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Basics of creating an applied intelligent system for diagnostic and management of illness cognition of patients with neurological pathology

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Abstract. The article is devoted to the creation of an applied intelligent system used for diagnosis and management of illness cognition of neurological pathology patients (IS DIMIC). The applied IS DIMIC is constructed based on the intelligent instrumental software IMSLOG using matrix method of data and knowledge representation, test methods for pattern recognition, fault-tolerant irredundant unconditional diagnostic tests and fault-tolerant mixed diagnostic tests. The application of applied IS DIMIC will allow to reveal various kinds of regularities of the patients' illness cognition on the basis of features that determine the peculiarities of basic constructs reflecting the process of cognitive overestimation of the illness consequences. The applied IS DIMIC will allow to make diagnostic decisions and justify them using graphic tools, including cognitive ones, which is very important for patient rehabilitation management.

1. Introduction
The feasibility of creating intelligent systems (IS) in the field of medicine, psychology, biology, ecobiomedicine [1–13] and for a number of others is well recognized. The solution of the problem of diagnostic and management of illness cognition (DIMIC) of neurological pathology patients is currently very relevant [14, 15]. This problem is interdisciplinary one, since high-quality diagnosis of a wide range of individuals requires both the use of modern methods of clinical psychology, psychiatry, sociology, and new methods of discrete mathematics, mathematical logic, pattern recognition, reliability, soft computing, system analysis, and statistics in order to build applied IS.

2. Problem Area Description
Both the relevance of diagnosis and management of cognitive ideas about the disease of patients with neurological pathology, and the rapid development of information technology have intensified research on the creation of diagnostic IS [1-3, 9]. The rationale for creating diagnostic IS based on various methods of pattern recognition is given in publications [1-3]. Among the expert diagnostics and IS diagnostics, we note the system for selecting new recruits for the army [4]; for the diagnosis of phobias FEARDEX [5]; for preliminary diagnosis of mental disorders [6]; for the diagnosis and

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decision support for depression [7, 8]. Very significant results were obtained by Russian scientists and presented in the publications [2, 3, 9, 10, 12, 16].

The approaches we propose to create an applied IS DIMIC are certainly relevant, since they are important in the diagnostic and management of the consequences of the most common diseases, especially for patients with neurological pathology, which entails severe psychological, social and somatic consequences for the patient and his environment, such as disability [14, 15]. Thats why it is necessary to develop diagnostic tools to determine disease psychological consequences and appropriate approaches to manage it. Unfortunately, we are not aware of analogues in the scientific literature on the construction of similar applied IS.

A prerequisite for the creation of an applied IP DIMIC was the work performed in the TGASU Laboratory of Intelligent Systems on the IS creation to identify various regularities and making medical decisions of a diagnostic, therapeutic, organizational and managerial nature, including military applications, environmental medicine, clinical psychology, etc. IS were constructed on the basis of IIS IMSLOG based on a matrix method of presenting data and knowledge, on test methods for pattern recognition, fault-tolerant irredundant unconditional diagnostic tests and fault-tolerant mixed diagnostic tests, making and substantiating decisions using graphical, including cognitive, tools [2, 3], as well as fuzzy and threshold logic [11, 12].

Analysis of the current state of research in the field of considered applied IS construction showed that for making and justifying a decision on the illness cognition diagnostic and management, it is advisable to use test methods for pattern recognition. In this connection, it is necessary to analyze data and knowledge, to structure them in the field of clinical psychology and choose a model for data and knowledge representation about the illness cognition of patients and the mathematical apparatus for creating the applied IS DIMIC. Applied IS DIMIC is created using fuzzy and threshold logic. This system is designed to identify various kinds of regularities between the parameters (signs) of illness cognition:

1) reducing the negative meaning of a stressful event of the disease (acceptance);
2) reflecting a positive reformulation of the disease situation (perceived benefits);
3) emphasizing the negative meaning of the disease (helplessness).

