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Intellectual Systems for Differential Diagnostics within Groups of hardly distinguished Diseases

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Abstract. A new method of mathematical modeling based on ideas of the artificial intelligence has been developed called as a method of a «mosaic portrait». A description of a universal computer system «Differentiated diagnostics» is given into which it is possible to introduce the «mosaic model» for any group of diseases which are difficult to distinguish. On its base a number of diagnostic medical intellectual systems have been developed.

1. Introduction

The diagnostics was, is and will be the most important problem in medicine and diagnostics accuracy, achieved in certain historical periods, points mainly to the level of medicine science.

In view of the complexity of a human organism which is characterised by practically infinite number of diseases development, significant impact of a patient's individual peculiarities on development of symptoms and on the treatment of a diseases, a medical diagnostics now is not only so much a science as an art of few highly qualified professionals.

In literature there are available many works where some attempts have been undertaken to formalise the process of diagnostics using mathematical models [1-3]. The results of these works, in physicians' opinion, did not justify hopes. Rare achievements were related to relative simplicity of the problem (in these works there were differentiated such disease which were quite far from each other in the space of symptoms) or with its inadequate simplification (as a result of this there appeared at best models which can «identify a disease not worse than an average physician»).

The theoretical analysis of the results of works on mathematical modelling of «large systems» conducted in the theory of complexity showed that when solving problems with the number of entering parameters (symptoms) more that 7 for digital method and more that 15 for discrete methods practically invincible methodical and calculation difficulties occur (a medical diagnostic system also refer to «large systems») [1-3].

2. Method

The discrepancy between possibilities of the known methods of mathematical modelling and the difficulties of real medical diagnostic problems resulted in the necessity of the search for alternative ways of diagnostics formalisation.

One of such being under intensive development in recent time is the development of expert medical systems.

As it is known an expert system - it is a computing system in which the formalised knowledge of specialists in certain specific branch is included. The expert system within the sphere allows to solve problems in the same way as if it could be done by a man-expert [1-3].

The efficiency of work of the expert system depends in first extent on the quantity and quality of the information being included into the knowledge base. This is directly a weak point of expert systems. Firstly - a knowledge base is being constructed on the grounds of subjective judgements of examiners whose knowledge are limited. Secondly - specialists cannot formalise this knowledge in the form of rules. Moreover, in general examiners do not report which rules exactly they follow [1-3].

It should be also noted that psychophysiological abilities of a man allows him/her to distinguish dependencies of this or that event intuitively no more that on 2 variables (e.g. differential syndromes of a disease including at least 2 variables). To distinguish dependencies in the interaction of 3 variables - this is a fortune of a genius.

On the grounds of the objective analysis of the efficiency of various medical expert systems we drew the following conclusions:

- when solving relatively simple problems of differential diagnostics (those problems which are easily solved by specialists using nonformalisation approaches) the accuracy of a diagnosis achieved with the help of expert systems and expert will be ***close and sufficient;***
- when solving the most important and complicated problems of differential diagnostics (differentiation of disease which are close by manifestations, prediction of the character of a disease development, etc.) the diagnostics accuracy achieved with the help of expert systems and expert will be ***close and significantly insufficient.***

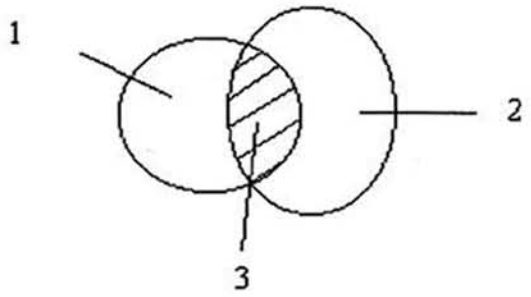

Fig.1 Matching properties of expert and intellectual medical systems.
1. Hypothetical information; 2. The trivial information; 3. Nontrivial, earlier not the known information.

Thus, it is necessary to transform the medical diagnostics from intuitive art of a few talented professionals into a strict science with high level of formalisation. The considerable progress in this direction can be achieved in the case if the problem of formal construction (without examiners) of adequate mathematical models for differential diagnostics within the group of diseases, which are close in their manifestations, could be solved.

