bayes formula:

$$P(X) = 0{,}001 \text{ P}$$

$$P(\overline{X}) = 1 - P(X)\,,\ P(Y/X) = 1{,}0\,,\ P(Y/\overline{X}) = 0{,}01$$

$$P(Y/X) \cong 0{,}009$$

where:

P (Y / X) – the probability of diabetic patients with insulin;

P $(Y/\overline{X})$ – the probability of patients with insulin in the absence of diabetes.

Previously, we had the a priori probability P (X), which is in the knowledge base. Receiving information Y and listing Bayesian probability formula, we can put it in the place of P (X). Having received following, the message leads to reupdate this probability. Each time the current value of this probability is considered a priori to apply Bayes formula[9]. Finally, gathering information that relates to all hypotheses, a conclusion may be made that ES delivers more likely hypothesis as the result of the examination. However, when more than one parameter is being examined, the schematic diagram of the system by Bayes becomes complicated and there is an indicator of uncertainty.

The authors will present the methods of cluster analysis, out of the seven classes of clustering methods the hierarchical agglomerative (unification) methods are mostly often used[10].

Let us consider one of the hierarchical agglomerative methods – a single method of communication. The essence of this method is to find two similar objects with a coterminous matrix. According to the rule of the combined method, a new candidate for inclusion in the cluster can be connected to an existing group, provided it has the highest level of similarity with a certain member of this group. Thus, to combine two objects we only need one connection between them[11].

All hierarchical agglomerative methods are searching the matrix N x N (where N – number of objects) and consistently attach the closest matching objects. The sequence of association parameters in the system can be presented visually in the form of a tree diagram – the dendrogram. The tree diagram shows the result of applying a single method of communication to six data points (shown in Fig. 1). To complete these clustering methods based on similar matrix

[9] А.В. Мисник, *Аналіз одновимірних…*

[10] Р.Б. Кравець, *Моделювання систем…*

[11] И.Д. Мандель, *Кластерный анализ*. – М.: Финансы и статистика, 1988. – 176 с.

of dimension N x Ne needs exactly N-1 steps. In the first step, objects are treated as separate clusters, and on the next steps all parameters gradually merge into the main group. The work of these clustering methods are clusters that do not overlap, but there is another element attached to a larger cluster at the highest level of similarity[12].

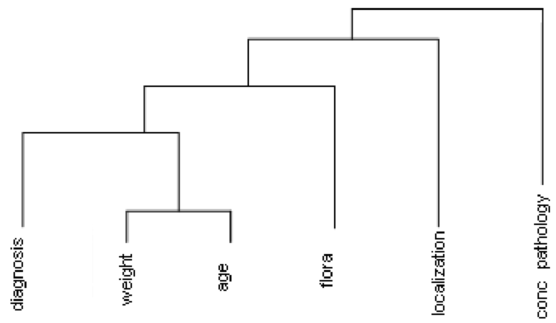

Fig. 1. The examplary dendrogram for the six data

The algorithm association rules (Apriori). Algorithms for finding association rules are designed to find all rules with th support and reliability of these rules should be higher for some in advance of certain thresholds, called respectively minimal support (minsupport), ie, the number of times is found in the database, and the lowest reliability (minconfidence)[13].

Example 2

Let us consider the work of Apriori algorithm as an example of transactional database BD. Minimally, the level of support is equal to 3. The value of variable preparations is assigned (Table 1). TID – a unique ID that identifies each operation or transaction.

Table 1. Sets of medications that are often prescribed

TID	Scheduled medications	Scheduled medications
100	Penicillin, paracetamol, asparcam	a, b, c
200	Paracetamol, calcium gluconate	b, d
300	Paracetamol, penicillin, calcium gluconate, asparcam	b, a, d, c
400	Biseptol	f

We shall consider a set of medications that includes, for example, penicillin, paracetamol, asparcam and present them by using variables:

[12] А.В. Алексеев, *Интеллектуальные системы…*

[13] Ю.Н. Арсеньев, *Принятие решений. Интегрированные интеллектуальные системы.* М.: ЮНИТИ – ДАНА, 2003. – 435 с.

$$abc = \{a, b, c\}$$

The set of medications found in our database three times, that support this set of products is equal to 3:

$$SUP(abc) = 3$$

With a minimum support levels (equal to 3) the set of abc products is a pattern that often occurs.
min_sup = 3. Penicillin, paracetamol, asparcam – a pattern that is common.

