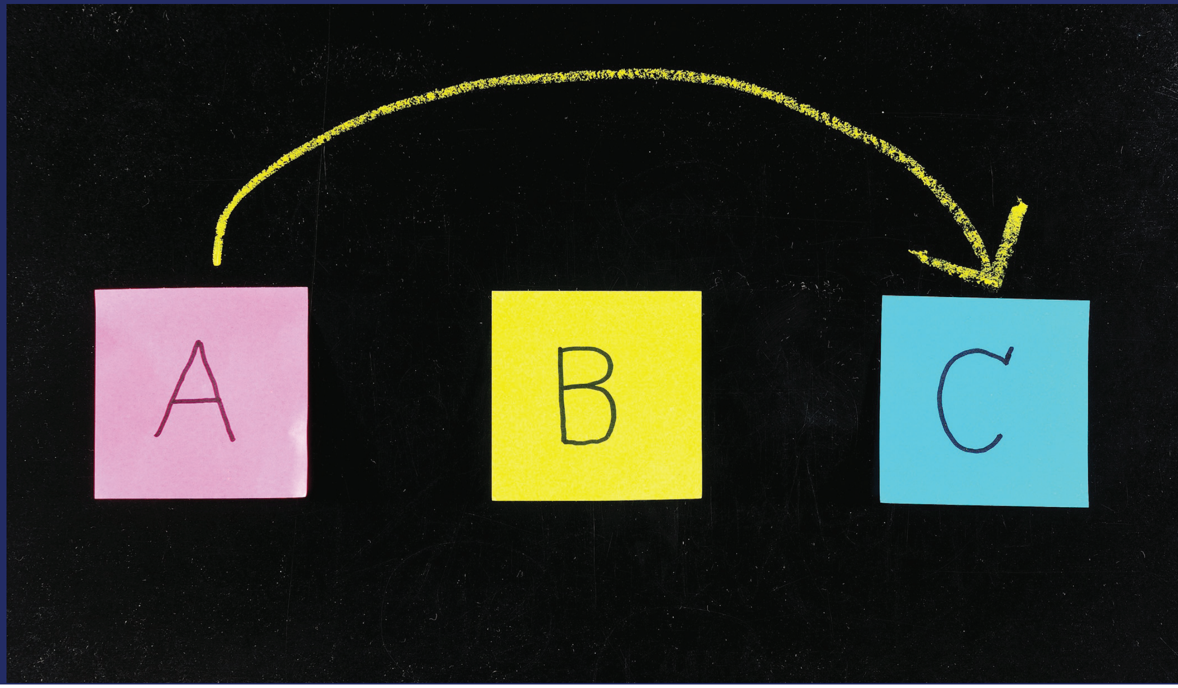
Textbook explains bases of medical informatics in the light of system approach. Authors discuss problems of usage of system analysis in medical researches, basic principles of biological, medical and physiological cybernetics, application of decision-making methods in medicine. Authors propose system analysis, cybernetics and decision-making as the basis for training program for students of medical universities.



Yevheniia Radzishevska
Olena Vysotska
Andrey Solodovnikov

Decision Making Theory for Doctors Training at Medical Universities

Radzishevska Yevheniia - Associate Professor at the Department of Medical and Biological Physics and Medical Informatics of KhNMU; Vysotska Olena - Professor at the Department of Biomedical Engineering of KhNURE; Solodovnikov Andrii - Senior Lecturer at the Department of Medical and Biological Physics and Medical Informatics of KhNMU.

978-613-8-38837-1

LAP LAMBERT Academic Publishing

Yevheniia Radzishevska
Olena Vysotska
Andrey Solodovnikov

Decision Making Theory for Doctors Training at Medical Universities

Yevheniia Radzishevska
Olena Vysotska
Andrey Solodovnikov

Decision Making Theory for Doctors Training at Medical Universities

LAP LAMBERT Academic Publishing RU

Imprint
Any brand names and product names mentioned in this book are subject to trademark, brand or patent protection and are trademarks or registered trademarks of their respective holders. The use of brand names, product names, common names, trade names, product descriptions etc. even without a particular marking in this work is in no way to be construed to mean that such names may be regarded as unrestricted in respect of trademark and brand protection legislation and could thus be used by anyone.

Cover image: www.ingimage.com

Publisher:
LAP LAMBERT Academic Publishing
is a trademark of
International Book Market Service Ltd., member of OmniScriptum Publishing Group
17 Meldrum Street, Beau Bassin 71504, Mauritius

Printed at: see last page
ISBN: 978-613-8-38837-1

Radzishevska Yev., Vysotska O., Solodovnikov A.

Decision making theory for doctors training at medical universities

Introduction

Having subject to own professional peculiarities every specialist in a varying degree meets the difficulties of decision making. However there are few fields for human activity where it is possible to apply decision making process as ordinary and basic professional skill. Medical activity being sequence of diagnosing and treatment is the typical representative of such field. Methods of decision making are multipurpose and universal though their successful application substantially depends on professional qualification of the specialist who must have exact understanding of peculiarities of the system he studies and must know how to lay down the task. Uninterrupted development of informational technologies and improvement of technological and industrial base put the problem of decision making theory in medical field to advanced level. This fact become apparent in all the fields of medical science relating to the activity of medical establishments, for instance, in form of creation and implementation of specialized medical programs, telemedicine technologies and projects of integrated automatization for hospitals or clinics.

Taking into account the professional point of application - a human, his health and ill health - in our opinion, a triad from system analysis, cybernetics and decision-making should be the basic to training program for medical university students.

1. System analysis in medical researches

1.1. Essence and principles of the system approach

The appearance and development of the system approach was prepared by the progress of scientific researches. Studying these or those elements of living systems, physiologists have been always interested in their structures, considering it as a key to the understanding of the principles of the system functioning, in general. At this the subsequent division of a complicated system to more simple ones was applied. Such an approach supposes the more subtle detailed elaboration of the investigated object structure. By separate elements of a system, its structure and functions the efforts to understand all the complexity of a complex were undertaken.

Simultaneously the second method of investigation – integral, was developed which was applied when the inner construction of a system and the complex interconnection of its elements were not known or not enough known. At this only its “entrance”, through which the information enters from the outside world and “exit” – through which the system “passes” reactions, developed by it in the result of some unknown process of the information procession, are available. All the bases of study about conditional reflexes were laid in the result of experience, carried out by the means, known as a problem of a “black box”. Under the “black box” a system is meant where only input and output signals are available to the outside observer and the inner device isn't known. At this, it turns out that the set of important conclusions about the system behavior can be made, by means of observing only the reactions of output values at the change of input values. “Black box” is used in modern medicine. When a patient visits a doctor, then on the basis of complaints, anamnesis, check-up and initial examination data an assumption about the probabilistic diagnosis appears.

The system approach allows to reveal and explain mechanisms which provide the research object integrity, disclosing all the diversity of its connection and joining them by the unified theoretical basis.

The principle of the object integrity comes from the fact that the whole (for example, human's organism) possesses such quality which isn't possessed by any of its parts separately, for example the system of blood circulation. Such a feature is called the emergence (from eng. “emergent”)

The system approach requires the consideration of the investigated phenomenon or process (for example, digestion) not as a separate system, but as a subsystem of some supersystem of the higher level (human's organism). At the system approach the maximum possible quantity of connections is studied out in order not to omit essential connections and factors and to evaluate their efficiency.

Any object of the investigation can be represented as a subsystem of some system of higher rank (it leads to the problem of the system assignment and setting its margins) or as a system regarding the aggregate of subsystems of lower rank which are formed from elements (it leads to the problem of the choice of an initial element).

1.2. General notions of the systems theory. Systems and their features. System definition

The term “system” is used in different domains of science and technical science. For example, astronomers use the notion “sun system”, physiologists – “digestion system”, mathematicians – “system of equations”, etc. The general meaning of all these variants of the usage of the word “system” are united by the fact that it is accompanied by the notion of some order of the multitude of elements, the presence of some connection between elements.

System – is the aggregate (multitude) of elements between which there are connections (relations, interactions). This way, under a system not any aggregate is understood, but the ordered one. If to gather together (unite) all homogenous or inhomogeneous elements (medical equipment, patients, doctors, medicines), then it won't be the system, but more or less accidental mixture.

In other words, under the system the multitude of interacting elements is understood. The functioning of each element is subdued to the necessity of the system preservation in general. The separate elements of the system are linked to each other by cause-and-effect relations. It means that the change of one or several relations between elements leads to the change of other elements and relations. For example, the pathological change of the gall-bladder, pancreas and other elements of the stomach structure (gastritis) can evoke the pathology of a gastrointestinal tract. System elements in the frames of the systematic approach are considered, taking into account their "place" and functions within the whole.

Whether to consider this or that aggregate of elements as a system or not depends in many aspects on the researcher's aims and analysis precision which is defined by the possibility to observe and describe a system, for example, for a developer and a doctor the cardiologic diagnostic complex is a system and for a patient it is just the diagnostics means.

Signs which allow to distinguish a system from "non-system" are the following:

1) system as an aggregate of elements which can be considered as systems. Any initial system is the part of a more general system. For example, electrocardiograph can be considered as a part of diagnostic means of a hospital or part of diagnostic means of a city etc (as a system element can be a system itself);

2) the presence of integrative means which are peculiar to the system in general, but not peculiar to any of its elements separately are typical for a system. For example, the blood pressure can be measured by a device, but not by its separate parts (i.e. every system element separately doesn't possess the features which are peculiar to a system in general);

3) for the system it is typical to have the presence of essential connections between elements, i.e. the aggregate of separated and not connected parts isn't a system, (i.e. all the elements must interact between each other). All three signs are connected between each other and the presence of one of them leads to the presence of the other two signs.

An example of a system is the medical information system, which represents the complex of mathematical and technical means which provide the collection, storage, processing, analysis and the giving out of medical information in the process of the solution of medical tasks.

Human's organism is also a system. If to consider it on organ's level, then organs are separate elements. All organs are connected and form the comprehensive whole. Features of an organism in general are not peculiar to its separate organs (they have their own features).

Subsystem is the subset of interconnected elements, joint by some designated purpose.

The division of a system by subsystems and the division of subsystems by smaller ones can continue until 2 elements (minimum) united by the common feature or aim are left.

Any system can be presented as a union (composition) of subsystems of different levels and ranges.

Decomposition (division) of a system by subsystems can be carried out according to certain signs. The decomposition will be considered further in more details.

The division of a system by subsystems by their levels is called hierarchy.

"Structure" is the separate notion of the system theory.