3. Results

In order to solve this problem a new method of mathematical modelling has been developed basing on the ideas of artificial intellect which was named a method of «mosaic portrait» [4-8].

The problem of differential diagnosis model construction can be mathematically formulated as follows:

Given: Table of experimental data $M=XxY$ $(X=\{Xij\},\ i=1,m,\ j=1,n;\ \ Y=\{Yil\},\ l=1,k)$, each line of the table contains information about symptoms values (Xij) and verified diagnosis Yil for the i-th patient. (Here m is a number of lines (patients) in table M, n is a number of columns (symptoms) in table M, K is a number of diseases to be differentiated.)

Required: to construct, based on table M and using formalised procedures, a mathematical model consisting of K disjunctions of differential syndromes each disjunction containing differential syndromes of only one of K diseases to be differentiated.

Thus, the method of «mosaic portrait» allows to construct a mathematical model by using a table of experimental material and verificated diagnosis in one patient with the help of formalised procedures (without specialists). This model contains the corresponding subset of differentiated syndromes for each of N differentiated diseases. Each line of the table contains information on the meaning of the parameters (the data of: history of a diseases, treatment, instrumental and clinical researches, etc.).

The essence of the method of «mosaic portrait» is in the following:

1. To differentiate the range of possible meanings of each of the parameters into subranges giving each subrange a corresponding code;
2. To distinguish the combination of codes of different parameters which occurred in-patient with the same disease and not occurred in any other patient with other diseases.

In the «mosaic model» the subranges of possible meanings of each of the parameters are interpreted as symptoms and the combination of symptoms which occur in patients with the same disease (e.g., A) and do not occur in any other patient with other diseases (B, C, ...N) as differentiated symptoms of the disease A.

As far as in the method of the «mosaic portrait» there are no limitations to the scope of the task (quantity of parameters used for diagnostics) and to the scope of the syndrome (quantity of entering symptoms) a model received with its help contains a large number of new, nontrivial symptoms which were unknown earlier.

When developing a model of differentiated diagnostics the parameters can be used which traditionally are not used for solving this problem. The formalised procedure for the assessment of the informativity of each of the parameters in relation to each of the differentiated disease is laid in the algorithm of the construction of the mosaic model. Using this procedure it is possible to withdraw the variables which are not significant for solving specific problems.

Let us take an example. When constructing a model of differentiated diagnostics « gastric ulcer - gastric cancer» the table included 12 parameters in addition to traditional parameters which were never used earlier for solving this problem. It turned out that 11 of them are less informative and the 12^{th}- - electric cardiac position is a significant symptom and it was included in many differentiated syndromes of gastric ulcer. Another example: a patient has a combination of symptoms - weakening of pains after induced vomiting, duration of a disease for more than a year, electrical cardiac position is semivertical, the content of neutrophiles 6%, the content of lymphocytes 24% - so the diagnosis is a gastric ulcer. Under the other combination of symptoms a diagnosis - gastric cancer can be made (lack of appetite, electrical cardiac position is uncertain, content of albumines 51,2% of the total protein quantity).

The particular feature (advantage) of the mosaic model is a possibility to limit the number of diagnostic tests (because of their high cost, difficulty in access or hard endurance by a patient). This can be achieved because «mosaic models» exhibit a high descriptiveness. For each of the differentiated diseases a large number of syndromes can be distinguished which contain different combinations of symptoms. So, it is possible to introduce any limitations to the use of diagnostic tests (parameters). But an «effective mosaic model» can be constructed in any way. For example, it is possible to use mostly parameters of any group of the given subsets (anamnesis and electrocardiography). It is possible to exclude invasive tests (gastroscopy with the aimed biopsy, liver puncture, spinal puncture, etc.) as well as to exclude expensive tests.

We consider the method of «mosaic portrait» as the base of intellectual medical system, generating new systemic knowledge by means of formalised procedures (differentiated syndromes which were unknown before) from the table of the initial experimental material.

Using this knowledge it is possible to make a formal (computer) diagnostics within a group of the differentiated diseases.

