# Set-Theoretic Model of the Telemedicine with Patient State Consideration

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*Abstract* – **it is developed set-theoretic model for the system of telemedicine services.**

*Keywords* – **telemedicine, set-theoretic model, emergent telemedicine services.**

## I. INTRODUCTION

Permanent increasing of working temp and modernization of the medical equipment enlarge the data capacity for analyzing by the medical stuff. This situation defines the need of telemedicine systems use for solving various problems in health facilities, ranging from simple diagnosis of the patient and the tasks of emergent telemedicine.

For this purpose, it is necessary to formalize the medical information and tools for its processing and transmission in consideration with international standards. This task belongs to a class of complex and hardly-formalizing problems. Its solutions is associated with the use both formal and heuristic approaches to modeling. The designed model has to be adequate to describe the process of collecting, processing, storage and transmission of telemedicine information and the development of topologies and structures of telemedicine systems to automate and improve the diagnosis of the patient state.

## II. MAIN PART

The analysis of well-known definitions and characteristics of the organization and principles of functioning of telemedicine allowed formalizing the patient as a set of coefficients:

$$\mathbf{S^{\circ}<A, QA, R, QR, B, Z, CU, DT, N, LN>.} \qquad (1)$$

where: $\mathbf{A=\{a_1, a_2,\dots, a_n\}}$ – is the set of diagnosis elements; $\mathbf{Q_A=\{q(a_1), q(a_2),\dots, q(a_n)\}}$ – is the set of telemedicine elements properties, $\mathbf{R=\{r_1, r_2,\dots, r_m\}}$ – is the set of functional and communication connections between the elements of telemedicine; $\mathbf{Q_R=\{q(r_1), q(r_2),\dots, q(r_m)\}}$, – is the set of properties of connections between the telemedicine elements; $\mathbf{B=\{B_1,B_2,\dots,B_n\}}$ – is the vector of the telemedicine network parameters; **Z** – is the goal for achieving extreme values of telemedicine network efficiency criteria; **U** – - terms of achieving the goal, D**T**– is the interval of setting an adequate diagnosis (decision); **N** – a person or group of persons who make a decisions, **LN**– is the observers communication language.

This paper proposes the method of the telemedicine systems development and analysis, its aims and functions definition, which includes structuring method and structure's evaluation methods. It provides a choice of original structures and the most appropriate for the class of diagnostics methods of its evaluation. Purposes and functions structure forms as a graph model.

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Initial data for the purpose of telemedicine system structuring are the follows: Z – is an overarching goal of telemedicine; the set of criteria K={k1,k2.,km}, which determine the operational efficiency of telemedicine; the set of components and subsystems of the telemedicine S={s1,s2.,sk}; the set of tasks F={f1,f2.,fr}; the set of D={d1,d2.,db} determines medical and organizational business processes.

Let's define the conceptual model of telemedicine in some formal way, which allows defining the rule (operator) of input X parameters transformation into the output Y:

$$\mathbf{Y=W(Z,X)} \qquad (2)$$

where W – the transformation rule (operator), which is a combination of mathematical and logical operations, or set-theoretic representation allowing to establish a correspondence between input parameters and states and output parameters.

The set-theoretical model objective is formed as conversion functions and output function. It is established the correspondence (output function) between the elements of set Y and elements of the sets X and Z in general as fuzzy matching:

$$\mathbf{\tilde{q} =<\{(V´U´PP´W´S)´(Z_1´Z_2´\dots´Z_n)\},}$$
$$\mathbf{(K´PW´R´RP),}\tilde{G}>, \qquad (3)$$

where $\tilde{G}$ - is a dynamic graph of fuzzy matching $\tilde{q}$.

Between the elements of the set Z and elements of sets X and Y there is compliance (conversion function), which in general should also be considered as a fuzzy matching:

$$\tilde{j}\ \mathbf{=<\{(V´U´PP´W´S)´(Z_1´Z_2´..´Z_n)\},}$$
$$\mathbf{(Z_1´Z_2´..´Z_n),\ \tilde{F}}>,(4) \qquad (4)$$

де $\phi\%$ - is a dynamic graph of fuzzy matching.

For practical use of telemedicine task is reduced to comparing the actual state of the patient with standard conditions and determine the closest reference standard state. Thus, it is decided the disease diagnosis or chosen of reference appointments in that fuzzy situation. The essence of the model is shown on fig. 1.

