Algorithms for individual assessment of future changes in heart condition

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Abstract. The goal of the research is to develop and implement algorithms for individual assessment of possible changes of the heart condition in the future by means of software based on the results of previous examinations. The input data is presented by the results of cardiac examinations and individual patient parameters. In accordance with dynamics analysis results of the cardiac function changes, the mathematical models of diseases are elaborated. The certainty factor is calculated, demonstrating the probability of a patient having this disease. The testing of the proposed algorithm on the objects of the training and control samples is then performed.

Keywords: algorithm, individual prognosis, heart disease.

1. Introduction

Assessment of possible future changes in the patient's heart condition is one of the cardiologist's most important tasks in prescribing treatment and recommendations. To achieve this, it is necessary to conduct a detailed analysis of the medical history, which is represented by a multitude of parameter values obtained through a variety of examinations. It is important to monitor the dynamics of changes in the parameters of work over time for prior periods to assess how the condition of the heart will change in the future [1,2].

Goal of research is to develop algorithms for individual assessment of possible changes of the heart condition in the future.

The condition of the heart is determined by values of performance parameters.

Each of the diseases of the cardiovascular system corresponds to a certain value or the interval of parameter values**.** Since diagnosis and assessing future changes need to be analyses a lot of parameters, it is very difficult and time consuming to determine the compliance of parameter values with the patient’s heart disease.

Most intervals of characteristic values are close to each other in various diseases $Y_m, m = 1,2,3,...,M$. Therefore, we will use a relative assessment of the probability of occurrence of the researched attribute analyzed value with the given disease. Therefore, it is necessary to analyze the histogram of characteristic values for each disease. Besides, it is important to take into account the significance values of investigated parameters for the studied diseases [3].

2. Methods

The algorithm for computing the importance of signs for the diagnosis of cardiovascular diseases consists of the following steps:

1. The histogram of characteristic values $Q = \{q_i\}$ is calculated using the known algorithm [2] for each disease $i = 1,2,3,...,I$.
2. The maximum, minimum and average values of characteristics in groups of diseases, and standard deviation are calculated [3]:

$$p_{\max,\pi}^{Y_m} = \max_j p_\pi^{Y_m}$$

$$p_{\min,\pi}^{Y_m} = \min_m p_\pi^{Y_m}$$

$$p_{avg,\pi}^{Y_m} = \frac{1}{\left|p_\pi^{Y_j}\right|}\sum_m^M p_\pi^{Y_m}$$

$$p_{std,\pi}^{Y_m} = \sqrt{\frac{\sum_m^M (p_\pi^{Y_m} - p_{avg,\pi}^{Y_m})^2}{\left|p_\pi^{Y_m}\right|}}$$

where $\left|p_\pi^{Y_m}\right|$ is the number of values of π-th symptom in the disease Y_m .

3. The coefficient of the resistance characteristic is calculated, showing the relative spread of values:

$$Kust_{\pi,Y_m} = \frac{p_{std,\pi}^{Y_m}}{p_{avg,\pi}^{Y_m}}$$

4. The minimum deviation of the average characteristic value with the given disease Y_m from the values of this attribute in the disease are calculated Y_{m-1}:

$$Kmo_{\pi,Y_m} = \min_q \frac{p_{avg,\pi}^{Y_m} - p_{avg,\pi}^{Y_{m+1}}}{p_{avg,\pi}^{Y_m}} .$$

5. The width of the interval is determined and the ratio of the width of the interval is calculated for assessment of scatter of the characteristic values:

$$Ksh_{\pi,Y_m} = \frac{\left|p_{\max,\pi}^{Y_m} - p_{\min,\pi}^{Y_m}\right|}{p_{avg,\pi}^{Y_m}} .$$

6. The weighted resistance characteristic within the group is calculated, which allows to take into account that he common value characteristic and rare characteristic value make a different contribution to the quantitative assessment of the properties:

$$Kust'_{\pi,Y_m} = \frac{1}{\left|p_\pi^{Y_m}\right|} + \sum_{m=1}^M \left[\frac{p_\pi^{Y_m} - p_{avg,\pi}^{Y_m}}{p_{avg,\pi}^{Y_m}} \cdot Q\left(p_\pi^{Y_m}\right)\right].$$

7. The complex ratio of the importance of the symptom for the disease is calculated:

$$k_\pi^{Y_m} = \frac{Kmo_{\pi,Y_m} \cdot Kust'_{\pi,Y_m}}{Ksh_{\pi,Y_m}} . \quad (1)$$

Thus, the significance of symptoms is determined by their statistical properties.

To assess the reliability of individual assessment of future changes the calculated certainty factors calculated

$$KY^{Y_m}(\pi+1) = KY^{Y_m}(\pi) + \mu^{Y_{mj}}(d_{\pi+1}) \cdot k_{\pi}^{Y_m} \cdot \left[1 - KY^{Y_m}(\pi)\right], \tag{2}$$

where $KY^{Y_m}(\pi+1)$ - the certainty factor in the presence of the disease given the symptom $(\pi+1)$, $\mu^{Ym}(d_{\pi+1})$ is the membership function $d_{\pi+1}$ of the symptom for the disease Y_m.

The membership function μ^{Ym} is represented by the probability of finding the characteristic value in this interval. It is calculated as follows:

1. The interval of characteristic values is divided into small sections.
2. The occurrence number of characteristic value from the training sample is calculated for each section. Thus, the histogram of the characteristic value is calculated.
3. Each sign is compared with the occurrence probability of the characteristic in the interval where its value is located.