3. Matrix representation of data and knowledge

The applied DIMIC is constructed on the basis of the IMS IMSLOG [13] and is based on the matrix model of data and knowledge representation, including an integer matrix of description **Q** and a distinction matrix **R** [2]. The rows of the Q matrix are compared to training objects (patients with different neurological pathologies in accordance with ICD-10 (Parkinson's disease (G20), multiple sclerosis (G35), spinal osteochondrosis (M42), stroke consequences (I69), dizziness and impaired stability (R42)) [17]. Columns **Q** matrix are compared to characteristic features (CF) of illness cognition: acceptance, perceived benefits, helplessness. The $q_{i,j}$ element of the **Q** matrix sets the value of the j-th feature for the i-th object. If the value of the sign is not significant for the object, then this fact is indicated by a dash in the corresponding element of the matrix **Q**. For each CF z_j, $j = 1, 2, ..., m$, either the intervals of change of its values or an integer value are specified.

The rows of the matrix **R** are assigned to the rows of the matrix **Q**, the columns of the matrix **R** are assigned to the classification features (ClF): *k1, k2, ..., l* (*l* – number of classification features), which divide the learning objects into equivalence classes [2]. The set of all non-repeating rows of the distinction matrix is mapped to the set of selected patterns represented by a one-column matrix **R'**, whose elements are the numbers of the patterns.

This model allows to represent not only the data, but also the knowledge of experts, since one row of the **Q** matrix can be specified in an interval form (using the dash "-" symbol) a subset of objects characterized by the same final solution, given by the corresponding row of the matrix **R**. An example of a matrix representation of data and knowledge is shown in Figure 1.

$$
\boldsymbol{Q}=\begin{array}{cc}
\begin{array}{ccccccccccc} z_1 & z_2 & z_3 & z_4 & z_5 & z_6 & z_7 & z_8 & z_9 & z_{10} & z_{11} \end{array} & \\
\left[\begin{array}{ccccccccccc}
1 & 4 & 6 & 3 & 2 & 2 & 1 & 2 & 3 & 4 & 1 \\
4 & 4 & 5 & 2 & 3 & 2 & 7 & 8 & 3 & 4 & 1 \\
3 & 4 & 5 & 3 & 3 & 2 & 4 & 5 & 3 & 4 & 1 \\
3 & 4 & 4 & 1 & 4 & 4 & 2 & 3 & 1 & 5 & 1 \\
2 & 4 & 2 & 1 & 6 & 3 & 4 & 5 & 2 & 3 & 1 \\
2 & 4 & 5 & 1 & 3 & - & 4 & 3 & 1 & 2 & 1 \\
1 & 4 & 3 & 2 & 5 & 2 & 1 & 2 & 3 & 4 & 1 \\
3 & 4 & 2 & 2 & 6 & 2 & 2 & 3 & 3 & 2 & 1 \\
5 & 4 & 2 & 2 & 6 & 3 & 5 & 6 & 2 & 4 & 1 \\
4 & 4 & 6 & 1 & 2 & 5 & 5 & 6 & 1 & 4 & 2
\end{array}\right] &
\begin{array}{c} 1\\2\\3\\4\\5\\6\\7\\8\\9\\10 \end{array}
\end{array}
\quad
\boldsymbol{R}=\begin{array}{c}
\begin{array}{cc} k_1 & k_2 \end{array} \\
\left[\begin{array}{cc}
1 & 2 \\ 1 & 2 \\ 1 & 2 \\ 2 & 1 \\ 2 & 1 \\ 2 & 1 \\ 1 & 3 \\ 1 & 3 \\ 3 & 2 \\ 3 & 2
\end{array}\right]
\end{array}
\quad
\boldsymbol{R'}=\left[\begin{array}{c}
1 \\ 1 \\ 1 \\ 2 \\ 2 \\ 2 \\ 3 \\ 3 \\ 4 \\ 4
\end{array}\right]
$$

Figure 1. Matrix presentation of data and knowledge.

According to the above matrix model, we represent the data and knowledge in the considered area by the matrices **Q** and **R**. The rows of the matrix **Q** represent various combinations of CF values. CF include CF of illness cognition:

z_1 - acceptance of the disease (number of CF - 6),

z_2 - perceived benefits of the disease (number of CF - 6),

z_3 - helplessness (number of CF - 6).

