**ABSTRACT**

The aim of the work is to study the algorithmic solutions of non-invasive medical remote monitoring of human health based on the wearable biosensor platform in the mode of everyday wear. The relevance of the topic is due to the need to improve the quality and reduce the cost of medical services provided to the population due to the release of medical personnel from the painstaking and lengthy analysis of complaints, anamnesis, examination, laboratory research, shortening the time for specialists to select, search and summarize information, giving the opportunity about the adoption of health of the patient on the basis of visualization, convenient for visual perception, visualized by analytical methods of geometry concise generalized by diagnostic picture. The proposed method is implemented on the basis of non-invasive medical monitoring of human health based on the wearable biosensor platform in the mode of everyday wear. The relevance of the topic is due to the need of ideological recognition of geometrized images. The work responds to global trends in contextual visualization of large streams of heterogeneous data.

**KEYWORDS**

Biosensor platform, diagnostication, non-invasive monitoring, nosology, cloud technologies, body sensory network, telemedicine, digitalization.

1. **INTRODUCTION**

The peculiarity of the task of automating medical diagnostic procedures is that the processes of current pairing of heterogeneous data from biosensors fixed on the patient's body with personal and reference information extracted from the knowledge base in most cases cannot be strictly formalized. This circumstance hinders the evolution of medical sensor-network technologies in world practice and stimulates the development of methods for establishing a clear affiliation of the state vector of a biological object to a characteristic diagnosis, as well as methods for compact and, if possible, full data visualization.

The developed method of geometric modeling the interactive diagnostic processes of a medical monitoring object (patient) differs from analogs by the possibility of visual representation of fuzzy information in a geometrized form, which increases the possibilities of data interpretation in medical terms. The algorithm underlying the method automatically recognizes the most reliable diagnosis, predicts the nature of the course of the disease and its outcome.

The goal of the research is achieved by optimizing the management of virtual geometrized objects, reflecting the current state of the patient's health. The introduction of the method will improve the accuracy of diagnosis and will ensure the scaling of medical tasks in the sense of generalizing them to large groups of people on critical characteristics. It will also improve the efficiency of measures taken according to the results of an automated survey by providing specialists with the capabilities of a comprehensive analysis of systematized data summarized in a vivid integral geometric model that allows quantitative and comparative evaluations of diagnostic signs and differentiates between therapeutic and preventive measures by population groups.

2. **MATERIALS AND METHODS**

The formulation of the task of diagnosis and diagnostic prediction is set out in [1]. To solve a particular problem of geometric visualization, the algorithm proposed in [1-4]. The problem in the general formulation is solved in two stages. The initial data are taken from the detectors of the sensor network of signals [5]:

\[ U = \{U_i\}, i=1,N \]  

(1)

Where \( U \) – output signals; \( N \) – sensor network detectors.

At the first stage, the training of the intellectual diagnostic system is carried out on test samples with a priori given composition of signs corresponding to known diagnoses. Herewith the formation of arrays of diagnostic is signing according to the results of an automated survey by providing specialists with the capabilities of a comprehensive analysis of systematized data summarized in a vivid integral geometric model that allows quantitative and comparative evaluations of diagnostic signs and differentiates between therapeutic and preventive measures by population groups.
RESULTS AND DISCUSSION

0...1

Combination of signs \( \Omega[S, C] \) reflect variations in the patient’s health status and may indicate the presence of some diagnosis.

At the second stage, by successive comparison of the current value of a set of symptoms \( U \) with reference diagnoses \( \widetilde{U} \). The condition of the organism is determined to be the closest diagnosis according to the condition:

\[
\mu = \| U^\nu - U \| < \frac{E}{\min} + \epsilon
\]  

This measure is applicable for the final set of reference diagnoses. However, the diagnostic error in the joint matrix processing of data on \( U \) non-linearly increases from the number of sensor-sensor networks.

In the proposed method, the accuracy of the fuzzy model is increased by reducing the dimensional space through the use of Kohonen maps [6]. The positive effect can be illustrated by the following example. Let the sensor network include 10 sensors. Accordingly, the dimension of the measurement matrix will be \( m = 10 \times 10 \), and the number of elementary mathematical operations when solving a regression problem using the Gauss method is determined by the formula [7]:

\[
k = m^2 / 3 = 1000 / 3 = 333
\]  

The number \( k \) is critical - the errors included in the matrix elements are inherited; they are subjected to multiple multiplication and subtraction operations and increase the uncertainty with increasing \( k \). Offered instead of matrix \( 10 \times 10 \) use 10 two-dimensional functions of time, on each of which the current values of the pairwise signals will give the coordinates of a point, while calculations are not needed at all, since \( k = 0 \). Accordingly, inherited errors are also absent. These intermediate results in the next stage of processing are transferred to the plane of solving the geometric problem of pattern recognition (Figure 1).

\[
\Omega[S, C] \rightarrow \Omega[S, C] \text{ (k=0)}
\]

Measure (3) allows you to quantify the proximity of the assessment of the current state of health \( \Omega[S, C] \) to the supporting area marked out when teaching a fuzzy system [8]. Thus, visualization is achieved by lowering the dimension \( (N+M) \) – dimensional space \( (N \) options, \( N \) biosensors, \( N > 3 \)) by projecting it into a Kohonen two-dimensional map with a set of \( N \) indicators \( C \) in the form of a point with coordinates \( (c_1, c_2) \), and allows a medical interpretation of a pair of diagnostic signs.