The algorithm for calculating the certainty factor is constructed in such a way that it represents the iterative process where the coefficient is determined at each step with provision for new feature. Therefore, the coefficients $\{KY^{Y_m}(\pi)\}$ are a series of numbers. If the disease is recognized, these series converge to the unit. The certainty factor is calculated for all cardiovascular diseases investigated. The higher the certainty factor fort he given cardiovascular disease, the more probability of a patient having this disease.

The value of certainty factor is used in the development of mathematical models for assessing the possible changes in cardiovascular diseases:

$$Y_m = KY^{Y_m} \cdot \frac{1}{1+e^{-(\beta_0+\beta_1 d_1^i+\beta_2 d_2^i+...+\beta_{16} d_{16}^i)}} \tag{3}$$

The use of certainty factor as a multiplier contributes the element to the mathematical model describing the CVD in general terms that takes account of the individual patient characteristics and the behavior in the characteristics value of the work of heart-vascular system over time.

Thus, the algorithm for an individual assessment of future changes is presented in the figure:

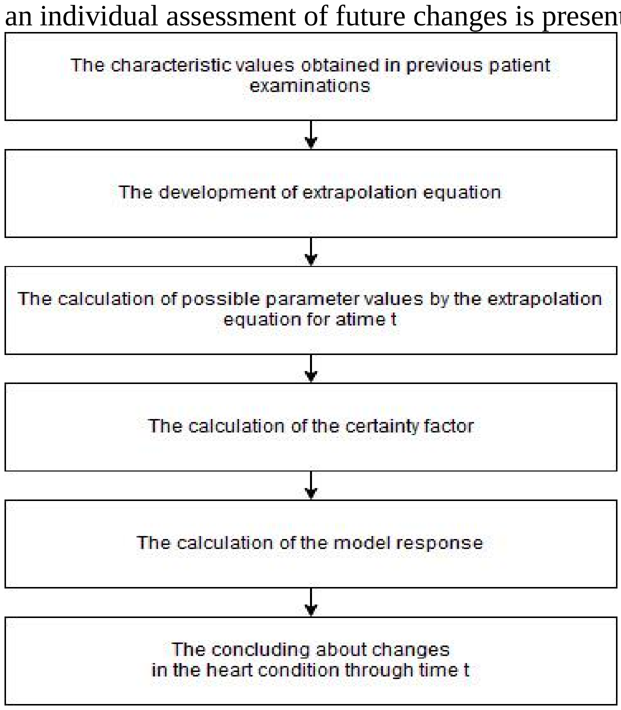

Figure 1. The algorithm for individual assessment in the heart condition.

A number of parameters values describing the heart condition are formed during examination, where changes could contribute the predict formation. The offered algorithm offers to account the influence of all parameters at the disposal of the doctor. Moreover, the more detailed the patient's examinations were, the more accurate predict would be.

3. Results and Discussion

The experimental research of the algorithm was carried out on the sampling, containing the results of an examination of 104 patients observed for 3-5 years at a frequency of once every six months. The sampling size is 908 registers. Each patient was examined using the cardiovascular screening system "CardioVisor-06C", blood pressure measuring was carried out, anthropometric options of patients and complaints were analyzed. Heart's images were segmented into 15 areas, color channels R, G, B were allocated. For each area, six statistical characteristics of the first order and 13 statistical characteristics of the second order were calculated. The number of analyzed options was 1740 elements.

In accordance with the algorithm presented in Figure 1, an assessment of future changes was carried out for the short-term period of 2-3 months (Table 1) and for the long-term period of 12-15 months (Table 2).

Table 1. An assessment of future changes for the short-term period.

CDV	**Initial condition**	**Assessment of future changes**	**Properly predict**	
			Absolute values	**%**
Y_1	15	15	15	**100,00**
Y_2	11	14	10	**90,91**
Y_3	13	12	10	**76,92**
Y_4	9	9	7	**77,78**
Y_5	17	15	13	**76,47**
Y_6	11	17	10	**90,91**
Y_7	15	9	11	**73,33**
Y_8	13	12	10	**76,92**
Total	**104**	**104**	**86**	**82,91**

Table 2. An assessment of future changes for the long-term period.

CDV	**Initial condition**	**Assessment of future changes**	**Properly predict**	
			Absolute values	**%**
Y_1	14	14	13	**92,86**
Y_2	10	12	7	**70,00**
Y_3	11	12	7	**63,64**
Y_4	9	7	6	**66,67**
Y_5	13	10	9	**69,23**
Y_6	11	12	7	**63,64**
Y_7	14	11	9	**64,29**
Y_8	11	14	7	**63,64**
Total	**93**	**92**	**65**	**69,24**

Thus, as a result of the survey this approach allows for a individual assessment of the presence and changes this type of illness the patient for short periods with a probability of proper assessment of future changes of at least 73%, and for long-term periods with a probability of at least 63%, which is a particularly important for the doctor - cardiologist in deciding about current and further treatment.

The probability of correct prognosis in healthy patients for short periods was 100%, and for the separated 92%. Patient patients for short periods were identified correctly with a probability of 79%, and in remote cases - 66%.

4. Conclusion

The offered algorithm for individual assessment of the patient's condition allows:

1. Analyze existing results of patient examinations, because of their importance to diagnose of heart diseases under consideration.

2. To take into account the dynamics of changes in the parameters of circulatory system of a given patient in the course of time.

3. To take into account the specific meaning of the sign for determining the existence of the disease under consideration the patient.

4. Help the cardiologist when making recommendations and making a diagnostic decision.

5. References

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