System structure – is the partial ordering of system elements and relations between them according to some sign. In other words, structure is everything which puts in order the set of objects, i.e. the set of connections and relations between parts of the whole, necessary for the achievement of the aim. An example of structures: brain convolutions, faculty, state structure, crystal lattice of substance, microscheme. Crystal lattice of a diamond is a structure of inanimate nature; honeycombs, zebra's strips – structures of animate nature; lake is a structure of ecological nature; party (social, political) is a structure of the social nature, etc.

Structures can be of different types: linear (metro stations at one (non-circular) line in one direction; hierarchy: (structure of the higher educational establishment "rector – pro-rector – dean – head of the chair"); network (the organization of work during the construction of a building: some works, for example, the wall mounting, site improvement, etc can be done in parallel); matrix (structure of employees of the scientific research institute, working upon the same topic). In biology and medicine the structure is the morphologically and functionally homogenous part of the system, which is connected with other structures.

System structures are closely connected with the system environment – set of factors which influence the system from outside.

One of the basic notions of the system theory is the notion of a system element.

System element – is the part of system considered in every concrete research as the simplest one and which has the connection with other elements. This way under system elements objects, which execute the certain functions and not subject to further partition (in the frames of the set task), are meant.

There is no "element" in the absolute view and it doesn't exist outside the system. Here is one of the manifestations of the gnoseological approach: an element as the indivisible part can be considered only applied to the concrete system model. If to consider the model of another system, then the "element" of the previous model in this model won't be indivisible already. For example, from the point of view of an economical model of the society, a person can't be considered as an element, and from the point of view of a biological model a human is the complicated supersystem, which consists of the multitude of systems (nervous, musculoskeletal, blood circulation).

Each system can be represented as an element of the system of higher level. At the same time elements or groups of elements of this system can be considered as separate systems of the lower level. I.e. this refers to the hierarchy of systems. For example, organs can be considered as systems for elements – cells, and cells, in their turn, can be considered as systems which consist of elements – molecules, atoms, etc.

Living organisms can be considered at different level and in different planes of the system analysis. This way, the structure, elementary for the formation of a system of a higher level is simultaneously a system, formed from elements of the preceding level (Fig. 1).

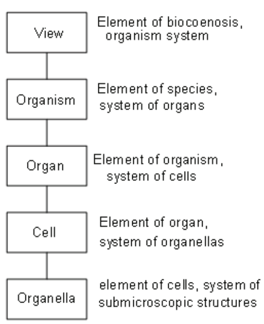


Fig. 1. Schematic image of hierarchy of the organization of a living object, each of which is both an element and a system.

A biological object in the context of a task being solved can be considered as a system as well as a subsystem and structure.

Besides the subdivision of systems according to their complexity, they are subdivided into determined and probabilistic ones.

For a completely determined system only one state is possible which probability is equal to 1. Such system doesn't possess the flexibility and can't adapt its features to environmental conditions.

Real systems are probabilistic-determinate, and their division for probabilistic and determinate ones is conditional: systems where the most of possible states have close values of probability, at this the sum of these probabilities is big enough (close to 1) belong to probabilistic ones; those systems at which the probability of one of possible states is bigger than the sum of probabilities of all the other states belong to determinate ones.

Methods, used for the investigation of probabilistic and determinate systems, in most of the cases are different. For example, for the research of determinate systems more often the apparatus of differential equations and theory of automated regulation is used and for the research of probabilistic systems an apparatus of the probability theory and methods of mathematical statistics is used.

In general, the research of all the types of systems is based, mainly, on the study of connections between elements, structures and subsystems of these systems.

Three types of connections are the basic ones:

- stochastic (correlation) – between random events and random values;
- functional – between structures, determined by the quantitative influence of the change of a characteristic of one structure on the change of a characteristic of another structure;
- causal – connection between events.

Let's explain the notion of the stochastic (correlation) relation. Let's remind that a random event is such an event which can take place or not at the given conditions, and the random value is the value which takes one of the multiple possible values in the experiment's course, at this the appearance of this or that value of this value is a random event.

For example, the flu contamination of a person who was in contact with an infectious patient is a random event.

If the value of one value strictly corresponds to the certain value of another one, then the dependency between them is called functional. For example, one can assume that in some limits the changes in blood pressure almost linearly depend on the dose of the prescribed medicine. In this case, knowing the approximate value of the corresponding structure coefficient, it won't be difficult for a doctor to prove this dose for a concrete patient.

The study of causal relation between events allows to build cause-and-effect schemes which connect some event which we take for an initial one with events which follow initial ones. A task in this case is, first of all, to mark out the most important events from other events (the limitation of cause-and-effect scheme), and second, to mark out events which can appear as a sequence of an initial event.

Cause-and-effect schemes are very perspective for the medical diagnostics, where an initial dysfunction (disease) can be considered as an initial event, and pathological events (symptom complex) connected with it can be considered as a sequence. The detection of such a symptom complex will testify about the presence of a disease with big probability.

1.3. Main features of systems and their peculiarities

The main features of a system are:

A) purposefulness – defines the system behavior;

B) complexity – many systems (including medical systems) are characterized by big quantity of inhomogeneous elements and connections. They depend on the multitude of components which are included to the system, their structural interaction, complexity and dynamics of external and internal connections. The level of complexity is a determinative feature of systems. The complexity has different meaning while applied to systems: structural, dynamic and calculating one. Usually the level of complexity is evaluated by the information quantity, necessary for the description of a real system. At this approach the evaluation of the system complexity is made through an observer. For example, for the neurophysiologist the brain is complicated and its adequate description demands a lot of information, for a butcher, brain is easy, as it needs to be separated from other types of meat. The system and task complexity is distinguished. The latter is called the computational complexity.

C) divisibility – a system consists of a set of subsystems and elements, distinguished according to a certain feature, which corresponds to concrete aims and tasks;

D) integrity – functioning of the multitude of system elements is subject to the unified aim. At this the system shows integrative and emergent features, i.e. all the features which are peculiar to a system in general, but absent in its separate elements;

E) diversity of elements and the difference in their nature – it is connected with their functional specificity and autonomy;

F) structuredness – is defined by the presence of set connections and relations between elements inside a system, distribution of elements of a system by levels and hierarchy;

F) system adaptivity lies in the capability of a system to preserve its functions at the influence of environment, i.e. to react to the environment so that to receive the favorable sequences for the system activity.

The less adaptive are non-living systems, more adaptive ones are biological (living) systems and technical systems, the most adaptive ones are social systems.

The adaptivity feature is closely connected with the system vitality which lies in the capability of a system to keep balance with the medium.

1.4. System analysis

The system analysis found the wide usage in different spheres of activity. It is applied for the modeling of the decision-making process in situations with big initial indeterminacy during the development of information systems, etc.

System analysis is applied when a task (problem) can't be presented and solved at once by means of formal mathematical methods, i.e. the big initial indeterminacy of a problem situation and multicriteriality of a task The application of the system analysis helps to organize the process of the common decision making, joining specialists in different knowledge domains.

The main method of a system analysis is the division into tasks which are more visible, better subject to the task investigation, during the preservation of integral (system) presentation about a research object and a problem situation.

System analysis means the system division into its subsystems with the intention to discover which of the subsystems and why it can (can't) execute aims (subaims)set in front of it. The notion “system” and “system aim” are inseparably connected between each other and the system analysis allows to reply to the question: why this system can or can't execute the set aim.

Not every analysis is a system analysis.

For example, organ-morphological analysis allows to carry out the classification of diseases according to external anatomic signs (signs of a structure, texture, form), according to organ features (cardio..., pulmo.., gaestro, etc.) and according to morphological signs (tumors, inflammations, structure's defects, etc). Essentially it is the structural analysis and its main analytical tool is statistic mathematical models. However, this analysis doesn't give the system classification of diseases. It is connected with the fact that the central notion of a “system” is a notion of “aim” and organ-morphological analysis can only show which elements the given object consists of. At this organ-morphological analysis doesn't explain for which aim it was meant and which is the role of each element in achievement of the given aim (an object “consist of... and meant for...”).

The most important chain of the system analysis is the formulation of a concrete aim. At this the aim of the system analysis is considered from the point of view of decision-making.

Under the aim the system assignment in the frames of a concrete task is meant. Most systems are multi-purpose, as for any system it is possible to compose several sets of limits, which lead to new aims and respectively to new tasks.

The aim setting allows to formulate many possible decisions, corresponding to the set aim, in the very beginning of the task solution.

For example, the task aim is the choice of optimal tactics of the treatment of patients with some complex of diseases and symptoms. Initially a lot of medicines are appropriate. Let's formulate the set of limits:

a) pharmaceutical form of the medicine – tablets.
b) intake mode – once a day.
c) the absence of side effects (taking into account contraindications)
d) price of not more than 100 grivnas.
e) the presence of a medicine in a pharmacy.

As it can be seen, the set of limits is significantly decreases the number of decisions.

Aims can be negative and positive. It is connected with the fact that problems can be of two types: some of them are connected with destruction, removal or limiting something, others – with the achievement or acquisition of something.

The solution of problems of the first type means the removal of the source of the dissatisfaction by the existing state of events (for example, a disease, noise) – these are negative aims. The solution of problems of the second type means the access to the source of satisfaction (for example, the purchase of the necessary medicine) – positive aims.

Positive and negative aims are relative notions. For example, the desire to get rid of a disease can be considered as a wish to be healthy. However, it is necessary to treat the similar identification with caution. If, for example, someone just doesn't want to undergo through the course of treatment, then the refusal from this treatment represents the negative aim. However, this unwillingness is connected with the fact that the treatment will be carried out by another, more effective means, then it is a positive aim.

Positive aim often supposes the presence of a negative aim, however the inverse proposition is wrong: the refusal from the undesirable isn't always equal to the achievement of the desirable. This way, for example, the release from toothache by means of the medicine intake or the extraction of a tooth won't be able to provide the full health for a human's organism. At the same time at the achievement of a positive aim – providing with the full health – is automatically achieved by releasing from toothache.

Efforts, aimed to the release from what is undesirable (negative aims), represent the retrospective solution of problems, oriented for the analysis of the past.

Efforts, aimed to the achievement of something which doesn't exist, but is necessary (positive aims) represent the prospective solution of problems, directed to the future.

The problem of the definition of a true aim of a system is a very important stage and it requires the right choice of the efficiency criteria. The most important requirements during the choice of an efficiency criterion are:

- representativeness (criterion must directly reflect the system aim, completely correspond to it, evaluate the efficiency of the main, not secondary task);
- criticality to investigated parameters (sensitivity of a criterion to changes of the investigated parameters);
- maximum possible simplicity (the introduction of secondary values to it can make an investigation complicated).

