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MATHEMATICAL SUPPORT OF THE INFORMATION SYSTEM FOR DECISION SUPPORT IN THE SPHERE OF HEALTHCARE

Abstract: The relevance of the topic is that currently modern medical information systems are aimed at providing management, economic and in some cases medical practice in the collection and processing of anamnestic data, including dental, ophthalmological, radiological, anesthesiological, resuscitation.

This study goal is to develop models of basic principles and structural and functional scheme of the decision support system as a tool that allows to model the process of "clinical thinking" of an endocrinologist in determining plans for drug treatment of diabetes based on a scenario approach and decision theory.

In accordance with the set goal, the research tasks are formulated and solved, the essence of which is as follows:

- analyze existing medical decision support systems and identify shortcomings of such systems;

- creating the criteria for developing medical decision support systems to improve usability;

- develop acceptable algorithms to create a medical decision support system.

Recommendations for modeling the functions of the doctor's intelligence in the process of processing and evaluation of medical information using a personal computer are offered, which will improve the operation of existing medical information systems.

The research was conducted within the framework of project management methodology and decision theory using information technology tools.

The algorithms for the creation a medical decision support system proposed by the authors are based on the method of multicriteria ranking of alternatives, which is a tool for modeling "clinical thinking" and logical reasoning of an endocrinologist. Unlike existing medical information systems, it will not only collect, store and process information about patients, but also increase the efficiency of endocrinologist decisions regarding the prediction and development of a patient treatment plan.

Keywords: information technology, medical information system, making decisions, algorithm, strategy, health care system.

Introduction

Currently, one of the most important problems that determine the further socio-economic development of the country is the health of the nation. The Extensive network and variety of forms of existence, autonomy of medical institutions make them one of the most complex objects of management within the entire state health care system. An urgent scientific and applied task now occurs, which is associated with the study and creation of medical decision support systems.

In the field of development of information retrieval and expert information processing systems for decision-making, creation of medical decision support systems is the most relevant and widely developing area. Medical decision support systems provide assistance in the decision-making process support and strengthen the thinking and assessment of the situation by the doctor, increase the efficiency of decision-making, because they cover the maximum amount of information. Decision support systems are currently being developed in many countries and in all areas of medicine [1].

Analyzing today's large number of works on the application of mathematical methods in medicine and the creation of decision support systems (DSS), expert systems, DSS allows to partially or completely automate the management of the treatment process, to use the experience gained over many years of practice, to process large amounts of data quickly. There are medical systems for various purposes, which account for only 9.6% of all software for the treatment and diagnostic process in medicine when at the same time the most common now are programs for automation of financial and administrative departments of treatment and prevention facilities (TPF).

The main disadvantage of the large number of medical information systems (MIS) presented on the market in 2017-2020 is their narrow specialization. The most popular are systems for dentistry, ophthalmology, radiology, anesthesiology, resuscitation, and others. Hence, there is an acute problem of developing an information system to support decision-making in the formation of prognosis and treatment plans for diabetes [1].

Research of existing solutions of the problem

The authors in [2] noted the importance of the use of information technology in the development of all spheres of the regional economy, which provides efficiency of management of innovative, economic, business, functional activity at all levels, and also to make economically important decisions. This study will be useful in the development of a health decision-making information system.

In [3], a review of existing information technologies for business process management in organizations was conducted, but these IT products do not allow to manage the process of medical practice, in particular, to forecast and plan treatment.

The authors in [4] proposed the structure of information technology of integrated risk management of scientific projects in conditions of uncertainty and behavioral economics, as well as the scheme of its implementation, which in turn will allow project manager and project team to ensure the successful and timely implementation of scientific project to meet the needs of its stakeholders. This study will provide a basis for developing the structure of health decision-making information systems.

In [5] the authors proposed information technology for the formation of a risk base for the construction of complex energy facilities, which can be used to collect information about the positive and negative consequences of patient treatment.

The authors in [6] proposed information technology for value-oriented management of art projects, from which the part related to the formation of stakeholders' register in treatment projects and the consequences of patient treatment can be used.

In [7] the analysis of tools of the theory of stakeholders is carried out and the necessity of quantitative methods' improvement for the stakeholders' analysis in the project and stakeholders' requirements, in particular, the necessity of introduction of multidimensional resource estimation is shown. This research can be used to develop a health decision-making information system.

The author in [8, 9] proposed to apply project-oriented and value-oriented approaches to medical project management. These studies will be useful in developing an information base to support health decision-making.

In [10, 11] the authors considered the issues of medical management and developed recommendations for improving the efficiency of their management. These studies can be used to fulfilling a health decision support information database.