We form a diagnostic matrix **R**, the number of ClF of which is 5. The name and values of ClF are as follows:

1st ClF is a sign that reduces the negative meaning of the stressful event of the disease (acceptance of the disease, perceived benefits of the disease);

2nd ClF - signs that emphasize the negative significance of the disease (presence, lack of helplessness);

3rd ClF - the severity of acceptance of the disease (low, medium, high);

4th ClF - the severity of perceived benefits of the disease (low, medium, high);

5th ClF - the severity of helplessness (low, medium, high).

A database and knowledge will be created based on the results of a study of patients with neurological pathology who are being treated in neurological clinics.

4. A brief description of the mathematical foundations of building applied intelligent system

The base of data and knowledge of the applied IS DIMIC is created on the basis of the knowledge of highly qualified experts on neurological pathology patients, who are being treated in neurological clinics, features of illness cognition, as well as on the basis of medical history data and expert diagnostic solutions for the studied.

The construction of the space of characteristic features for recognizable subjects (patients) is carried out on the basis of a study of patients, and the values of classification features for recognizable subjects will be revealed by using the applied IS DIMIC.

Applied IS DIMIC is based on the original matrix model of data and knowledge representation, the convergence of several sciences and scientific fields [16], the identification of various kinds of regularities, on test logical–combinatorial methods of pattern recognition, decision making and decision-justification with the use of graphic, including cognitive, tools [13].

The regularities in knowledge will be understood as the following subsets of features [2]:

1) **constant** (taking the same value for all patterns);

2) **stable** (constant inside the pattern, but not constant);

3) **uninformative** (not distinguishing any pair of objects of different patterns);

4) **alternative** (in inclusion in diagnostic tests (DT));

5) **dependent** (in the sense of including subsets of distinguishable pairs of objects);

6) **unessential** (not included in any non-redundant DT);
7) **obligatory** (included in all irredundant unconditional diagnostic tests (IUDT));
8) **pseudo-obligatory** (not obligatory but included into all IUDTs that are involved in decision making);
9) **subsets of signal attributes of the first** (distinguishing the studied objects from two patterns) and **the second kind** (distinguishing the studied objects belonging to one image, with objects belonging to another image);
10) **CF weighting coefficients** (distinguishing objects from different classes (patterns));
11) **IUDT weighting coefficients**;
12) **all minimal** and **all** (or **part - at** a large feature space) **irredundant distinguish subsets of features**, which are, in fact, the **minimum and IUDT.**

In the presence of measurement errors of certain features or their entry, original test methods for pattern recognition, fault-tolerant (FT) IUDT and fault-tolerant mixed diagnostic tests (FTMDT) are used, which are the optimal combination of unconditional and conditional components; voting procedure on a variety of decision rules; final decision making and its justification using cognitive graphics tools [2].

5. Construction of applied intelligent system

The construction of an applied IS DIMIC is carried out in 5 stages (the first four of which are based on IIS IMSLOG [13]):

1) systematization and structuring of data and knowledge in the field of clinical psychology, determining the functional composition of applied IS DIMIC, its architecture and methods most suitable for revealing regularities in data and knowledge and making decisions relatively illness cognition of patients with neurological pathology;
2) layout of the required configuration of the applied IS DIMIC by connecting corresponding software modules to the core (with automatic registration);
3) creation of a knowledge base module by means of a knowledge analysis module and optimization of the knowledge base, processing a knowledge module to revealing regularities by which a set of decision rules is formed, used later by the decision module and justification of decisions using cognitive tools for analyzing the illness cognition of patients with neurological pathology;
4) configuration the applied IS DIMIC for specific customer;
5) installation of an applied IS DIMIC on customer base.

Since the mathematical apparatus and the rationale for making decisions that underlie the construction of the applied IS DIMIC are presented in many publications devoted to the construction of the IIS IMSLOG and the construction of the applied IS based on it, we present in Figure 2 only the block scheme of the final decision using the applied IS DIMIC.