Concrete examples of the choice of the efficiency criteria won't be considered in this lecture.

This way, the main task of the system analysis is the search of ways to transform the complicated into the simple, division of a task hard for understanding for the set of tasks for which there are elaborated methods of investigation or decision. The division of complicated tasks for the simple ones in many cases allows to evaluate them not only qualitatively, but quantitatively and it is meant to raise the accuracy of the cognitive process. For the quantitative evaluation of the efficiency of the achievement of the system efficiency measures (criteria) are used.

The definition of system margins in general and environment. System in general includes all the systems, which supposedly, will influence the considered problem.

By the method of exception we refer to the environment all the systems which were not included to the system in general and which don't influence the considered problem.

If to include in the system in general few systems it will lead to extreme simplification and wrong decisions, if too many – it will complicate the description, there won't be enough of computational resources and we won't be able to find a solution. This way, the systems margins depend on the analysis aims, which require the accuracy of a result and resources which are at hand.

For example, if it concerns the treatment of one patient (solvable problem), a head doctor can be limited by the frames of a hospital. However, there can be factors which take the system limits beyond the hospital frame: complications which can't be treated in this hospital, negative attitude of relatives to the particular hospital, etc.

1.5. Methods of the system analysis

For the solution of a task regarding the division of the complicated by more simple components, the system analysis possesses the set of methods:

– expert-intuitive or non-formal methods: expert evaluations, scenarios, “brainstorming”;

– quantitative (formal) methods: mathematical, statistic;

– graphic methods: tree of aims, tree of interconnection;

– methods of modeling: imitation, game, models.

Let's briefly stop at basic types of expert-intuitive methods.

Method of expert evaluations is based on the receipt, procession and generalization of information of specialists (experts) which have high qualification and experience in the respective knowledge domain (activity).

Method of «brainstorming» is based on stimulation of creative productive activity of experts by means of general discussion of a concrete problem, which is regulated by certain rules. At this the evaluation of the quality of suggested ideas is “forbidden”, the time of one performance is limited and all the suggested ideas, etc are fixed.

Method of the scenarios creation is used more often during the solution of the task prediction. Scenario is a description of the probabilistic development of the process or state in the future. Usually three types of scenarios are drafted: optimistic, medium and pessimistic ones.

One of the main tasks of the building of the tree of interconnections, which belong to methods of the system analysis is to find the full set of system elements at each level of the analysis, definition of interconnection and subordination between them, and also the definition of a coefficient of the relative importance of elements of each level.

For example, for a medical problem, the structure of such a tree is defined in the result of the problem detailed elaboration towards the disclosure of its content, down to concrete normative values of separate indices. These indices (elements) characterize the measure of achievement of the set medical aim. The main aim at null (general) level is the problem aim itself (for example, to provide the necessary level of medical service). On the first level of aims the content of the main aim is disclosed, for what it is structured for separate elements (aims of the first order) by the principle of covering all trends of medical service. On the second level the further concrete definition of the main aim is realized. On the third level, and if necessary, on the fourth level concrete values of normative indices of the set medical aim are formulated. For example, such concrete norm can be the augmentation of the level of medical service in two times.

1.6. System analysis of pathogenesis and symptom complex of a disease

The complexity of an organism as a system is defined by the presence of huge quantity of connections on all levels in it. Directly or indirectly, all subsystems are connected between each other. Due to the presence of big quantity of interconnections in a healthy body there are no organs or group of cells which function separately and independently from each other. This way, for example, the breathing subsystem is connected with circulatory subsystem, which in its turn is connected with other subsystems, etc.

Human organism is an open system which is constantly influenced by outside factors: temperature, moisture, sun radiation, etc. Any changes of these factors evoke the adaptation changes in an organism itself and are called disturbing influences. Besides, an organism is connected with the environment energetically, as it consumes from outside all the necessary energy components (oxygen, fats, proteins, carbohydrate).

Apart from connections, directed from the medium to an organism, there are connections from an organism to medium. These connections are conditioned by functions of excretion of food waste, metabolic products, surplus of heat energy, surplus of liquid and salt.

The support of vitally important parameters of an organism in its tight limits favorable for it, the provision of adaptation features of an organism in the conditions of disturbing influences of environment, is provided by diverse negative feedbacks which duplicate each other to the certain extent. Keeping constant the most important parameters (homeostasis) is realized in an organism in a rather reliable way. The dysfunction or weakening of some connection influences the interaction between structures in more or less insignificant way, as other structures and other connections take for themselves the binding load.

Any pathological phenomenon which appears in an organ or tissue, by means of existing connections is the source of the disturbing influence towards other organs.

1.7. Principles of the system analysis of the interaction of organism structures

The obtaining of integral, complex presentation about an object is possible only in the result of the study of its structure components. The type of the system analysis, known as structural analysis, is the methodological basis of this fact. It was developed in the 60-70ies of the XX century by Douglas T. Ross. The main principle of the structural analysis is a structural element – object which executes one of elementary functions of a modeled object, process or phenomenon. The structural analysis assumes the investigation of a system by means of its graphic modeling representation, which starts from the general review and then is worked out in details, obtaining the hierarchy structure. For such an approach it is typical to use the formal rules of a record. The aim of the structural analysis lies in transformation of general, vague knowledge about the initial object domain into precise models. None of the particular subsystems of the human's organism can't completely provide the modeling of biological processes in an organism. That's why for the receipt of the integral picture of organs functioning it is necessary to take as the basis the description of one of chosen structures and integrate it with other ones. For medicine the methods of structural analysis are rather topical as they allow, in particular, to determine the pathogenesis of a disease. As it was mentioned above, the division of a system for subsystems is called decomposition.

Decomposition is the conditional technique and allows to represent a system in the form convenient of perception and to evaluate its complexity. In the result of a decomposition of a subsystem by certain signs separate structural elements and connections between them are distinguished. Decomposition is a method to avoid difficulties in understanding the system. The decomposition solution of an initial global task is the definition of a solution by means of the system of interconnected local tasks. At this it is meant that private or local tasks are less complicated than an initial task to the certain extent.

The main problem is the research of the structure interaction and their influence on each other in the process of the life support of an organism, its adaptation to current conditions of environment and reacting at different types of pathological processes.

Let's consider the rules of the research formalization of interaction between structures which don't depend on their level.

If changes Δx of x structure evokes changes Δy of y structure, then it can be expressed in the following way: $\Delta x \rightarrow \Delta y$, when an arrow points from the reason to the consequence. At this if the increase of x value results in the increase of y value, then above the arrow the sign "plus" is placed: $\Delta x \xrightarrow{+} \Delta y$. For the simplification of the equation it is possible not to put the sign Δ.

If it is known that during the change of x for one unit, y is changed for a units (a – constant value), then the record form of the dependency of y on x looks in the following way: $x \xrightarrow{a} y$ (in the analytical record it is $y = a \cdot x$).

If the change in the characteristics of the structure x defines the change in the characteristics of the structure y, and it, in its turn, defines the change in the characteristics of z, then it is written down as $x \xrightarrow{a} y \xrightarrow{b} z$, where b is the dependency of z on y ($z = b \cdot y$).

As $y = a \cdot x$, then excluding y from the consideration, the equation can be written as $z = a \cdot b \cdot x$ or $x \xrightarrow{a\,b} z$.

Any parameter which determines the dependency of the change of characteristics of one structure on changes of another one is called a structure coefficient.

In many cases it is ought to suppose that these coefficients are variable values, depending on the time of the day, organism state, environment state, etc. They are different for the same interconnecting structures of different individuals. For example, let's consider, the biochemical process, which describes the influence of adrenaline on glucogenesis.

$$\textit{Adrenaline production} \xrightarrow{+a} \text{Adenylate cyclase activity} \xrightarrow{-b} \textit{ATP content}$$
$$\xrightarrow{-c} \text{Adenosine monophosphate content} \xrightarrow{-d} \text{B phosphorylase content} \xrightarrow{-e}$$
$$\text{phosphorylase content} \xrightarrow{-g} \text{Glycogen content} \xrightarrow{-k} \text{Glucose content}.$$

In this chain in the result of adenylate cyclase activity increase the content of ATP is decreased (b- negative), adenosine monophosphate content is decreased which in its turn evokes the decrease of *B* phosphorylase content; etc.

The same characteristics can be simultaneously influenced by independent influence of 2 or more structures. If, for example, structure y is simultaneously influenced by structures x and z, then graphically it is displayed as $\begin{matrix} & z \\ & \downarrow b \\ x \xrightarrow{a} & y \end{matrix}$.

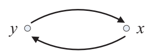
Analytically it corresponds to the equation $y = a \cdot x + b \cdot z$.

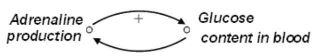
If not the change of y under the influence x is evaluated, but an absolute value of y, then it is reasonable to apply a formula $y = a \cdot x + k$. Graphically the corresponding record has the following view $\begin{matrix} & \downarrow k \\ x \xrightarrow{a} & y \end{matrix}$. The special case is the presence of constant component k in the characteristics of some structure, which in the chain of interacting structures is the intermediary one. The simplest similar scheme has the following view: $x \xrightarrow{a} \overset{k\downarrow}{z} \xrightarrow{b} y$. Analytically the influence of structures x and z on the structure y has the following view:

$$z = a \cdot x + k;\ y = z \cdot b; \Rightarrow y = (a \cdot x + k) \cdot b.$$

In those cases when some structure doesn't only undergo through the influence of another structure, but influences it by itself, the feedback which has the name of a feedback loop or just a loop is formed.

Graphically this loop is portrayed as:





As, for example, the increase of adrenaline synthesis evokes the glucose level increase in blood. At this glucose is more intensively expended in an organism, in particular, as with the increase of adrenaline production the intensification of the standard metabolism is usually connected. However, in case of the excess of the normal level of glucose content in blood the negative feedback with the cells of meduila of adrenal cortex appears, in the result of what the adrenaline synthesis decreases again. Similar cases of mutual stimulation are observed in the process of the organism development, when the coherent mass augmentation of separate organs and tissues take place.

Besides, one more rather rare variant characteristic for some development processes of an organism is possible, when the elimination (withdrawal, exclusion) of some structure and the replacement of its functions by another structure takes place. The interaction process is over at this point if either one of interacting structures stops its existence or its qualitative regenerations take place. For example, the augmentation of a womb during pregnancy is stimulated by a foetus development, at the foetus growth in its turn is stimulated by the womb augmentation during the whole period of its development till the delivery.