The author in [12] developed information technology for integrated management of abnormalities in projects, which is based on the comparison of abnormalities with the treatment of diseases, and can be the basis for developing an information system for decision-making in the process of forecasting and planning treatment of patients.

The purpose and objectives of the study

This study aims to develop models of basic principles and structural and functional scheme of the decision support system as a tool, which allows to model the process of "clinical thinking" of an endocrinologist in determining plans for drug treatment of diabetes based on the scenario approach and methods of decision theory.

In accordance with the set goal, the research tasks are formulated and solved, the essence of which is as follows:

- analyze existing medical decision support systems and identify shortcomings of such systems;
- creating the criteria for developing medical decision support systems to improve usability;
- develop acceptable algorithms to create a medical decision support system.

Methods of research

Diabetes mellitus (DM) is one of the diseases with high mortality. According to the World Health Organization (WHO), between 1980 and 2018, the number of people suffering from

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diabetes increased from 108 million to 422 million. In low- and middle-income countries, the prevalence of diabetes is growing faster than in high-income countries [13]. Diabetes is a leading cause of blindness, kidney failure, heart attacks, stroke, and lower limb amputation.

From 2000 to 2020, premature mortality from diabetes increased by 5%. It is estimated that in 2019, diabetes was the direct cause of 1.5 million deaths. In addition, in 2016, 2.2 million deaths were due to high blood glucose.

Healthy eating, regular physical activity, maintaining a healthy weight, and abstaining from tobacco use can prevent or delay the onset of type 2 diabetes.

Diabetes is treatable, and diet, physical activity, medication, regular monitoring, and treatment of complications help prevent or delay the onset of its effects.

In the practice of diabetes treatment and research, the term “blood sugar level” is defined, which means a condition of a person with a level of glucose concentration, mmol / l> 4.0 <6.1 is the norm and <> 7.8 <11.1 is a violation of tolerance to glucose. Thus, the real number of patients with diabetes in Ukraine should be 3-4 million people [2].

This provision puts forward the urgent task of the mass survey of the population in order to diagnose diabetes and determine effective drugs. However, insufficient development and reform of the health care system in Ukraine (especially in rural areas), poor equipment of endocrinologists with portable measuring equipment, the variety of types of diabetes, its diagnoses, the cost of drugs and more make it difficult to solve the problem. Therefore, one of the ways to improve the efficiency and effectiveness of endocrinologists may be to equip them with another tool - an information system that can perform two main functions: as a guide and decision support systems in the formation of plans for medical treatment of diabetes. Such a system can be installed on a laptop, which is especially important when conducting research during field trips.

The decision support system should allow for operational surveys of the general population and solve the problem of optimizing the cost of drugs. From an economic point of view, there is an opportunity to save extra money on a doctor’s call to a remote area, increases the ability to detect and prevent more patients.

Interest in expert systems as a variety of artificial intelligence systems is not waning, although the emergence of the first “real” medical expert systems date back to the early 70’s. Over the years, considerable experience has been gained in the development of expert systems (medical systems occupy one of the key positions among them), summarized in numerous articles, monographs and reference books. However, today the construction of effective expert systems for various purposes, including medical systems, remains a task relevant and still far from complete. Only the first segment of the long way has been covered, the difficulties of overcoming which are due, on the one hand, to the extreme complexity of the object modeling using expert systems - the human brain, and on the other hand – the high complexity of tasks relied on by medical expert systems.

Experimental studies of human mental activity have shown that 85% of the time is spent on creating conditions for the actual mental work, which is reduced to finding the necessary information, printing, plotting and other “stationery” work, which, in principle, can be performed by various technical devices. This conclusion can be applied to the work of a medical researcher or practitioner.

In a broad sense, the medical information system means a form of organization of activities in medicine and health care, which combines physicians, mathematicians, engineers, technicians with a set of technical means that provide collection, storage, processing and issuance of medical information of various profiles in the process of solving certain problems of medicine and health care [14].

In a narrow sense, a medical information system is a set of technical means and mathematical software designed to collect, analyze medical and biological information and issue results in a user-friendly form.

The creation of a medical information system has several goals:

- improving the quality of medical staff and health care facilities by organizing the processing of medical information (to the appropriate level of technical means used), including the improvement of management and planning processes;
- facilitation of medical workers' work, elimination of labor-consuming and inefficient processes of manual processing and analysis of medical data;
- ensuring effective exchange of information with other information systems.