However, Apriori algorithm reduces the number of candidates, and cuts off a priori those who knowingly cannot meet often, as based on information about the candidates truncated at earlier stages of the algorithm.

The advantage of a priori methods is the high accuracy and stability, but they work only with binary attributes of objects and "not found" associative relationships with small support.

The presentation of the reverse output method. In actual productive systems the reverse chain of decision making is often used. It is characterized by proof of the hypothesis on which there is a corresponding rule that applies to the established fact[14]. This ES looks more focused, especially when the confirmation respective treatment regimens.

Example 3

Supposing, we have a set of parameters that influences the search for the optimal solution, ie treatment regimen. The main objective is to confirm the existence of the situation (the fact) x_{n+1}. Each regimen is characterized by a set of facts (symptoms) that affect its implementation.

$$X_1 = \{x_1, x_2, \ldots\ldots, x_n\}$$

where – set parameters or symptoms (fever, sore throat, toothache, headache, etc.). The system checks the fact (paracetamol) set X_1.

$$x_{n+1} \in X_1$$

According to the set of rules $P = \{P_1, \ldots\ldots, P_n\}$ is the rule:

$$P_1 = x_6 \wedge x_2 \rightarrow x_{n+1}$$

$$x_2 \in X_1 \text{ and } x_6 \notin X_1$$

where:

x_2 – sore throat
x_6 – bleeding

$$P_2 = x_3 \wedge x_4 \rightarrow x_6$$

$$x_3 \in X_1 \text{ and } x_4 \notin X_1$$

where:

x_3 – high fever

[14] Ю.Н. Арсеньев, *Принятие решений…*

x_4 – rash

$$P_3 = x_1 \rightarrow x_4$$
$$x_1 \in X_1$$

where:

x_1 – headache.

If the latter examination confirmed the presence of x_1, which belongs to the set X_1, it is a confirmation of the existence of a situation x_{n+1}, so therapeutic scheme is confirmed and requires "paracetamol" medication. Some facts having had the character of importance (knowledge of the first kind), are truly present in the knowledge base[15]. When the process comes down to their level, then there are no questions in the dialogue system.

The feasibility of this method is confirmed by a relevant decision in the knowledge base, which simplifies and speeds up the confirmation of the output result. In case of uncertainty, when the scheme of treatment or diagnosis is unknown, then the search of the optimal result is complicated.

Conclusion

Dissemination of complicated forms of diseases creates the need for the formulation of modern medicines. They are designed to enhance efficiency of methods in the selection of a methodology, diagnosing and treating patients on the basis of the processed input parameters. Building a knowledge base and rules of inference in the EU, based on the reasoning of experts in a particular subject area is a complex process in their formalization. Having reviewed the methods of decision making for medical systems, the authors argue that methods of fuzzy logic, expert systems should be used for solving problems related to medical diagnosis and treatment.

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Черноруцкий И.Г., *Методы принятия решений*. СПб.: БХВ – Петербург, 2005. – 416 с.

Summary

The article undertakes an analysis of decision-making methods used in solving difficult-formalized problems of medical diagnostics and treatment. A formal model of a medical expert system is proposed, with the purpose of selecting medical pharmaceutical treatment systems.

The important task at any stage of the medical evaluation is to determine the general condition of the patient, the depth of the pathological process and the operational control of the effectiveness of treatment for timely correction. These problems can be attributed to a large class of practical problems in the weakly formalized decision-making process in the treatment of patients.

Analiza metod wspomagania procesu podejmowania decyzji przy leczeniu pacjentów

Streszczenie

W artykule przedstawiono analizę metod wspomagania podejmowania decyzji, które są przeznaczone do rozwiązywania słabo sformalizowanych problemów diagnostyki medycznej i leczenia. Zaprezentowano formalny model systemu eksperckiego, którego celem jest usprawnienie sposobu farmaceutycznego leczenia pacjentów.

Najważniejsze zadania na każdym etapie oceny medycznej to określenie ogólnego stanu pacjenta i głębokości procesu patologicznego oraz prowadzenie kontroli skuteczności leczenia i jego odpowiednia korekta. Zadania te są powiązane z szeroką klasą praktycznych problemów występujących w słabo sformalizowanym procesie podejmowania decyzji dotyczących leczenia pacjentów.