1.8. Analysis of causes of phenomena, which appear during the pathological process

At the analysis of causes of a pathological process the insignificant quantity of links (more often, it is one) which is the initial for this process can be distinguished. Factors which are the initial cause of the disease influence these links/ such a link (links) can be called the basic ones in the pathogenesis of the disease. For example, the stenosis of the left atrioventricular aperture is the main link in the system of the big quantity of subsequent dysfunctions: formation of constant excessive intrinsic pressure and as its sequence the appearance of the dilatation of the left atrium, dysfunction of the right ventricle due to the insufficient blood flow, stagnation in the greater circulation due to the decrease of the volume of blood pumping by a heart, etc

2. Biological, medical and physiological cybernetics

2.1. Main notions of cybernetics.

Cybernetics studies the laws of functioning of the special type of systems, called cybernetic systems, which are closely connected with the control notion. Functioning of these systems is based on the information perception, memorization, exchange and procession. Cybernetics is often called the control science.

The American mathematician Norbert Wiener, who laid the theoretical basics of cybernetics, is considered to be a founder of cybernetics.

Cybernetics is a young science which formation started only after the 2nd World War. Nevertheless, it is being developed so rapidly that already has big influence on the research methods and means of the solution of practical tasks in the diverse areas of science and engineering: biology and medicine, economics and sociology and computer engineering.

Cybernetics considers the control theory regarding the systems, which consist of the elements aggregates and function as one binding unity. Besides, cybernetics studies not isolated systems, but their aggregate. It takes into account all the diverse connections which are regularly formed between separate parts of complicated systems, as these connections define the systems features, their behavior, development, decay and reproduction.

The task of cybernetics isn't the study of the material system content and not the structural submission of its parts, but the result of the system operation and its influence on other systems.

<u>According to the nature of interaction with cybernetics</u> all the sciences can be subdivided into 2 groups:

- sciences which study more general forms of connections and relations than cybernetics (philosophy, mathematics and logic);
- sciences which investigate particular types of control systems (systems of blood circulations, systems of education, health care, etc.).

The main notions of cybernetics systems *are feedback and control.*

The environment is the most complicated system where different events arise as the result of interaction of multiple various elements. While influencing some system events, one can never be sure that it won't lead to such a reaction of the system which will destroy all the efforts for the achievement of the set aims. That's why in order to augment chances for the favorable outcome, there should be the active, purposeful and thought-out influence on the course of event, in other words, the **control** is needed.

The control notion is the basic one in cybernetics as it defines a subject of the investigation of this science.

The presence of control in cybernetic systems involves the presence of 2 interacting blocks: control object (the one who is being controlled) and control subject (the one which/who controls). The control subject produces the control signals which change the controlling impacts. A control subject is also called a controlling system and a control object is called a controlled system.

Control – is the purposeful impact of one system (control subject) on another one (control object), which is chosen from the multitude of possible interactions on the basis of the current information and serves for the condition (behavior) change of a control object in accordance with changing conditions of the environment for its development and functioning improvement.

The division of the cybernetics system for the controlling and controlled components not always can be defined unambiguously. In difficult and developing systems these blocks can be combined. Such a mode is called self-response.

The general control scheme looks in the following way (Fig. 2). The controlling system (control subject) transmits the controlling impacts for a control object through effectors via direct communication channel. The information about the condition of a control object is perceived by means of receptors and goes back to the controlling system via feedback channels.

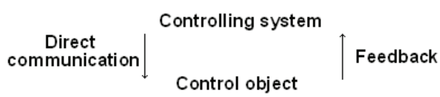


Fig. 2.

Feedback is one of the main notions of cybernetics and means the influence of output system signal for its working parameters. The feedback provides the self-regulation of the system and its adaptation control. The glucose level augmentation in blood stimulates the formation of endogenous (inner) insulin of the pancreas, which lets maintain the glucose level within the physiological norm (3,3-5,5, mmol/l).

The feedback can be negative and positive. Negative feedback counteracts the tendency of the output parameter change and contributes to its stabilization. Negative feedbacks provide the stability of the organism functions, constancy of its parameters and steadiness to external exposures. The heat regulation mechanisms of all living beings work according to the principle of the negative feedback.

Positive feed-back, vice versa, saves the tendencies of the system output parameters. The example of the positive feed-back in an organism can be the humoral self-regulation of the excretion of digestive juices, when the absorption of the albumen digestion products, stimulates glands, improving the digestion progressively.

However, positive feedbacks not rarely act as a mechanism of so called “vicious circle”, when malignant impacts, violating the norm, evoke changes in an organism which stimulate the malignant impacts even more. For example, cardiac insufficiency deteriorates the blood circulation of myocardium, which deteriorates its contractility.

This way, if the negative feedback contributes to the restoration of the initial state of organs and their functions, then the positive feedback takes them far from initial state.

The main task of the controlling system (control subject) is such a transformation of the information which enters the system and formation of such controlling impacts which provide the achievement of control aims.

One of the characteristic features of the controlled system (control object) is the ability to change its parameters and to pass to different conditions under the influence of the controlling impacts. As for example, a person can take different positions in space, can move into different directions with different speed. Blood pressure, sugar level in blood, heart rate can be decreased and increased, for example, after the intake of certain drugs.

Under the influence of controlling impacts the system takes the best (in a certain meaning) state, than during the absence of controlling impacts. For example, for the improvement of the patient's condition the correspondent medical-prophylactic means can be considered as controlling impacts. As far as concerns the artificially controlled system created by a person and used in his aims, the notion “best” is evaluated by a system creator.

Biologically controlled systems were formed in the process of the evolutionary development of wild life and during its consideration it is practically impossible to point the subject which has certain aims for the achievement of which the control takes place. The evaluation of the behavior of the biologically controlled system is defined by its medium and the best behavior is the one which augments the chances of the given organism to survive and procreate.

Between all the possible states of the controlled system (control object) there should always be a choice of the optimal condition. **Where there is no choice, there is no control.**

The presence of control is the essential feature of a complicated system which provides with one of it its main features – integrity.

One of the simplest control type is so called <u>programmed control</u>. The aim of such control is to give for a control object this or that strictly definite sequence of controlling impacts. The feedback during this control is absent.

The aggregate of rules according to which the information which enters the controlling system, is transformed into controlling signals, is called the control algorithm (law).

Clinical medicine today is the modern industrial technology which demands scientifically-based approaches to control.

Under the control of the quality of medical help the following options are meant:

- organization of the correct handling of healthy people (discovering the risk factors);
- organization of the correct prophylactics of diseases in the groups of risk;
- organization of the correct *treatment* and correct rehabilitation of patients.

The aim of such control is obtaining maximally possible *results* taking into account the modern level of knowledge at minimal level of expenses. Modern computers can be treated as the universal information converters and represent the main technical means, the main research device of which cybernetics possesses. The other known example of the universal information converter (though based on absolutely different principles) is human brain.

Cybernetics uses the diversity of different mathematical methods: information theory, coding theory, probability theory and mathematical statistics, mathematical logic, theory of image recognition and others, appeared inside cybernetics in the process of its development. However, cybernetics isn't limited only with theoretical researches. This is an experimental science in which frames such a system research method as computer modeling is developed. The artificial intellect model is considered to be the main achievement of the cybernetics.

Academician A.Ch. Berg offered to divide all the cybernetic researches for 3 main parts:

1) general (theoretic cybernetic), which deals with general mathematical control models and represents the mathematical or physical mathematical discipline;

2) technical cybernetics, which area is the technical realization of different complicated objects – robotics, development of technical complexes, systems of management of technical objects;

3) applied cybernetics, which unites different applied directions: biological, economical, etc..

Nature is complicated and diverse, that's why several directions of biological cybernetics, which studies different biological systems and their private functions: medical, physiological, psychological cybernetics. The study of the nervous system activity as the most perfect apparatus of control and connection is defined as a field of neurocybernetics.

Cybernetic study of all living organisms opens and discovers general laws of adaptive functioning of complicated systems as well as private qualities of self-regulation of separate organs and organism in general.

2.2. Subject, methods and content of biological cybernetics

Biological cybernetics occupies the important place among biological sciences completing classical methods of life study with new approaches, which allow to discover more deeply and precisely the laws of its complicated course.

At present time there is no field of study of living organisms where they wouldn't use new achievements with the usage of cybernetics methods.

The object of the study of biological cybernetics is general principles of existence, specific for living organisms and also concrete mechanisms of expedient self-regulation and active interaction with the surroundings.

Biological cybernetics studies life phenomena predominantly from the point of view of processes taking place in living creatures: processes of system self-organization, information processes and control processes.

At present time the following 7 levels of cybernetic study of life are distinguished:

- Subcellular (on the basis of biochemistry and biophysics);
- Cellular (on the basis of cytology and cell physiology);
- Tissular (on the basis of embryology, histology and histophysiology);
- The level of organs and systems (on the basis of normal and pathological physiology);
- The level of an organism as one unity (on the basis of higher nervous activity);

- Specific (on the basis of evolutionary and ecological physiology, zoology and botany);
- Biospheric (on the basis of biogeocenology, general biology and sociology).

2.3.The notion «functional cybernetics». Theory of functional systems as the basis of understanding of processes of vital functions

Patterns of self-regulation of physiological functions in norm make up the trend in psysiological cybernetics. The conception of functional system of Anokhin P.K., completed by K.V. Sudakov, which allows to describe the work of all systems of a human's organism – from biochemical to psychic and social levels, belongs to it.

On the basis of theory of functional systems mathematical models of the control processes in the human's organism are built. The theory of functional systems lets describe the most important systems of human's organism for the realization of complex approach in diagnostics and provision of active vital functions.

The main clauses of the general theory of functional systems are:

1. The leading factor of functioning of functional system of any organization level is the adaptive result useful for the vital functions of an organism (i.e. every functional system should be able to adapt).

2. Any functional system of an organism is built on the basis of the self-regulation principle (self-regulation includes the self-response; this is the process of higher level).

3. Functional systems are central peripheral formations, selectively joining different organs and tissues for the achievement of useful for an organism adaptive results (i.e. every system should have controlling (central) and controlled (peripheral) system to provide adaptive reactions.

4. Functional systems of different level are characterized by functional isomorphism: they have an unidirectional (“similar”) functional scheme of organization of all the processes in a system (i.e. all the elements in a system should be subject to one aim by their functions).

5. Separate elements in functional systems interact for the achievement of the results necessary for an organism.

6. Functional systems and their separate parts get mature in the individual development (ontogenesis) in that order and level which are necessary for the organism development. This is the general expression of the system genesis.

