Medical knowledge-based decision support system

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Abstract
This paper is devoted to the problem of automated supporting of decision-taking process in healthcare. The theranostic process is typified as an especial case of administrative process. Correct solutions of problems in medicine is based on metering big data. These data is represented by facts from real-life experience and numerous guidance of evidence-based healthcare. Taking into account of enormous aggregation of data for special isolated case is possible on application of automated decision support system based on technology of artificial neural network or genetic algorithm.

Keywords: decision-taking process , theranostic process , artificial neural network , genetic algorithm, automated decision support system, machine learning.

1 Introduction

Currently one of the priorities in health care system development is improving quality of provided medical services. The key factors in providing high quality medical help are establishing correct diagnosis and choosing optimal clinical route. Despite constant development of diagnostic methods and training of medical personnel the problem of medical errors is still relevant.

Treatment and diagnosis process is a particular case of a management process, where doctor is an agent of management and patient's organism and external factors are objects. The management process consists of four main stages:

- gathering information about an object and processing that information (history taking, laboratory and instrumental survey);
- determining object's state (establishing diagnosis);
- arrival at the solution about the required impact to transfer object into the goal state (forming clinical route);
- implementing the solution (treatment).

To arrive at the solution doctor must compare actual results of comprehensive survey (identified characteristic signs of diseases) to the information describing diseases. Establishing correct diagnosis is a challenge, since a doctor has to consider sets of symptoms and particular organism qualities unique for each individual. The fact that a lot of symptoms are common for several different diseases should also be considered. The next challenge is choosing a plan to treat the patient.

Decision Support Systems (DSS) are used to help doctors in solving these problems. DSS are computer automated systems that aim to provide informational support to persons who make decisions under complex conditions. DDS allow them to enhance completeness and objectivity of analysis of the investigated problem in accordance with profession specificity [1]. Medicine is a complexly formalized area of expertise. Making the wrong decision can lead to serious consequences not only for a single patient, but for many more patients with a similar symptomatology should a systematic decision making mistake occur [2]. To develop DSS one needs to formalize of doctor's logical conclusions, to account for international practice recommendations and to form a decision making model on their basis.

2 Classification and operation principles of decision support system in medicine

Classification

Decision support systems in medicine are divided into several main types depending on purpose of their use – to establish diagnosis or to choose the way to treat a patient.

DSS, that provide informational support to establish a diagnosis, form a list of possible diagnoses based on the input. These systems are applied on the stage of diagnostics in the admission room or even before a patient is admitted to a hospital. After diagnosis is established, DSS that can help to choose the optimal treatment are used.

Another DSS classification divides them on systems based and not based on knowledge.

DSS based on knowledge consist of these main elements: knowledge base, inference engine and user interface. The knowledge base of DSS of this type is based on the conceptual domain model. An ontological domain model describes relationships and connections between objects, as well as processes and phenomena occurring in the domain. The meanings of all notions used in the conceptual model are defined in an ontology of the domain.

Such models contain cause-effect relations between different objects of the domain. These relations are framed as «IF → THEN" rules. For example, the rule to choose a treatment for a patient with stomach cancer could look like this: "IF associated disease = 'pneumonia', THAN surgical intervention is contraindicated". Using interface for input a user can edit the knowledge base to keep it updated. The inference system allows forming and testing various hypotheses using rules from the knowledge base and real patients' data.

DSS not based on knowledge use machine learning that allows the system to find patterns in medical data based on previous experience. There are two main classes of such systems: using genetic algorithms and using artificial neural networks [3-4].

Artificial neural networks have nodes and weighted connections between nodes. Node weighs are selected so that with the input of a specific set of symptoms the output was the actual diagnosis. The process of selecting nodes is called training. Training helps find patterns in patient data. Through such an analysis connections between symptoms and diagnosis, that are often incomprehensible to a human, are revealed. The use of neural networks makes writing rules and expert knowledge unnecessary. However, such systems cannot explain their decisions and can be unreliable.