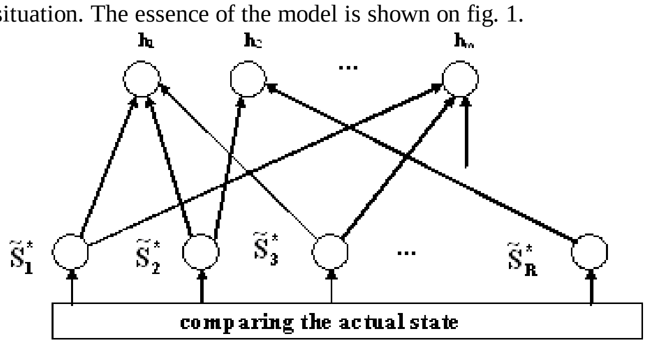


Fig.1. Patient state formalizing for the telemedicine system

Standard conditions are defined by the set of $\mathbf{S^* = \{\tilde{S}_1^*, \tilde{S}_2^*,\dots, \tilde{S}_R^*\}}$, which consists of the elements h1,h2,...,hm. $\tilde{S}$ - is a second-order fuzzy set which describes the patient state:

$$\tilde{S} = \{<\mu_S(a_i)/a_i>\},\ a_i \in A\ , \qquad (5)$$

where $a_i,\ (i=\overline{1,n})$, is a linguistic variable *i* which characterizes ***i***-component of the fuzzy state $\tilde{S}$ .

Patient state is characterized with some fuzzy situation $\tilde{S}_i^*$. For determining the proximity of real and fuzzy situations it is used the standard operations on fuzzy logic. As a result, it is obtained the follows: n – is a quantity of linguistic variables that characterize the patient's condition; the set of linguistic variables, defined fuzzy sets, specified second-order fuzzy sets (the set of fuzzy standard situations):

$$S^* = \{\tilde{S}_k^* = \{<\mu_{S_k^*} a_i)/a_i>\}\},\quad i=\overline{1,n},\ k=\overline{1,R}. \qquad (6)$$

The fuzzy reference on the elements of the set S* defining the fuzzy standard situations and on the elements of the set H defining decision making is set as triple set $\tilde{\Gamma} = (S^*, H, \tilde{F})$, in which $\tilde{\Gamma} = (S^*, H, \tilde{F})$ is a fuzzy set of $S^* \times H$.

The medical experts define fuzzy standard situations $\tilde{S}_i^*$ for making decision. For determining the proximity of real and fuzzy situations it is used the operations on fuzzy logic.

For solving the structural optimal synthesis task it is selected the integral criteria. All methods of integral criterion definition can be reduced to its generalized form:

$$F = \frac{\sum_{i=1}^{m} b_i f_i}{F_0} \qquad (7)$$

where ***fi*** – is a criteria; $F_0$ – standard effectiveness value; bi – expert rating of the criteria ***fi*** importance.

Integral criteria formalizing can be shown as a task on multidimensional linear observation's model:

$$h = b_0 + \sum_{1<i<k} b_i x_i + \sum_{1<i<j<k} b_{ij} x_i x_j + \sum_{1<i<j<l<k} b_{ijl} x_i x_j x_l + \ldots +$$
$$+ b_{123\ldots k} x_1 x_2 x_3 \ldots x_k\ , \qquad (8)$$

where $b=(b_1, b_2,\ldots, b_n)^T$ – is the ***n*** - dimensional vector of undefined parameters (linear effects); $\{f_j=(x_1,x_2,\ldots,x_p)\}$ – are defined functions; $b_{ij}$, – are the second-order interaction effects; $b_{ijk}$, - are the third-order interaction effects etc.

Let's define the integral assessment function of the telemedicine system effectiveness on the basis of linear observation's model without considering any interaction effects:

$$Q = \sum_{i=1}^{n} b_i f_i + \sum_{1\le i<j\le n}^{n} b_{ij} f_i f_j + \sum_{1\le i<j<k\le n}^{n} b_{ijk} f_i f_j f_k + \ldots + b_{12\ldots n} f_1 f_2 \ldots f_n\ . \qquad (9)$$

The set of criteria F={f1,f2...,fn} is defined as vector of medical center output parameters.

As part of developed telemedicine structural model it is performed a formalization of patient parameter's vector. The components of the patient parameter's vector can be formalized in the form of three parameter's types: numerical, set and verbal.

## III. Conclusion

It is proposed the set-theoretic model of telemedicine, which is characterized using the concept of complex systems, formalization of the patient parameters in the form of fuzzy intervals and linguistic variables. It is systemized the results of the expert's survey and algorithmized the information flows and information's processing.

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