Academician Sudakov formed 3 general principles of interaction of functional systems in an organism: *hierarchy principle, multiparameter principle and principle of sequential interaction*.

Hierachy principle lies in the the fact that at every time moment the organism activity is defined by that functional system which dominates in the terms of survival and adaptation to the surroundings. The rest of functional systems are built in hierarchy order regarding the dominant one. Changes of dominant functional systems take place during the whole life of a person.

Multiparameter principle of different functional systems defines the compatibility of their functioning. As a rule, the change of the resulting index of one functional system leads to the changes of indices of other functional systems.

Principle of the sequential interaction lies in the fact that the activity of one functional system in time changes by another one. This principle clearly becomes apparent, for example, in sequential process of intake and procession of food essences. The functional system of the search for food is changed by the system of procession in the mouth cavity and act of swallowing. The functional system of mechanical and chemical procession of food in a stomach comes to its stead (the result is the food intake to duodenum), etc. The sequential activity of functional systems which provide the nutrition of an organism, are genetically programmed by special centers of the nervous system. The programming of the sequential work of functional systems, i.e. systems of digestion is realized according to the advanced principle: only after the perception and evaluation of the result of activity of the previous system by receptors of the subsequent system the change of one functional system by another one can take place.

Principles and features of organism's functional systems need to be taken into account during the consideration of the common functioning of different organs. It is possible to evaluate the casual relationship of the events by means of following direct communications and feedbacks: from controlling centers to the result of work of executive organs and back to controlling centers.

In every functional system the main cybernetic principles are executed:

– regulation by the final result with feedbacks,

– information evaluation of the final result.

The usage of the functional cybernetics allows to distinguish in the general dynamics of the activity of vital functions the most important links, the impact of which can augment the life potential of an organism.

The general cybernetic pattern in the operation of functional systems in the evolution process was formed many millions years before it was discovered in technical devices.

2.4. The notion «medical cybernetics». Main trends in medical-cybernetic researches

Regulation of the organs' functions, their systems and human's organism in general with the aim to keep the homeostasis at extreme conditions and pathology makes up the basis of the wide area of research – medical cybernetics.

Medical cybernetics is the scientific trend, connected with the implementation of ideas, methods and technical means of cybernetics into the medicine.

Medical cybernetics is mainly occupied by the creation of statistic models of diseases to use them with the aim of diagnostics, prognosis and treatment and also studies the control processes in medicine and health care.

The development of ideas and methods of cybernetics is mainly realized, by means of the development of computer informational systems (i.e. diagnostical) on the basis of mathematical methods of the analysis of data of a patient's examination by using the methods of mathematical modeling of the activity of different functional systems.

Inner organization of a diagnostic system consists of the "medical memory" (accumulated medical experience in the given group of diseases) and "logical device" which allows to compare symptoms, revealed during the investigation of a patient with the existing medical experience and to make the complicated statistic procession of the clinical material in any set direction.

Method of computer modeling of the activity of different functional systems of an organism allows to discover many important sides of their activity and is the basic method to obtain new knowledge in medicine. In order to reveal the patterns of the interaction of studied out systems according to the following parameters, characterizing the function of this or that organism system (for example, cardiovascular system), mathematical equations are written. The solution of these equations allows to evaluate the patterns of an investigated system.

Cybernetical methods are used for the quick evaluation of the patient's state during big and complicated operation and during post-operation period. Traditionally, during such operations the control after the important functions of an operated patient is realized by the entire staff of specialists by means of different electronic devices and apparatuses. The cybernetic system allows to execute their functions within several seconds: to evaluate, compare and integrate the readings of multiple devices and also to take the correct decision during taking the necessary measures for the restoration of the patient's main functions.

The subject of investigation of the medical cybernetics are medical and other types of information, systems of information accumulation and procession, systems of connection and control, existing in a human's organism and health care. Medical cybernetics is based on knowledge, accumulated by medicine and health care and also on the cybernetics medical apparatus and possibilities of a computer.

Stages of the development of medical cybernetics are divided into 2 periods. In the first period only means of finding a solution for special tasks were developed, for example, diseases diagnostics. The second stage is known by its system approach to the solution of the modeling problems and the control of the health care system in general. At this time medical information systems, which provide the accumulation, procession and giving of any medical information in the process of finding the solution for tasks, which are connected with diagnostics, treatment and control in medicine and health care.

Medical diagnostic process is a typical cybernetic process and is connected with the information accumulation, transmission, storage and procession. The analysis of the diagnosing process by a doctor showed that only this process in the insignificant level depends on the intuition. In general, during diagnosing a doctor widely uses the experience accumulated in his memory, data obtained during the examination of a patient and acts according to the certain rules, which he was either been taught or he has achieved himself in the process of the medical practice. This way, a doctor acts in accordance with the diagnostic algorithm. During the solution of medical-diagnostical tasks a doctor comes across difficulties connected with taking solutions in the condition of uncertainty:

– insufficient qualification, i.e. to simplified algorithm from a concrete doctor;

– the impossibility to process all the incoming information (about a patient, drugs, etc) because of the big quantity of information and from the limited possibilities of the memory (during the rare usage the data are forgotten).

Having analyzed the listed difficulties, it is easy to notice that in all the cases a computer can be as a reliable and unfailing doctor's helper. Automation of the medical diagnostics is the aggregate of mathematical methods and technical means which provide the augmentation of efficiency, accuracy, reliability and the speed of the medical diagnosing. In distinction from usual means of disease diagnosing, common in clinical practice, the medical cybernetics offers methods of the disease recognition, based on the criteria formalization and diagnostics rules, i.e. diagnostic algorithms (or decision rules).

Medical cybernetics studies the functions of the human's organism, on the basis of the control laws, and also considers the problems of treatment and disease prophylactics on the basis of the control laws, objectively peculiar to all natural and artificial objects. A living organism in general and its separate elements in particular are considered to be systems where the information perception, accumulation, procession and transmission take place and also the corresponding reactions are developed (control actions), which provide the normal course of all the vitally important processes. From the point of view of the medical cybernetics any disease is considered to be the violation of the processes of information receipt, transmission and procession or the result of the wrong controlling impact (wrongly prescribed treatment) and it is very topical for medicine as among all the types of medical errors in the medical practice the leading ones (56%) are the medicines mistakenly chosen by a doctor and their doses, 34% of errors are connected with incorrect dose prescription and the length of the application of drugs.

Maximum quantity of errors are made by doctors at combined therapy. In the USA and Germany about 100 000 patients die annually because of medical errors. The usage of medical cybernetics (mathematical modeling, methods based on the usage of computers, etc) are directed to the augmentation of the range of means to research living organisms, augmentation of possibilities of doctors during diagnosing as well as during the treatment of diseases. The intensive development of medical cybernetics is closely connected with the development of computer engineering and newest means of the receipt of information about an organism's condition or its separate organs and systems.

3. Decision-making in medicine

3.1. Problem of the decision-making. Basic components of the decision-making process.

In different medical tasks (accumulation of information about a patient, diagnostics and choice of decision tactics) a doctor faces a general problem – problem of the decision-making. At this with every year the requirements to the diagnosis accuracy and its reliability grow. In other words, to its verity.

Decision theory - a field of study involving the concepts and methods of mathematics, statistics, economics, management and psychology to study the patterns of choice people solutions to all sorts of problems, as well as ways to find the most favorable of the possible solutions.

Under the decision-making is meant a special process of human activity, directed to the choice of the most acceptable variant of decision-making. The example can be process of the decision-making about the type (form) of disease, about the known initial information (results of analyses, external manifestations of a disease) or the solution of a problem of so-called group choice of decisions, when the main task consists in mentioning the “fair” principles of the calculation of individual choices, leading to a reasonable group decision. This task is solved for example, by means of a consultation where every participant expresses his/her opinion regarding the treatment plan and in the result, one optimal variant is chosen. How to make it? Which result is considered to be the good one and which features should it possess?

The choice of a director of a medical center can be one more example. Let's assume that two candidates claim for the position of a head doctor. Each of them is supported by a group of colleagues. At skillful running of business the minority can impose their opinion on the majority, though the voting will always be carried according to the rules of majority (paradox of the multi-step voting). The idea of this method is shown at Fig.3.

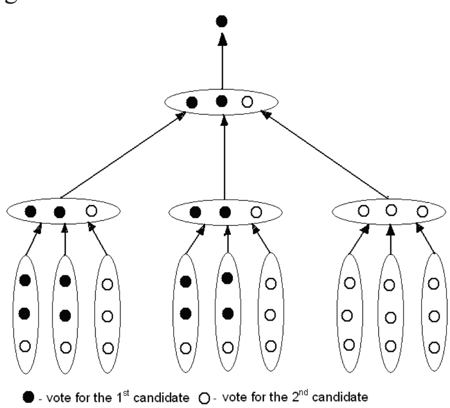


Fig. 3.

In the given scheme the second candidate is initially supported by 19 colleagues versus 8 colleagues which support the first candidate. The advantage is evident. However, during the skillful grouping of voters and the carrying out of step-by-step elections, the situation is changed for the quite opposite one and the advantage is in favor of the first candidate.

Let's give one more example. A doctor chooses the medicine for a patient taking into account the following multitude of alternatives:

- x_1: medicine of the world-famous company-producer at the price of 100 USD .

- x_2: medicine of the company producer famous in one country at the price of 70 USD.

- x_3: medicine of the little-known company producer at the price of 30 USD .

It is easy to imagine the situation when a doctor will prefer x_1 to x_2, having considered that the positive experience of application of this medicine will cover the price difference.

This preference can be marked as (x_1, x_2) which will mean that "x_1 is better than x_2", In the similar way it can be assumed that x_2 is better than x_3. At the same time, comparing x_1 and x_3, the choice "x_3 is better than x_1" (too big difference in price). This way, the system of preferences is set by multitude of pairs (x_1, x_2), (x_2, x_3), (x_3, x_1). Which principles to be guided with for the decision-making in similar situations?

Given examples don't exhaust all types of decision-making tasks.

Medicine is the semi-structured knowledge which creates serious difficulties for the process of decision-making. In some cases which are characterized by classical manifestations of diseases, hypothesis or even a final decision appears in the process of an examination, in other cases – after special research. It is important to note that the sequence of diagnostic researches can be subject to correction and sometimes to the fundamental transformation, depending on results obtained in the research process. The speed of the decision-making depends on the qualification and diagnostic "feeling" of a doctor also on the peculiarities of the disease manifestation from a concrete patient.