4. Convolution \( N \) – two-dimensional graphs \( \Omega[S, C] \), on each of which \( m \) points, \( x \) characterizing states – in \( m \) two-dimensional coordinate systems, each of which will contain only scaled coordinates characterizing pairs of diagnostic features:

\[
\{ U_{i,m} \} \text{, } i = 1, N - 1; U_i \in \{ 0...1 \}
\]

In accordance with (1), any response of a parameter \( (u_i, u_j) \) in the coordinate system (6) has a prototype in the form of a point with coordinates \( (c_1, c_2) \), and allows medical interpretation of a pair of diagnostic signs.

5. Selection of characteristic invariants in geometric images of states that are diagnostic characters.

6. Transform \( \Omega[S, C] \) – Error! Reference source not found., of vector \( \widetilde{U} \) reference signs to bring the compared geometric images to the same context.

7. Identification of a probable diagnosis by calculating the maximum coincidence of the images of the current value with a set of supporting signs by finding the minimum of the criterion:

\[
\Delta = \min \text{, } j = 1...M
\]

Where \( M \) – the number of diagnoses in the reference database.

To calculate measure (8), characteristic geometric points or regions of polygons can be used — interactive and from the base of diagnoses. For example, when overlaying images: the distance between the centers of gravity of polygons, their respective vertices, the ratio of perimeters and areas, the proximity of intersections of certain medians, bisections or diagonals, the distance between arithmetic averages of the coordinates of corners, areas of overlapping areas of parts of figures, etc. These figures are calculated by methods analytical geometry. A polygon can be triangulated and fragmentary analyzed using the mathematical apparatus of set theory, trigonometry, sine and cosine theorems.

3. RESULTS AND DISCUSSION

The obtained fuzzy geometric model reflects the topology of the prototype – the human body and allows for a meaningful interpretation in a medical diagnostic context. On the diagrams, it is possible to state that the state of the organism is out of the normal range or to detail the causes of the
disturbance in the normal functioning of the organism. The search algorithm detects patterns by which groups of characteristic diagnostic features are identified. The distances between the vertices and the magnitude of the angles of the polygon can indicate the hidden links between the signs or the presence of prerequisites for the development of certain diseases. The search for characteristic invariants allows you to create lists of probable diagnoses and rank them.

A visual geometrized map provides convenient classification and grouping of patients, marking of the diagnostic space and a compact combination of heterogeneous data on one image for ease of comparative analysis. For automatic interpretation of a geometric model, the stability of the distance between a pair of signs in two-dimensional coordinate systems (7) and proximity to the optimal value in (8) of the most probable diagnosis number are most valuable. These indicators may serve as a possible basis for the appointment of an additional examination of the patient to confirm the identified symptoms.

The movement of characteristic points in (7) beyond the established norms for pairs of signs, as well as the registration of their movement in sectoral risk directions, can serve as indicators of the threat to health problems. The approximation of the geometric shape of the polygon to some contours recognized critical for groups of homogeneous diseases may also indicate an increased danger.

For the convenience of visual perception, the "correctness" of a geometric figure is achieved by selecting normalization scaling coefficients [9]. The mathematical calculations for 2D Kohonen maps can be applied with equal success to 3D maps, which contributes to the improvement of visual perception and complexity of monitoring [10,11]. With the same purpose, background tinting, selection of the contours of certain sides of the figures, hatching of zones, tracking with interactive text or speech machine comments, pop-up queries, etc. are used.

An algorithmic solution was obtained for non-invasive medical remote monitoring of human health based on body-worn biosensor platform in everyday wear mode, characterized by a geometric form of biomedical data presentation and advanced interpretation by experts, which provides an increase in the accuracy of recognition of the diagnosis according to characteristic symptoms [12].

4. CONCLUSIONS

The approach based on fuzzy logic has the advantage that, when used, it is possible to dispense with building a rigorous mathematical model that drastically loses efficiency in terms of noise and data redundancy. The geometric model takes into account the scaling of the functions of the complex in time, the set of objects of observation, as well as the variation of the parameters of diagnostic processes in the ranges of changes in physiological parameters of the human body.

The practical and theoretical significance of the results obtained is to ensure the convenience of visual perception and understanding by specialists of multiple heterogeneous information due to the consistency, complexity and compactness of the form of its presentation. Further studies suggest testing automatic diagnostic algorithms for patient groups. At the same time, special attention will be paid to geometric visualization of characteristic features for early recognition of diseases, prediction of the course and outcome of diseases.

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