In [1] the most general tasks of MIS in clinical institutions are described:

- objectification of interpretation of research results (according to some data, false positive or false negative, clinically insufficient or incorrectly interpreted results of X-ray, electrocardiological and laboratory researches lead to misdiagnosis in 31% of cases);
- automation of information processing at the stage of preliminary work of medical personnel on diagnosis and development of tactics of treatment (the doctor makes the final decision concerning diagnostics and treatment of the patient);
- automation of laboratory researches: biochemical, electrophysiological, X-ray radiological and others;
- creation of databases (banks): collection and storage of information about each patient for further analysis of the material, organization of processing of this information by appropriate mathematical software (including database management systems (DBMS));
- creation of knowledge bases: acquisition of experts' knowledge in the medical field and public health services necessary for expert systems development of diagnostics, treatment, and rehabilitation, professional inspection, examination, planning, and management;
- streamlining the flow of information within the institution (organizational management tasks, personnel tasks, logistics, statistical reports, evaluation of hospital departments on some in-depth indicators and others).

Virtually all of these problems can be effectively solved with the use of expert systems - one of the progressive areas of modern computer technology, which is essentially based on the ideas of creating artificial intelligence (AI).

The development of any medical information system should be based on some principles of building systems in general (the study and formulation of these principles is engaged in systems engineering, also called "large systems theory", "complex systems theory").

The principle of formulating the purpose of the system is that the purpose of construction and use of a particular system should be clearly formulated, the whole sequence of tasks and conditions should be presented, the implementation of which will lead to the goal.

The principle of new tasks is that most of the new tasks solved by the system would be fundamentally unfeasible or ineffective in solving them without MIS. Adhering to this principle, the development of MIS should lead to increased efficiency in tasks' solving.

The principle of an integrated (systemic) approach involves careful coordination of tasks and a set of technical means. The components of the MIS must meet a certain set of requirements (accuracy of equipment, methods of data presentation, types of computing devices, etc.) that provide the most efficient solution for tasks.

The principle of projects' solutions typification is to use the positive experience gained in the development of analogues that have been successfully tested in practice.

The principle of continuous development of the system means that the MIS project should provide opportunities for the modernization of the system in order to increase its efficiency.

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The principle of document automation involves the use of unified documents - standardized medical histories, epicrisis of discharge and posthumous. The introduction of this principle significantly increases the efficiency of the system, facilitates the implementation of the remaining non-automated manual operations for data collection.

The principle of a single and flexible information base involves the efficiency of operating data stored in information arrays – this principle is usually implemented using mathematical databases, which allows to effectively operate these databases (DBMS).

The principle of completeness of tasks and work programs is realized by creation of the applied programs packages (APP) combining tasks on the basis of uniform methods of the decision and interdependent information.

In the development of MIS, the use of knowledge possessed by modern medicine is of paramount importance. In practice, this means constant consultations with leading specialists (clinicians, health care organizers, hygienists, etc.), expert evaluations of all decisions related to medical issues or health care organization at each stage of the system.

When developing a specific diagnostic or prognostic system, it is necessary to consistently address a number of issues:

- the choice of the target and definition of system's main purpose;
- selection of system's structural scheme;
- preservation of nosological forms list and collection of statistically reliable information on symptomatology of states;
- construction of a decisive rule for solving problems in medical information evaluation and issuance of conclusions on diagnosis and prognosis, i.e. development of system's algorithmic basis [1, 10, 11].

The main problems that arise in the development of MIS can be represented as follows:

Development of such documents forms that are convenient for medical information fixation, information's searching and processing. Issues of medical documents forms standardization. Data classification. Development of medical information language (use of medical terminology).

The choice of rational methods of organizing medical data that provide effective search, storage, recovery, retrieval of information from machine memory.

Development of a set of software and hardware that provides data transmission within the system, information exchange with external systems, information analysis (graphic information, laboratory data, etc.).

Implementation and operation of MIS. Methodical instructions on system implementation, the procedure for filling in standardized medical documents, development of instructions for MIS operation.

It is worth remembering that the introduction of any kind of MIS always affects the scope of activities of the management of the medical institution, doctors, paramedics. Therefore, the finalized and repeatedly tested solutions (documents, programs, methods of collecting, processing and transmitting information) should be put into operation

The effect of the implementation and operation of the information system must be clear and accessible.

The set of data and knowledge used by the system in solving problems is the information base of the system. An integral part of the information system are also ways of presenting information, its storage and processing.

The development of the information base includes the following section:

- determination of the set of indicators used in this MIS;
- classification of information, creation (selection) of classifiers and dictionaries of the system;
- coding of information;

- creation of standardized and uniform for the system forms of documents;
- selection of information links between sections of the system;
- assessment of volumetric-temporal characteristics of information;
- organization of information arrays;
- determining ways to control information.

Information support of MIS consists of: medical histories, extracts from medical histories, epicrisis, standardized examination cards, diagnostic and informative assessments of indicators and conditions ("medical memory"), criteria for the effectiveness of examination and treatment, catalog of medical concepts and terms.