Obtaining the information from the surrounding world, analyzing the arisen situations a doctor constantly refers to data stored in his memory.

The characteristic feature of the human's (doctor's) memory is that the general quantity of the reproduced information is smaller than the quantity of the perceived information while in a technical storage device these quantities are equal. Besides, in distinction from technical devices in the human's memory in the process of fixation, storage and reproduction, the information loss always takes place.

Lately there has been an immense leap in the development of PCs and software. A lot of software products, which realize the methods of decision-making, have been created. It gives the opportunity to verify the made decisions, preliminary having built a model of the medical-biological process.

3.2. Interactive approach to the decision-making

The free access to the software permits to solve medical tasks in the interactive (dialogue, on-line) mode. The interactive mode is the operation mode which realizes the interaction between a person and computer. Applying interactive procedures, a doctor can find optimal task solutions in a dialogue mode, changing conditions-restrictions of a task or parameters of objective functions. In every iteration (program execution step) a doctor, as a person who makes decisions (DMP) can generate new conditions of a task for the further investigation.

Interactive procedures give the possibilities for effective division of labor: a computer executes what it does best of all (processes data) and DMP develops methods for the obtaining of the best decision on the basis of new information. At this the main role always remains with a person.

To make a decision means to make a choice out of several alternatives.

Regardless the diversity of existing problems, the following basic stages of the decision-making procedure are distinguished:

- Aim definition.
- Formation of the multitude of alternatives (the definition of the multitude of possible decisions).
- Formation of the evaluation which allows to compare alternatives (evaluation task).
- The choice of the best solution from the multitude of possible solutions (optimization task)

In the theory of decision-making the aggregate of listed tasks makes up the general problem of the decision-making.

The theoretical basis of three first tasks is the system analysis (it will be considered later), and the fourth one is the theory of mathematical programming.

If a task solution isn't known (the analogue is absent or the solution is ambiguous), then the problems of the definition of decision search method come forth.

Most of these methods are based on strategies of complete enumeration, implicit enumeration and enumeration on heuristics basis (heuristic search).

The strategy of the complete enumeration is used at the absence of efficient a priori (initial) information about a task and relatively small multitude of alternatives (up to 10^3 elements at manual computation and up to 10^9 elements at computer computation).

Implicit enumeration contains a big group of so-called gradient methods: simplex method, method of minimal cost, dynamic programming, etc. All of them were based on the consideration of each step of search, not of all the task space, but of some of its fragment.

Heuristic methods are methods of tasks solution based on heuristics or heuristic argumentation, i.e. on the usage of rules and techniques which generalize the past experience and intuition of a person who decides. Heuristic considerations in the broad sense is the division of psychology which studies out the nature of human's intellectual activity, intellectual operations at his/her solution of different tasks. Only those methods belong to heuristic methods which are directly connected with abilities of a person, with suddenly offered decisions, i.e. directly with the term - eureka, insight.

Their application is also appropriate at hard resource limits (actions in extreme and unknown situations).

As it was mentioned already, decision-making, essentially, is nothing but a choice. To make a decision means to choose the concrete variant of actions from multitude of variants. Variants of choice are commonly referred to as alternatives.

Multitude of alternatives, first, depend on the existing knowledge base: either an algorithm of the task solution is already contained in the base or there is no algorithm in the base, but there is its analogue, or a task doesn't have analogues in the knowledge base. Second, multitude of alternatives depend on the problem situation: either a new task is solved or the condition of the system functioning changes or the new information has appeared or the shutdown of a system or its elements has taken place.

The event (outcome), which possibility of occurrence is dictated by the given decision, is called **the sequence of the decision-making**.

System of preferences – rules, criteria, by means of which alternatives are compared and decisions are taken.

Solution – solutions (alternatives), which conform to the rules contained in the system of preferences.

The common task of the decision-making (task of choice) can be formulated in the following way.

Let X be the multitude of alternatives (decisions), Y – the multitude of possible sequences (outcomes, results). The existence of the casual relationship between the choice of some alternative x_i and the occurrence of the corresponding outcome y_i. Besides, the presence of the choice quality evaluation mechanism – usually by means of the outcome quality evaluation – is supposed. It is necessary to choose the best alternative, for which the corresponding outcome has the best quality evaluation .

3.3. Classification of decision-making tasks

Based on the connections between decisions and outcomes the following **classification of the decision-making tasks** is common.

<u>Determined tasks of the decision-making.</u>

The most simple type of connection – determined – corresponds to it, when each alternative leads to the only one result. In this case there is the functional dependency between the alternative x_i and outcome y_i (Fig. 4).

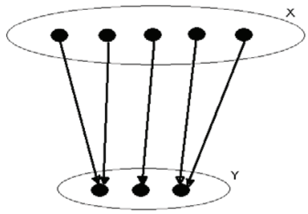


Fig. 4. Determined connection.

In case when not only one result corresponds to each alternative, i.e. there is the undetermined type of connection, then the decision-making tasks are divided into two subclasses:

a) task of the decision-making in the conditions of risk;

b) task of the decision-making in conditions of stochastic (probabilistic) indeterminacy.

In Case (*a*), in distinction from Case (*b*), the probability density function at multitude of outcomes Y corresponds to each x_i alternative (they say that with every x_i some lottery is connected).

At Fig. 5 each arrow is characterized by the weight, i.e. Pij number – the probability of the outcome y_j at the choice of x_i alternative.

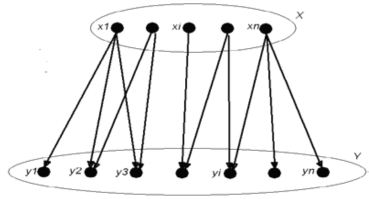


Fig. 5. Probabilistic connection.

In conditions of indeterminacy (case *b*) of the undetermined connection “alternative-outcome” two types of tasks appear :

c) decision-making tasks in the conditions of the passive interaction of DMP (decision making person) and environment, i.e. environment is passive towards DMP;

d) decision-making tasks in the conditions of a conflict (game). In this situation the environment is active towards DMP which is reflected by actions of another person.

At Fig. 6 Case 1 corresponds to the decision-making in the conditions of indeterminacy; outcomes, which correspond to the choice of x_1, x_2, x_3 alternatives, are marked by y_1, y_2, y_3 points (three alternatives and three outcomes). Case 2 characterizes the task of the decision-making in the conditions of risk: after the choice of any x_1, x_2 or x_3 alternative only the interval of the corresponding *y* outcome can be indicated. Case 3 reflects the situation of the choice in the conditions of risk. Graphs of the corresponding densities of the distribution of the event *y* depending on the choice of x_1, x_2 or x_3 alternatives are shown.

Let's consider in details the notion "decision making person" (DMP). DMP is a person who sets the priority and in whose interest decisions are taken. As a rule DMP (for example, a doctor) tends to obtain the best (optimal) decision from its point of view. The choice of a decision depends on the information which DMP possesses in the given knowledge domain and also on the fact how he sets the priorities, i.e. the thinking style and behavior strategy.

For example, one person likes to risk, another one is too cautious, the third one prefers the "golden mean", etc. This way DMP possesses some freedom of choice. However if he doesn't take into account the peculiarities of the problem solution, then the obtained decision can differ from the reality

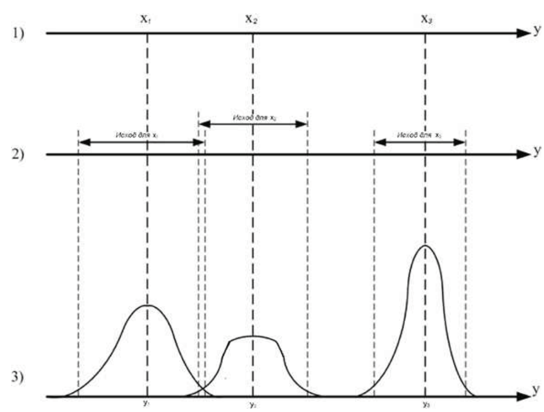


Fig. 6. The connection of alternatives with outcomes at different types of indeterminacy.

and lead to negative consequences.

For example, at the calculation of the expenses for nourishment, the necessary quantity of fats, proteins and carbohydrates, etc. should be taken into account: at the choice of remedies it is necessary to take into account the contra-indications, side effects, a pharmaceutical form of the medicine, its price, etc.

In examples shown below the minimum of expenses, maximum treatment effect are objective functions (optimized criteria) and the necessary quantity of fats, proteins and carbohydrates; pharmaceutical forms of the medicine, changes of the patient's condition, side effects and contra-indications of drugs are conditions-restrictions.

There are no principal differences in finding maximum and minimum, that's why they usually talk about optimal (lat. optimum – the best), or extreme values of an objective function. The task of finding the minimum of an objective function *f(x) (for example, expenses for nourishement)* is equivalent to the task of finding the maximum of the same function with the minus sign and vice versa.

All the requirements, formulated in real tasks and written down as mathematical expressions, make up so-called the mathematical task definition. The process of the mathematical task definition and its further solution can be presented as number of stages.

1. The study of an object represents the analysis of object functioning peculiarities. At this stage factors, which influence an object, are revealed and the level of their influence is defined; object characteristics are studied out at different conditions; optimizing criteria (objective functions) are chosen.

2. Descriptive modeling lies in setting and fixation of basic connections and dependencies between characteristics of a process or event according to the optimized criterion.

3. Mathematical modeling.

4. Choice and creation of the method of solution.

Let's give an example of a mathematical model of the nourishment task. Let 3 different nutrients (proteins, fats and carbohydrates) be included in a patient's ratio and they are required to be in the quantity not less than b_1, b_2, b_3 units. They are contained in 5 different products which can be purchased at the price of c_1, c_2,…, c_5.

The product unit of ith product contains a_{ij} of units of j-th nutrients, i.e., for example a_{23} shows that in the unit of the second product there will be a_{23} units of the third nutrient.

How many products of each type x_1, x_2, x_3, x_4, x_5 should be purchased so that their price was minimal and a patient's ration contained all the necessary essences in the required quantity?