After elaborating and patenting the intellectual system of the differentiated diagnostics for a specific group of diseases will represent a final product (as a set of computer programs) suitable for sales.

Practically all expert systems known today and intellectual systems generating knowledge by means of the method of the «mosaic portrait» use one and the same language of logic algebra in which any hypothesis is formulated as an expression «if... then...». In addition, expert systems accumulate (or should do that) all available knowledge in this subject. So, a statement is true that when there are available examination and intellectual systems constructed for one and the same subject area their crossing (common hypotheses) represent a priori known trivial information. The logic difference between expressions of expert and intellectual systems will be a false information (disinformation). The logic difference between expressions of intellectual and expert systems represent a new, nontrivial information unknown to specialists of this subject area.

That is why intellectual medical systems can take a place of expert systems in the market of intellectual medical products.

A universal computer system «Differentiated diagnostics» has been developed into which it is possible to introduce the «mosaic model» for any group of difficulty-distinguished diseases. On its basis a number of diagnostic medical intellectual systems have been developed.

Among them there is a computer system «Prediction of myocardium infarction complications in an acute period» for which a mathematical model was developed as a result of a collaborative work with the Military Medical Academy (St. Petersburg, Russia) [4, 5]. The following functions can be examined with this system:

- to predict probable complications of miocardium infarction (cardiogenic shock, cardiorrhexis, ventricle fibrillation, insufficient blood circulation, without complications);
- to evaluate the probability of manifestations of each of the predicted complication;
- to propose recommendations on preventive therapy of the predicted complication (complications) and corresponding symptomatic treatment with account of compatibility of drugs and treatment procedures;
- to put out the information about differentiated syndromes basing on which a diagnosis has been made.

All initial information on the state of health of a patient including the data of the anamnesis, results of examination, electrocardiography (39 parameters in total) put out from the keyboard by clicking one key as responses to questions appeared on the screen.

The experimental checking of the efficiency of this system has been conducted on the base of the cardiological clinic of the Medical Military Academy, 20th and 42nd city hospitals (St. Petersburg, Russia), 23rd Moscow clinical hospital (Moscow, Russia). It is established that the accuracy in prediction of complications makes up 85-88%. Owing to the purposeful preventive therapy of prognosticated complications the lethality from large focal myocardium infarction succeeded to be decreased by 36% and from small focal one - by 45%. The comparison was performed on the computer prediction received on the basis of the data about a patient collected at the first day of his/her stay in the hospital fixed by the delayed effects. It was found that in 90% cases a formal prediction of the future complication coincided with the final diagnosis (the data of the Institute of Therapy of the Academy of Medical Sciences of Ukraine (Kharkiv, Ukraine).

In collaboration with the Medical Military Academy a non-invasive express method of differentiated diagnostics has been developed - « Gastric ulcer - gastric cancer» (without using gastroscopy with the aimed biopsy). The experimental checking of efficiency of the use of a syndrome mathematical model for diagnostics conducted in a group of 120 new patients showed that for 117 of them (96,4%) the computer diagnosis coincided with the final one.

On the base of the Burn Center (Kharkiv, Ukraine) a computer system has been elaborated - «Differentiated diagnostics of various pathogens of pneumonia in burned persons» («a shocked lung», aspiration atelectatic, toxico-septic, hypostatic and bronchogenic pneumonia). The system allows to make an earlier diagnostics (on the 1st day of a disease development), to significantly differentiate methods of treatment and to raise its efficiency [6, 7].

4. Conclusions

A method of «mosaic portrait» allows: - to strictly formalize and automize a medical diagnostics; - to carry out an effective earlier noninvasive diagnostics (including that in latent periods) of chronic diseases which are dangerous for life (e.g. cancer diseases); - to predict courses and complications of diseases according to the information received on the first days of its manifestation; - to decrease loads on the patient by full exclusion of invasive tests in diagnostics; - to cut down the expenses for diagnostics by excluding tests that give insufficient information and are expensive; - to conduct a correct formal screening in mass preventive examination of the population.

5. Summary

The problem of formal (without participation of examiners) development of adequate mathematical models has been solved for differentiated diagnostics within groups of diseases, which are close in their manifestations.

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