MIS are characterized by the presence, as a rule, of larger amounts of data and knowledge. Data and knowledge processing is reduced to three main stages. At the first stage, the elements of information are placed in certain structures – databases (DB) and knowledge bases (KB). In the second stage, DB and KB are streamlined: their structure changes, the order of information placement changes, the nature of the relationships between information elements changes. At the third stage DB is operated: search of the necessary information, decision-making, editing of databases and knowledge.

Research results

The current state of development of computer diagnostic systems in endocrinology can be characterized by the fact that they are aimed primarily at solving problems of collecting and processing anamnestic data.

Analysis of the existing functional structures of such systems allows to identify their main three indicators:

- assessment of information symptoms;
- processing of results of symptoms assessment according to their diagnostic algorithm;
- decision making (diagnosis, choice of treatment method).

According to the latter indicator, the main difficulties are due to the fact that the doctor usually lacks not so much the ability to collect anamnestic information and objective data about the patient, as experience in understanding (processing) and evaluating these data to determine the diagnosis. This is especially true when choosing a treatment plan. In this case, of great interest are the ideas of modeling the functions of the doctor's intelligence in the process of processing, and evaluation of medical information using a personal computer.

At present, this problem is far from being solved, but from the point of view of the cybernetic approach it can be represented by two components: the model of the doctor's memory ("medical memory") and the model of the doctor's logical reasoning. The first model is based on medical knowledge in the form of lists of diagnoses of diseases, their corresponding signs, connections between them, etc. The second component refers to the process of reference to "medical memory" (the input data for such a link are the observed symptoms). In this sense, "medical memory" is primary, and logical reasoning is secondary. Currently, as "instrumental methods" that contribute to the logical conclusion of the doctor, widely used tabular decision-making algorithms based on calculations using tables and probabilistic approaches based on the Bayes's strategy or using the method of Wald's sequential statistical analysis.

This study considers methods of decision support as promising, which are based on such operations on knowledge as: pairwise comparison, ranking and classification. As a result of such operations, a number of decision-making strategies can be formulated, including the following:

- adaptive utility strategy: the decision-maker (DM), represented by the doctor, allegedly "summarizes" the assessments of alternatives by criteria in one image, and then compares the alternatives;

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- adaptive differences strategy: DM seems to "summarize" the differences in the evaluation of alternatives by criteria and choose the best alternative;
- exclusion strategy by aspects: DM excludes from consideration alternatives that do not meet the requirements of at least one aspect (criterion);
- requirements exclusion strategy: DM excludes alternatives that do not meet the minimum requirements by all criteria [15, 16].

Consider the main content of the procedures of ranking and pairwise comparison of alternatives, which can be different drugs for the treatment of diabetes.

Ranking is a procedure for arranging alternatives performed by DM (endocrinologist) while considering two situations [15, 17, 18]:

Among the alternatives there are no identical comparable indicators, i.e. there are no equivalent alternatives. Which suggests the existence of a strict order that has the properties of transitivity (if $A_i > A_j$, $A_j > A_k$, then $A_i > A_k$) and combination (for any two alternatives, either or $A_i > A_j$, or $A_j > A_i$). As a result of comparing all alternatives in a relatively strict order, an ordered sequence of type $A_i > A_j \dots A_n$, is obtained, where the alternative with the first number is the best of all alternatives, the alternative under the second number is slightly less better than the first, but better than all the others..

Alternatives may be equivalent. This means that in addition to the strict order relationship, an equivalence relationship (non-strict order relationship) is possible between some alternatives. The ranking results in a sequence of the following type: $A_1 > A_2 > A_3 \sim A_4 \sim A_5 \dots > A_{n-1} \sim A_n$. In this sequence, the alternatives A_3, A_4, A_5 are equivalent to each other, and alternatives A_{n-1} and A_n to each other.

In this study, the task of choosing a study method of multicriteria ranking of alternatives as indicators of the attractiveness of alternatives was set, which will be a tool for modeling "clinical thinking" and logical reasoning of an endocrinologist. As such a choice was chosen a modern method – the method of analysis of hierarchies (MAI) [18, 19].

MAI is a systematic procedure for the hierarchical presentation of the elements that define the essence of the problem. The method consists in decomposing the problem into simpler components and further processing the sequence of DM judgments using pairwise comparisons. As a result, the relative degree (intensity) of interaction of elements in the hierarchy can be expressed. These judgments are then quantified. MAI includes procedures for synthesizing multiple judgments, prioritizing criteria, and finding alternative solutions. This approach to solving the problem of choice is based on the natural ability of people to think logically and creatively, to determine events and establish relationships between them.