The objective function of this task is to minimize the expenses for nourishment (x_1,…, x_5) by the quantity of products :

$$c_1x_1+c_2x_2+c_2x_3+c_3x_3+c_4x_4+ c_5x_5=\sum_{i=1}^{5}c_ix_i \to \min_{x_1,\dots,x_5}$$

Conditions-limitations of the task are the following: the quantity of the first nutrient should be not less that b_1, i.e.

$$a_{11}x_1+a_{21}x_2+a_{31}x_3+a_{41}x_4+a_{51}x_5=\sum_{i=1}^{5}a_{i1}x_i\ge b_1$$

Similar for other nutrients:

$$a_{12}x_1+a_{22}x_2+a_{32}x_3+a_{42}x_4+a_{52}x_5=\sum_{i=1}^{5}a_{i2}x_i\ge b_2$$

$$a_{13}x_1+a_{23}x_2+a_{33}x_3+a_{43}x_4+a_{53}x_5=\sum_{i=1}^{5}a_{i3}x_i\ge b_3$$

It is evident that the quantity of products is of non-negative value

$$x_1\ge 0, x_2\ge 0, x_3\ge 0, x_4\ge 0, x_5\ge 0.$$

Such set of sought quantity values (variables) which satisfies the set conditions-restrictions of a task is called **the feasible solution.**

That solution from the multitude of feasible solutions at which the objective function achieves its maximum (minimal) value is called **the task solution.**

5. The task solution by means of computer. Tasks which describe the behavior of real objects, as a rule, have a lot of variables and many dependencies between them. That's why in reasonable time they can only be solved by means of a computer.

6. The analysis of the obtained decision. Decision analysis can be formal and substantial. At formal (mathematical) analysis the correspondence of the obtained mathematical model (if the initial data are inserted correctly, if the computer programs function operate well, etc) is checked. At substantial analysis the correspondence of the obtained decision to that real object which was modeled is checked. In the result of the substantial analysis some changes can be introduced to the model and the whole process will repeat itself. The importance of the substantial analysis can be demonstrated on the example when the task about nourishment was solved for the first time. Then as an optimization factor they took the minimum of expenses and in the conditions-restrictions only requirements to the food caloric value were included. There was the following task solution: it is necessary to eat vinegar, which is contained in different foodstuff, then the calorie content will be provided and the price will be minimal.

7. The analysis of the decision stability. In order to verify the decision stability changes are introduced to the initial data within the limits of possible tolerances or intervals of sign existence and then the decision behavior is checked by analytical or numeric methods.

The development of the task solution methods, which contain the objective function and conditions-restrictions, is considered in the mathematics section called **mathematical programming**.

Mathematical programming is the mathematical discipline where theory and methods of the task solution about finding function extremes on multitudes defined by equality and inequality are studied out.

Tasks with several objective functions or with one objective function, but which take vector values or values of more complicated nature are called **multicriteria** tasks. They are solved by means of the information to tasks with the only objective function or on the basis of "game theory" where it is supposed that a person who makes a decision gambles while trying to achieve the maximally good result. «Game theory» – is the section of mathematics oriented towards the building of formal models of optimal decision-making in the situation of the competitive interaction strictly regulated by a table of wins and losses.

The application of "game theory" in clinical practice is connected for example with the presence of a conflict between a patient and a doctor – not fulfilled hopes for the recovery, non-satisfaction of subjective expectation of polite and courteous attitude, too high demands of a patient towards medical staff, etc. Conflicts in the clinical management are evident – between officials and practical doctors, insurance companies and hospitals, etc. Conflict of sides is the most important element of the play and normal event of the social life. A conflict can take place at the inner personal level, level of interpersonal interaction, between social groups, states. The conflict formation most often is explained by objective conditions: any development predetermines the conflict formation which can't be avoided. Studying the problems of the conflict development, it is necessary to concentrate on the ways to solve them, their transformation to not dangerous condition which can be controlled and changed by a person himself/herself. This way the necessity of the conflict solution appears, including the usage of the decision-making theory by the mathematical method "game theory".

If in the course of the decision-making DMP doesn't receive or lose information, then the decision-making can be considered as a momentary act. Corresponding tasks are called **static tasks**. On the contrary, if in the course of the decision-making DMP receives or loses information, then such a task is called a **dynamic task**. In dynamic tasks it is expedient to make decisions step by step (multi-step decision). The significant part of dynamic tasks is included to the section of mathematics **dynamic programming**.

In his/her professional activity a doctor constantly faces the situations where this information turns out to be incomplete and only indirectly connected with what he needs to know about a patient in reality. In these cases a doctor has to make decisions about a diagnosis and treatment in the conditions of indeterminacy (inaccuracy, illegibility, inconcreteness, fuzziness, fairness, vagueness, inauthenticity). The additional quantity of information, submitted to a doctor isn't always the means to decrease the indeterminacy.

3.4. Basic methods of decision-making in medicine

Diagnosis and the choice of action are terms used in researches of the decision-making in different areas of human's activity. In medicine they are equivalent to the terms of diagnostics and treatment. Processes of the decision-making about the diagnosis and choice of treatment are tightly connected and should be considered together.

As it was mentioned above, the additional information isn't always the sufficient condition to remove the indeterminacy which a doctor comes across with during the work with a concrete patient. That's why the choice of methods, which will help to the doctor to make a decision about a diagnosis according to the available data in the most efficient way and to choose the optimal decision, is very topical.

The term "optimal treatment" lies in the frames of conception of maximally expected value and the conception of minimally expected losses which is also connected with it, and it is the important moment in the treatment choice.

For example, it is necessary to analyze the medical data from the point of view of the diagnostic value, i.e. to determine which signs and symptoms are of the most importance for diagnosing (maximum informative weight, minimal information loss).

A person isn't capable to extract from the processed data all that level of determinacy which is contained in them in the hidden form. It is connected with several reasons, in particular, for example, with the errors of observers, misinterpretation of results of diagnostic tests (for example, roentgenograms), insufficient accuracy of diagnostic tests.

Referring to the set of problems, connected with technology of decision-making, medical diagnosis at that is of probabilistic nature and is connected with the hypothesis verification (you have already come across the notion "hypothesis" in the lecture "Statistic methods of the procession of medical-biological researches ").

At the decision-making DMP tries to verify some assumption or hypothesis. As, for example, if in the previous month the average quantity of bed days of patients who went through the treatment with some diagnosis was equal to 15 days, then we could expect that in the current month this quantity would be equal to 15. If it turns out that in the current month this index is equal to 10 days, then our expectations were wrong and the hypothesis that the average quantity of bed days in the considered month will be 15 days will have to be rejected.

However the problem here lies in the fact that the obtained result which is equal to 10 days represents the result of one accidental sampling. Probably, in reality the average quantity of bed days in the considered month consisted exactly of 15 days, but we had been checking that "unsuccessful" random sampling of the volume of, for example, 30 observations that we got the distorted result. What is the probability that the deviation between the factual sampling result (10 days) and our preliminary hypothesis (15 days) is conditioned only by the error of the accidental choice? Exactly these problems are investigated by means of methods of statistic hypothesis verification. As it was mentioned earlier, the special type of statistic hypotheses is so called "null hypothesis" (H_0). In our example the null hypothesis will lie in the fact that the average of the general population is equal to 15 (at the standard deviation equal to 4, i.e. $\overline{X} = 15$; $S = 4$). From the material of the first year you know that the sample average is the point estimate of the mathematical expectation of the general population. The confidence interval for M(x) is calculated according to the following formula

$$\overline{X} - t(\alpha,k)\cdot\frac{s}{\sqrt{n}} \le M(X) \le \overline{X} + t(\alpha,k)\cdot\frac{s}{\sqrt{n}}.$$

In our example $\overline{X}$=15, $S = \frac{4}{\sqrt{30}}$, α = 0,95 (significance level),

k = n-1= 30-1=29, t(0.95;29≈2).

Then the interval for the mathematical expectation consists of:

$$1 \quad - 2\,5\frac{4}{\sqrt{3}} \le \underset{0}{M}(X) \le 1 \quad + 2\,5\frac{4}{\sqrt{3}}$$

$$1 \;\; ,53 \le 5M(X) \le 1 \;\; ,46$$

From the data shown above it goes that the average value of any sampling from this population with the probability of 0,95 should lie in the interval 13,55 – 16,45, this way the value 10 is improbable. The assumption about the fairness of the null hypothesis led to the improbable conclusion. That's why the hypothesis needs to be rejected.

The choice of the null hypothesis is the decisive moment during the check of the significance of obtained results. "Significant" result is equal to the fact that the null hypothesis should be rejected as it turned out to be faulty. This way, DMP made an error during the choice of hypothesis, probably due to the lack of knowledge about an investigated object or due to the result of insufficient competence. The obtained results don't correspond to the initial assumptions. Significant results are “good”. It is often reported that the obtained results are significant at the significance level of 0,05%, 0,01%.

In general, it can be said that the essence of the hypothesis verification lies in the fact that the assumed object is compared with the certain standard and in the result of this comparison a correct or erroneous judgment, called the decision, is made. The essence of the statistic hypothesis verification consists in accepting or rejecting a hypothesis according to the data of a random sampling with the minimal risk of an error. Usually the checked out hypothesis is called “null hypothesis” and is marked as H_0.

Hypotheses, which affirm that the difference between the compared values doesn't exist, and the observed deviations are explained only by random fluctuations in samplings, are considered to be null hypotheses. Other hypotheses which differ from H_0***, and oppose it are called alternatives and marked as*** H_1***.***

The rightness or faultiness of a decision depends on the fact if a hypothesis is true or false. If a hypothesis is true and DMP accepts it, then it is a right decision from his/her side. Statistically, a right decision is characterized by the confidence probability, marked as $1-\alpha$. But if a hypothesis is true, but DMP rejects it due to some reasons, then it is his false decision. It is called the error of the first kind and it is evaluated by the probability marked as α. In case if a hypothesis is false but DMP accepts it, then it is a false decision. It is called the error of the 2nd kind and it is evaluated by the probability marked as β. If a hypothesis is false then the correct decision is its rejection. In scientific researches those means of the hypothesis verification are preferable by means of which the possibility of errors of the 2nd kind is minimized (i.e. to accept the false hypothesis as the true one). Features of some means to accurately reject false hypotheses is called the **power of** this **means**. Quantitatively the power is characterized by the conditional probability $1-\beta$, where β is the possibility of errors of the 2nd kind.

This way during the acceptance of a statistic decision there is always the possibility to miss an error, these errors can be of two kinds:

1) rejection of H_0 (i.e. thought to be false) while H_0 is true in reality (error of the 1st kind or error of α-type);

2) acceptance of H_0 (i.e. thought to be true) while H_0 is false in reality (error of the 2nd kind or error of β *type*).

All written above can be presented as a table.