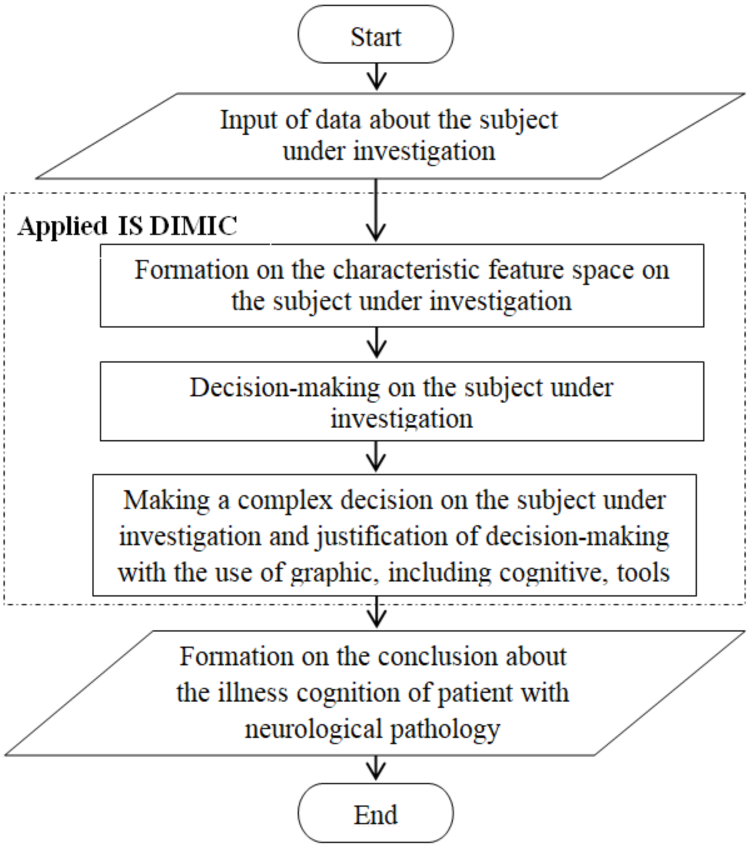

Figure 2. The block scheme of the final decision using the applied IS DIMIC.

Thus, the application of the applied IS DIMIC in practical health care will allow specialists to quickly and efficiently make diagnostic decisions, as well as justify these decisions using graphic, including cognitive, tools, which will improve the quality of the assistance provided.

6. Conclusion

We have proposed the creation of an original applied intelligent system for the diagnostic and management of illness cognition of neurological pathology patients. Such system is appropriate in practical health care due to the need to make diagnostic decisions efficiently, quickly and in time, and to justify these decisions using graphic, including cognitive, tools.

For the first time the analysis, structuring of data and knowledge of patients with various above-mentioned neurological pathology was carried out. The mathematical apparatus of the applied IS DIMIC is based on the convergence of several sciences and scientific areas. We have used the matrix method of representing data and knowledge (matrix of descriptions and differences); original test methods for pattern recognition; the reveal of various kinds of regularities, including negative images; alternative, dependent and signaling signs; making decisions and their justification using graphic tools, including cognitive ones.

IS DIMIC is constructed on the basis of the IIS IMSLOG, designed to reveal various kinds of regularities, including fault-tolerant diagnostic tests and their weight coefficients; making decisions and their justification using cognitive graphics. The base of data and knowledge will be created based on the results of a study of patients with neurological pathology being treated in neurological clinics.

The proposed applied IS DIMIC will make it possible to quickly reveal of various kinds of regularities of patients' illness cognition based on signs that determine cognitive strategies for acceptance, perceived benefits, helplessness. The appropriateness of using the applied IS DIMIC is associated with the need to improve the quality and reliability of diagnostic results based on brief questionnaires. Applied IS DIMIC is economical in terms of time and human resources; easy to use; is capable to timely issue an opinion and supply a specialist (doctor and psychologist) with information for further work.

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