At the first level of the hierarchy there is always one top – the purpose of the study. The second level of the hierarchy is the factors that directly affect the achievement of the goal. In this case, each factor is represented in the constructed hierarchy by a vertex that connects with the vertex of the 1st level. The third level consists of factors on which the vertices of the 2nd level depend, and so on. This process of building a hierarchy continues until all the main factors are included in the hierarchy or at least for one of the factors of the last level it is impossible to directly obtain the necessary information.

After completing the construction of the hierarchy for each parent vertex is an assessment of the weights that determine the degree of its dependence on the vertices that affect it at a lower level. The method of pairwise comparisons is used for this purpose.

The considered modification is intended for definition of structure of the investigated object. The authors describe the method of pairwise comparisons, in particular the modification by T. Saati. In this modification, as well as in a classical variant of a method of pairwise comparisons, comparison of the investigated factors among themselves is made. Moreover, in this method, the factors are compared in pairs in relation to their impact ("weight" or "intensity") with a common characteristic for them.

Suppose that in a specific task it is necessary to determine the composition of an object. And let $A_1, A_2, \ldots, A_n$ be the main factors that determine the composition of the object. Then the matrix of pairwise comparisons is filled in to determine the structure of the object (Table 1) [15, 20].

Table 1. Matrix of pairwise comparisons

	A_1	A_2	…	A_n
A_1	1	a_{12}		a_{1n}
A_2	a_{21}	1		a_{2n}
…			…	
A_n	a_{n1}	a_{n2}		1

If to indicate the share of the factor A_i by w_i, then an element of the matrix $a_{ij} = w_i / w_i$. Thus, in the proposed variant of application of the method of pairwise comparisons, it is not the magnitude of the difference in the values of the factors that is determined, but their ratio. At the same time it is obvious $a_{ij} = 1 / a_{ij}$. Therefore, the matrix of paired comparisons in this case is a positive definite inversely symmetric matrix having a rank of 1.

The job of experts is to conduct a pairwise comparison of factors $A_1, \ldots, A_n$ fills in the pairwise comparison table. It is important to understand that if $w_1, w_2, \ldots, w_n$ are unknown in advance, then pairwise comparisons of elements are made using subjective judgments, which are quantified on a scale, and then solves the problem of finding component *w*.

In such a statement, the task of solving the problem is to find a vector (w_l, w_2, w_n). There are several different ways to calculate the desired vector. Each of the methods allows in addition to directly finding the vector to answer some additional questions. The expert comparing n factors actually makes not n (as it happens when filling out the usual questionnaires) comparisons, but $n^*(n-1)/2$ comparisons. But that's not all. In fact, given the ratio $a_{ij} = a_{ik}{}^* a_{jk}$ valid for all index values k, conducts indirect comparison of factors A_i, A_j through appropriate comparisons of these factors with the factor A_k. The expert makes much more comparisons than even the first estimate of $n^*(n-1)/2$ shows. Thus, each cell of the matrix of paired comparisons actually contains not one number (the result of direct comparison), but an integer vector (taking into account all indirect comparisons through comparisons with other factors). Taking into account these additional comparisons can significantly increase the reliability of the results and significantly reduce the number of required experts [15, 21].

One of the main methods of finding the vector *w* is based on one of the statements of linear algebra.

Obviously, the vector sought is the eigenvector of the pairwise comparison matrix, which corresponds to the maximum eigenvalue $(l\max)$. In this case, one of the large number of existing algorithms $(l\max)$, and then it is enough to solve the vector equation $A^* w = 1$ and to find $l\max^* w$. It is known from linear algebra that in a positive definite, inversely symmetric matrix having a rank equal to 1 – the maximum eigenvalue is equal to the dimension of this matrix (i.e. n). When making comparisons in a real situation, the calculated maximum eigenvalue $(l\max)$ will differ from the corresponding eigenvalue for an ideal matrix. This difference characterizes the so-called inconsistency of the real matrix. And, accordingly, characterizes the level of confidence in the results. The greater this difference, the less trust. Thus, this modification of

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the method of pairwise comparisons contains internal tools to determine the quality of the processed data and the degree of confidence in them. This feature of this technique favorably distinguishes it from most methods commonly used in the study.

Another approach in determining the vector w is as follows. The elements of the matrix of pairwise comparisons are summed by rows (for each value the sum of $a_i = a_{i1} - a_{i2} + a_{in}$ is calculated). Then all a_i are normalized so that their sum is equal to 1. As a result, we obtain the desired vector w. In this way $w_i = a_i/(a_1 + a_2 + ... + a_n)$.