Hypothesis characteristic and DMP's actions	Statistic characteristic of	Probability

	a decision	
hypothesis is true and DMP accepts it	true decision	α
hypothesis is true, but DMP rejects it	error of the I kind	$1-\alpha$
hypothesis is false, bur DMP accepts it	error of the II kind	$1-\beta$
hypothesis is false and DMP rejects it	true decision	β

The probability of an error of the first kind is called **the significance level** $\boldsymbol{\alpha}$**.**

The probability to accept the true H_0, equal to $1\text{-}\alpha$, is called **reliability** (this is the probability not to make an error of the 1st kind).

The probability not to make the error of the 2nd kind (on the condition that H_0 is false, to reject the null hypothesis), equal to $1\text{-}\beta$, is called the **power of test.**

If H_0 is true, there is a possibility to make only the error of the 1st kind. If H_0 *is* false, there is a possibility to make an error of the 2nd kind. We chose ourselves the probability of an error of the 1st kind α. That's why it can be avoided by decreasing the numeric value of the significance level α. Simultaneous decrease of probabilities of both errors is possible with the augmentation of n sampling volume.

Those hypotheses, which can be verified in the future, belong to **scientific** hypotheses. The empiric verification of a hypothesis is called **verification**.

For the statistic verification of medical hypotheses the following tests are used: t-Student, λ-Kolmogorov, F-Fisher, χ^2-Pearson, G-Cochran etc.

Such criteria as λ, χ^2, are nonparametric tests as they serve for the verification of hypotheses about distributions in general. Tests t, F, G are parametric, as they serve for the verification of hypotheses about distribution parameters.

The powerful tool of the probability theory is Bayes' theorem which was considered in the course of biophysics. By means of Bayes' formula it is possible to accumulate the information which comes from different sources with the aim of confirmation or non-confirmation of the certain hypothesis (diagnosis). Bayes' formula allows to use together the observed data and information known before by means of conditional probabilities for the solution of the differential diagnostics task.

Let's give an example. Let a patient be suspected in having the flu. This way, there is some hypothesis H, which lies in the fact that a patient will have the flu, not something else. Let's think that in medical establishments on the basis of statistic data obtained earlier a priori (initial) probability $P(H)$ *i*s known that a patient will catch a flu in the given season and location. Let the sign *D* mean that a concrete patient has the high temperature. Bayes' formula allows to get the probability of the flu if a patient has high temperature P(H/D) (final or a posteriori probability). This way we want to precise a priori probability of the *H* hypothesis verity on the basis of the information we have. According to Bayes' formula we've got the following equation:

$$P(H/D) = \frac{P(D/H)P(H)}{P(D)} = \frac{P(D/H)P(H)}{P(D/H)P(H) + P(D/\overline{H})P(\overline{H})}.$$

In order to use Bayes' formula as an example it is necessary to know probabilities: *P(D/H)* – probability of a high temperature at the flu presence; $P(D/\overline{H})$ – probability of a high temperature at the flu absence. We suppose that both of these probabilities are known for us. They are obtained during the processing of statistic data accumulated earlier. It is clear that all three numbers *P(H), P(D/H),* $P(D/\overline{H})$, can be obtained earlier and don't depend on data of a concrete patient. Knowing that $P(\overline{H}) = 1 - P(H)$, we can use Bayes' formula. Let it be known that:

$$P(H) = 0,0 \quad ; P(\overline{H}) = 1 - P(H) = 0,9 \quad .$$

Let it also be known that:

$$P(D/H) = 1,0;$$
$$P(D/\overline{H}) = 0,0$$

Then according to Bayes' formula we get:

$$P(H/D) \approx 0,009$$

This way the probability of catching flu at getting the evidence about high temperature augmented and made up 0,009 in comparison with 0,001 (initial a priori probability).

Bayes' theorem is applied during the decision-making in expert systems. The work scheme of Bayes' expert system lies in the following. Initially we have a priori probability *P(H)* (in the example – a patient has got the flu), which is contained in the knowledge base. But having received the evidence B (high temperature) and having recalculated this probability according to Bayes' formula, we can write it in the place of P(H). The receipt of one more evidence leads to the renewal (increase or decrease) of this probability. Each time the current value of this probability will be considered to be a priori for the application of Bayes' formula. In the result, having gathered all the info, concerning all the hypotheses (for example, diagnoses of diseases), an expert system comes to the final decision, marking the probable hypothesis as the expertise result.

In conformity with diagnostics, Bayes' formula allows to chose one of several diagnostic hypotheses, basing on calculation of the disease probability according to the probability of symptoms revealed in patients.

Bayes' theorem says that the final probability of hypothesis *P(H/D)* is proportional to its initial probability *P(H)*, multiplied by its likelihood P(D/H).

The important role during the calculations according to Bayes' formula has the likelihood ratio (i.e. the ratio of two likelihoods).

$$\frac{P(D/H_i)}{P(D/H_j)} \qquad (i \neq j)$$

This value can express, for example, the ratio of probabilities of set of symptoms during asthma to the probability of the same set of symptoms of a control group. Let's give an example.

In the anamnesis of a patient (age – 16 y.o.) there is a primary osseous tumor. What is the likelihood ratio for chondroblastoma relative to chondrosarcoma for a patient of this age group? The sought likelihood ratio can be obtained by means of initial data: $P(D/H_1)$=P(age 16 y.o./chondroblastoma)=0,75; $P(D/H_2)$=P(age 16 y.o./chondrosarcoma)=0,25. *This way:*

$$\frac{P(D/H_1)}{P(D/H_2)} = \frac{0{,}75}{0{,}25} = \frac{3}{1}$$

For two diseases 1 and 2 and the same set of symptoms Bayes' formula can be written twice in the following way:

$$P(H_1/D) = \frac{P(D/H_1)P(H_1)}{P(D)}$$

$$P(H_2/D) = \frac{P(D/H_2)P(H_2)}{P(D)}$$

Having divided the first equation by the second one we will receive:

$$\frac{P(H_1/D)}{P(H_2/D)} = \frac{P(D/H_1)}{P(D/H_2)} \cdot \frac{P(H_1)}{P(H_2)} = Ch_1$$

Value $\frac{P(H_1)}{P(H_2)}$ is called initial chances (i.e. chances “not spoilt” by additional conditions).

Initial chances multiplied by the likelihood ratio (they say, modified by the likelihood ratio) represent final chances – Ch_1.

Let's give an example. If a patient younger than 21 year old has the primary osseous growth, what are the chances that this is, most probably, an osseous sarcoma than reticular cells if it is known that:

P(age below 21 y.o./ osseous sarcoma) =65

P(age below 21 y.o / reticular cells) =10

P(osseous sarcoma) =25

P(reticular cells) =5

$$Ch_1 = \frac{\text{P(age below 21 y.o./ osseous sarcoma)}}{\text{P(age below 21 y.o./ reticular cells)}} \times \frac{\text{P(osseous sarcoma)}}{\text{P(reticular cells)}}$$

$$Ch_1 = \frac{65}{10} \cdot \frac{25}{5} \approx 32$$

This way the technology of the decision-making in medicine actively uses the Bayes' theorem and the notion of chances connected with it.

Not less relevant is the technology of the verification of a diagnostic test reliability and the notions of sensitivity and specificity. Let's consider them.

The result of some test and two hypotheses regarding the function of distribution of this test result are given. It is necessary to make the best choice between these two hypotheses.

Regarding a medical diagnostic test, this statement can be paraphrased in the following way. The random population of patients, who can be in one of two states regarding some disease – norm or pathology – is given. The function of distribution of some test result corresponds to one of these states. It is required to make the best choice between these two states for each patient, i.e. practically to diagnose "norm" or "pathology" on the basis of a diagnostic test. The term "norm" is used here as "nonpathologic state".

The reliability of a test used to distinguish healthy people from sick people can be characterized by means of such test characteristics as sensitivity and specificity.

Sensitivity – is the capability of a test to give positive result when an investigated patient is really sick or "truly positive" regarding to the considered disease (i.e. to admit truly ill person to be sick according to the test results):

$$\text{Sensivity, \%} = \frac{\begin{array}{c}\text{number of patients with desease and positive TESTS results} \\ \text{(number of truly positive patients)}\end{array}}{\text{number of all patients with desease}} \times 100$$

Specificity – is the test capability to give a negative response when an investigated patient doesn't suffer from diseases or truly negative regarding to the considered disease (i.e. to admit genuinely healthy people to be healthy):

$$\text{Specificity, \%} = \frac{\begin{array}{c}\textit{number} \text{ of patients without desease and negative TESTS results} \\ \text{(number of truly negative patients)}\end{array}}{\text{number of all patients without desease}} \times 100$$

During the verification of the test efficiency for the presence/absence of concrete disease (pathology) 4 different outcomes are possible:

a) a patient is rightly admitted to be sick according to the test;

b) a patient is falsely admitted to be healthy according to the test;

c) a healthy person is falsely admitted to be sick;

d) a healthy person is rightly admitted to be healthy.

Faulty test results are characterized by errors of the 1st and 2nd kind.

Test results

«a» – truly positive	«b» – falsely negative (error of the 1st kind, α error)
«c» – falsely positive (error of the 2nd kind, β error)	«d» – truly negative

Error of the 1st kind is considered to be the less desirable for a test (it is bad "not to recognize a patient"), but in several situation the error of the 2nd kind when a healthy person will start to be treated can be very dangerous.

Tasks from the area of "decision-making" appear when a task is so complicated that for its setting and solution the appropriate formalization apparatus can't be determined at once and when the task setting process requires the participation of specialists in different knowledge domains. For these situation the technology of the "decision-making" has special approaches, techniques and methods. For the beginning the area of the decision-making problem (problem situation) is defined, factors which influence its solution are revealed, methods and techniques, which allow to formulate a task so that a decision would be made, are selected. Then an expression, which connects the aim with the ways of its achievement, is obtained. All this is realized in mathematical models – different criteria (functioning criterion, criterion or index of efficiency, objective function, etc.)

If one succeeds in obtaining the expression which connects aims with means, then a task can be solved practically always. It is easy to obtain such expressions if a law which connects an aim with means is known. If a law isn't known then it is necessary to choose the other way to reflect problem situations. The patterns on the basis of statistical researches or functional dependencies can be defined. If even this can't be done, then a theory which contains the set of statements and rules which allow to formulate the conception and construct on its basis the decision-making process, is chosen or developed. If the theory doesn't exist, then a hypothesis is set up and imitation models are created on its basis, by means of which the possible variants of a research are investigated.

In order to help to set a task on the tight schedule, analyze aims, provide with possible means, to choose the required information (characterizing the condition of the decision-making and influencing the choice of criteria and restrictions) and ideally to obtain the expression which connects the aim with the means, system representations, techniques and methods of system analysis are applied.

Content