Genetic algorithms are based on simplified evolution processes, which use directional selection to find the optimal result. Selection algorithms evaluate random sets of problem's solutions. Solutions, which are acknowledged as the most suitable, are being put at the top, combined, mutate and go through the whole process again. This repeats until the suitable solution is found. Genetic algorithms, just as neural networks, derive their knowledge from patients' data and cannot explain their solutions.

Logical model

Probability and statistics methods can be used to select a method of treatment for a patient. The use of quantitative parameters is needed to develop the medical decision support model. The result of a patient's treatment can be one of these parameters. The evaluations of the treatment results must be made in accordance with specially designed quality ratings of the treatment and give their quantitative characteristic. Giving quantitative evaluation of treatment quality ratings is the purpose of fuzzy logic methods, namely the membership function. Harrington's desirability function can be used as one of these membership functions [5].

The general form of the Harrington's desirability function is expressed by equation (1):

$$\mu_D(x) = e^{-e^{-x}} \tag{1}$$

This generalized function is based on the idea of transforming medical treatment quality ratings into dimensionless scale of desirability or preferability. The desirability scale is one of the psychophysical scales. Its purpose is establishing correspondence between physical and psychological parameters [6-7]. Physical parameters are understood as patient's state ratings that characterize treatment result within the nosology.

The value of the function $\mu_D(x)$ is located in the interval [0, 1]. To each value of $x \in X$ it assigns the number, which characterizes the degree of solution desirability relative to the subset D of effective and acceptable methods of treatment. Subset D determines the set of treatment methods that are suitable to treat the nosology.

The connection between quantitative values of dimensionless scale and psychological human perception is set out in table 1.

Linguistical variables of treatment results (desirability)	Quantitative ratings of treatment results (marks on the desirability scale)
Very good	1,00 – 0,80
Good	0,80 – 0,63
Satisfactory	0,63 – 0,37
Bad	0,37 – 0,20
Very bad	0,20 – 0,00

Table 1. The connection between quantitative values of dimensionless scale and psychological human perception

Value $\mu_D(x) = 0{,}37$ is customary used as an acceptable value [8]. Calculating the probability of the positive outcome of the treatment is necessary to get the subset D. An outcome of the treatment is positive when the value of medical treatment quality ratings evaluation falls into the interval [0,38 – 1,00]. In other words, it can be "satisfactory", "good" or "very good". Using linguistic variables ("satisfactory", "good" and "very good") doctor evaluates treatment quality ratings. Analyzing the treatment process during hospitalization, doctor n times fixes attention on whether the fact A (complication) occurs. If fact A occurred in k experiments, then doctor records the frequency $p = k / n$ of occurrence of the fact A and evaluates it using words "satisfactory", "good", etc. While evaluating frequency p doctor draws on his/her experience that reflects the frequency of occurrence of the fact A in the past events that seem similar to evaluated event. Doctor also receives information based on observations of the fact A made by other specialists in similar fields, i.e. statistical data of treatment results of other patients of the nosology. The probability of the positive outcome of a treatment is calculated with this formula (2):

$$P(y) = \frac{n}{m}, \quad (2)$$

where m is the total number of patients with the nosology; n is the number of positive outcomes of treatment of patients with the nosology. The most suitable method of treating a patient is the one with the highest positive outcome probability.

Conclusions

The problem of improving security and quality of medical treatment will always be relevant. The accumulation of practical experience and theoretical knowledge requires improvement of informational support instruments of medical personnel. Automated decision support systems will play an increasingly important role in reducing the number of random and systematic errors. The key factor in effective work of a DSS is the constant updating of the knowledge base, the improvement of the logical model of functioning, methods and means of implementation of the system. Today the use of genetic algorithms and neural networks, which provide an ability to develop flexible self-learning DSS, is a perspective direction of development in this field.

3 Acknowledgments

This work was supported by Competitiveness Growth Program of the Federal Autonomous Educational Institution of Higher Professional Education National Research Nuclear University MEPhI (Moscow Engineering Physics Institute).

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