This method of finding the vector w is much easier to implement, but it does not determine the quality of the original data.

The above description of the method is a development of T. Saati and his group, for all its advantages, this version is not without some disadvantages.

As we have already noted, the considered version of the method of pairwise comparisons allows to determine the quality of the original data. And Saati recommends at badly coordinated matrix or to change experts, or to find additional data, or to solve a problem by other method. In the case where the problem is not in the experts, but in the object of study. The inconsistency of the pairwise comparison matrix can be caused by at least two factors:

(a) personal qualities of the expert;
(b) the uncertainty degree of evaluation object.

Therefore, the inconsistency of the matrix acts as a result of the interaction of these factors. And, therefore, ignoring such a structure of reasons for inconsistencies leads to the fact that the measures recommended to increase the consistency of the matrix are carried out not only in situations where greater inconsistency is a consequence of low professionalism of the expert, but also in cases where such ambiguity is an integral part of the object under study, which usually occurs when studying the changing market. In the latter case, it is necessary to study the object as it is with all its inherent uncertainties [15, 22].

In order to highlight the component of inconsistency, which is determined by the expert, it is necessary to slightly change the view of the object and the expected result of processing the original data.

First of all, it is necessary to recognize that the object of study is characterized by some uncertainty. And, as a consequence, to expect an unambiguous result would not be reasonable. The answer should be formulated in the language of probability, i.e. either in the form of confidence intervals, or in the form of the probability of realization of the result of interest, or in the form of mathematical expectation of the result and its variance, etc.

To construct the algorithm of comparisons matrix processing, representing results in the necessary form, the above-stated properties of a comparisons matrix allow: each element of a matrix is, as a matter of fact, the whole vector consisting of various comparisons (direct and indirect) of the corresponding factors. Given this property, it is possible to compare its mean value and its standard deviation (SD) for each element of the matrix. Then, using the methods of stochastic modeling, we can build a sequence of comparison matrices, each of which will correspond to one of the possible options for the implementation of relations characteristic of this object within its ambiguity and competence of its evaluating experts.

Defining for each such matrix the vector w, we obtain a fairly large set of vectors representing possible realizations of the object's structure in accordance with its ambiguity and the competence of its evaluating experts. By perceiving a set of vectors constructed in this way as a statistical sample, it is possible to obtain the desired result in a form that corresponds to a particular case. In particular, it is easy to obtain the average values of the components of the vector w and the values of their SD.

The values of SD obtained in this way are a consequence of inconsistency degree of the pairwise comparisons matrix. The greater the inconsistency, the greater the SD value.

By filling in the comparison matrix, the expert can fill it only above the main diagonal. The rest of it is calculated taking into account the inverse symmetry. But if the expert fills not only the upper but also the lower part of the matrix, then there is additional information that allows to assess the degree of personal competence of the expert.

When comparing factor A_i with factor A_j the expert will evaluate a_{ij}, and when comparing factor A_j with factor A_i the expert will evaluate a_{ji}. In this case, the mutual ratio of these estimates is not affected by the state of the studied industry, but only the professionalism of the expert, so equality $a_{ji} = 1/a_{ij}$ must be observed. Thus, the deviation of a_{ji} from $1/a_{ij}$ is a random variable and its SD corresponds to the level of professionalism of the expert. Thus, given the properties of the variance, it is possible to remove from the estimates of comparisons matrix elements of the unprofessionalism expert influence and as a result reduce the SD components of the vector w. As a result, the vector w, or rather the average values of its components and their SD, will correspond to this object and adequately describe it.

A scale of relative importance was developed by T. Saati's for subjective pairwise comparisons (Table 2).

Table 2. Scale of relative importance

Intensity of relative importance	Definition	Explanation
0	Incomparable	The expert finds it difficult to compare
1	Equal importance	Equal contribution of the two activities to the goal
3	Moderate advantage of one over the other	Experience and judgment give a slight advantage of one activity over another
5	Significant or strong advantage	Experience and judgment give a strong advantage of one activity over another
7	A very significant advantage	One of the activities is given such a strong advantage that it becomes almost significant
9	A very strong advantage	The obvious advantage of one activity over another is most strongly confirmed
2, 4, 6, 8	Intermediate decisions between two adjacent judgments	Used in a compromise case
Inverse values of the above numbers	If when comparing one type of activity with another one of the above numbers is obtained (for example, 5), then when comparing the second type of activity with the first we get the inverse value (i.e. 1/5)	

The choice of scale was determined by the following requirements:

(a) The scale should make it possible to capture the difference in people's feelings when they make comparisons, to distinguish as many shades of feelings that people have;

(b) The expert must be sure of all the gradations of judgments at once.

As shown by the works of the author T. Saati in comparison with this scale with 28 other scales proposed by various researchers, this scale and its minor modifications are better than all other scales.

This method of pairwise comparisons and this scale are extremely well adapted to the peculiarities of human information processing. However, this scale is not mandatory.

The next step is to analyze the expert assessments aimed at solving two main tasks: checking the consistency of expert opinions (or classification of experts, if there is no consistency) and

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obtaining a generalized expert assessment within the agreed group. The results of expert statements can take various forms: words, numbers, rankings, partitions, fuzzy advantages, etc. An important place among them is occupied by pairwise comparisons. For example, the method of analysis of hierarchies is based on procedures of pairwise comparison of elements (alternatives or criteria) of the problem of decision-making using subjective judgments, which are quantified on a scale of relative importance. As a result, a matrix A is formed with the properties of inverse symmetry of the following form (1):

$$A=\begin{pmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nm} \end{pmatrix} \text{ or } A=\begin{pmatrix} 1 & a_{12} & \dots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & 1 \end{pmatrix}, \tag{1}$$

where $a_{ij} = 1/a_{ji}$, $i=\overline{1,n}$, and $j=\overline{1,n}$ belong to the row and column, and n – is the number of compared elements: a_{ij} – some positive numbers.

Next, the values of this matrix form a set of local priorities, which express the relative impact of many elements of one level of hierarchy on the element of the level of hierarchy adjacent to the top. To do this, the values of the eigenvector of the matrix are calculated, which in the process of normalization leads to the desired vector (set) of local priorities. The task is to determine the consistency of local priorities, because the matrix (1) in the general case is inconsistent.

There is a number of ways to determine the eigenvalues of an inversely symmetric matrix (1), which give different results in terms of determining the consistency (inconsistency) of local priorities.

This is especially true of relatively large matrices (1) with the number of comparable elements $n \geq 7$ in which it is often difficult to achieve a high level of consistency. However, the level of coherence must be commensurate with the risk associated with working with inconsistent results. For example, when comparing the effects of drugs on the body, it is necessary to have a very high level of consistency.

The paper recommends and considers in descriptive form four ways to find eigenvectors for an inversely symmetric matrix (1). We formalize their implementation in advance with the help of the following schemes – priority vectors (2), (3), (4) and (5):

way 1

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nm} \end{pmatrix} \Rightarrow \left\{ \begin{matrix} a_{11}+a_{12}+\dots+a_{1n}=A_1 \\ a_{21}+a_{22}+\dots+a_{2n}=A_2 \\ \dots\dots\dots\dots\dots\dots \\ a_{n1}+a_{n2}+\dots+a_{nm}=A_n \end{matrix} \right\} \Rightarrow \{A=A_1+A_2+\dots+A_n\} \Rightarrow$$
$$\Rightarrow \left\{ \frac{A_1}{A}=\omega_1^{(1)}, \frac{A_2}{A}=\omega_2^{(1)}, \dots, \frac{A_n}{A}=\omega_n^{(1)} \right\} \Rightarrow \left(\omega_1^{(1)}, \omega_2^{(1)}, \dots, \omega_n^{(1)}\right) \tag{2}$$

way 2

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nm} \end{pmatrix} \Rightarrow \left\{ \begin{matrix} a_{11}+a_{12}+\ldots+a_{1n}=B_1 \\ a_{21}+a_{22}+\ldots+a_{2n}=B_2 \\ \dots\dots\dots\dots\dots\dots \\ a_{n1}+a_{n2}+\ldots+a_{nm}=B_n \end{matrix} \right\} \Rightarrow \left\{ B^{-1}=B_1^{-1}+B_2^{-1}+\ldots+B_n^{-1} \right\} \Rightarrow \tag{3}$$

$$\Rightarrow \left\{ \frac{B_1^{-1}}{B^{-1}}=\omega_1^{(2)}, \frac{B_2^{-1}}{B^{-1}}=\omega_2^{(2)}, \ldots, \frac{B_n^{-1}}{B^{-1}}=\omega_n^{(2)} \right\} \Rightarrow \left(\omega_1^{(2)}, \omega_2^{(2)}, \ldots, \omega_n^{(2)}\right)$$

way 3

$$\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{pmatrix} \Rightarrow \left\{ \begin{matrix} a_{11}+a_{12}+\ldots+a_{1n}=C_1 \\ a_{21}+a_{22}+\ldots+a_{2n}=C_2 \\ \dots\dots\dots\dots\dots\dots \\ a_{n1}+a_{n2}+\ldots+a_{nn}=C_n \end{matrix} \right\} \Rightarrow$$

$$\Rightarrow \left\{ \begin{matrix} \frac{a_{11}}{C_1}=C_{11}, \frac{a_{12}}{C_1}=C_{12}, \frac{a_{121}}{C_1}=C_{1n} \\ \frac{a_{21}}{C_2}=C_{21}, \frac{a_{22}}{C_2}=C_{22}, \ldots, \frac{a_{12}}{C_2}=C_n \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ \frac{a_{11}}{C_1}=C_{n1}, \frac{a_{12}}{C_1}=C_{n2}, \ldots, \frac{a_{12}}{C_1}=C_{nn} \end{matrix} \right\} \Rightarrow \left\{ \begin{matrix} \left(C_{11}+C_{12}+\ldots+C_{1n}\right)/n=\omega_1^{(3)} \\ \left(C_{21}+C_{22}+\ldots+C_{2n}\right)/n=\omega_2^{(3)} \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ \left(C_{n1}+C_{n2}+\ldots+C_{nn}\right)/n=\omega_n^{(3)} \end{matrix} \right\} \Rightarrow \tag{4}$$

$$\Rightarrow \left(\omega_1^{(3)}, \omega_2^{(3)}, \ldots, \omega_n^{(3)}\right)$$

way 4

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nn} \end{pmatrix} \Rightarrow \left\{ \begin{matrix} \sqrt[n]{a_{11}\cdot a_{12}\cdot\ldots\cdot a_{1n}}=d_1 \\ \sqrt[n]{a_{21}\cdot a_{22}\cdot\ldots+\cdot a_{2n}}=d_2 \\ \dots\dots\dots\dots\dots\dots \\ \sqrt[n]{a_{n1}\cdot a_{n2}\cdot\ldots\cdot a_{nn}}=d_n \end{matrix} \right\} \Rightarrow d_1+d_2+\ldots+d_n=D \Rightarrow \tag{5}$$

$$\Rightarrow \left\{ \frac{d_1}{D}=\omega_1^{(4)}, \frac{d_2}{D}=\omega_2^{(4)}, \ldots, \frac{d_n}{D}=\omega_n^{(4)} \right\} \Rightarrow \left(\omega_1^{(4)}, \omega_2^{(4)}, \ldots, \omega_n^{(4)}\right)$$

Next, it is necessary to analyze the considered methods (2)-(5) in terms of ensuring the degree of consistency of the components of thelocal priorities vectors.

The consistency of a positive inversely symmetric matrix is equivalent to the requirement of equality of its maximum eigenvalue $\lambda_{\max}$ with n and the deviation from consistency is determined by the consistency index $ИП = \frac{\lambda_{\max}-n}{n-1}$. The consistency index (CI) generated randomly by an inversely symmetric matrix with a certain number of compared elements n is called a random index (RI). The ratio of the value of CI to RI for a matrix of a certain order is called the ratio of consistency (RC).

RC values $\geq$ 10% are considered acceptable. The consistency index in each matrix can be obtained as follows: first, each column of judgments is summed, then the sum of the first column is multiplied by the value of the first component of the normalized priority vector, the sum of the second column is multiplied by the second component, and so on. Then the obtained numbers are summed. Thus get the maximum eigenvalue (6):

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$$\lambda_{\max}\left(\sum_{j=1}^{n1} a_j\right)\omega_1 + \left(\sum_{j=1}^{n2} a_j\right)\omega_2 + \ldots + \left(\sum_{j=1}^{nn} a_j\right)\omega_n \qquad (6)$$

Inference

1. The study analyzed existing medical decision support systems and found that existing systems are aimed at providing management, economic and in some cases medical practice in the collection and processing of anamnestic data, including dental, ophthalmological, radiological, anesthesiological, resuscitation. Their main disadvantage is that they cannot be used for endocrinological practice, in particular for forecasting and developing a treatment plan for patients with diabetes.

2. Functional structures of existing medical information systems allow us to identify their main three indicators, including the information symptoms' assessment; processing the assessment results of symptoms according to their diagnostic algorithms, decision-making (diagnosis, choice of method of treatment). The authors of this study propose to develop recommendations for modeling the functions of the doctor's intelligence in the process of processing and evaluation of medical information using a personal computer, which will improve the operation of existing medical information systems. In the process of decision support, the authors consider and propose to apply such operations on knowledge as: pairwise comparison, ranking and classification. Which allowed to formulate a number of decision-making strategies.

3. The algorithms proposed by the authors to create a medical decision support system are based on the method of multicriteria ranking of alternatives, which is a tool for modeling "clinical thinking" and logical reasoning of an endocrinologist. Unlike existing medical information systems, it will not only collect, store and process information about patients, but also increase the efficiency of endocrinologist decisions regarding the prediction and development of a patient treatment plan.

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