COMPOSITE HEALTH INDEX BASED ON HEART RATE VARIABILITY

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Introduction

Expert studies [1] show, that ECG signals contain information about functioning of all body systems, not only heart. At the same time each disease "modulates" ECG signal in a unique way. In this regard, it is possible to create tools that can analyze the state of health on the basis of HRV.

Electrocardiography is a widely used non-invasive method of recording electrical changes in the heart [2]. The recording, called an electrocardiogram (ECG), shows a series of waves associated with the electrical impulse that occurs during each heartbeat. The results are printed on paper or displayed on your computer screen. monitor. The waves in the normal recording are called P, Q, R, S and T.

The purpose of this paper was to write software that would provide users with the ability to analyze heart rate variability to determine a person's overall health.

Heart rate variability

Heart rate variability (HRV) analyzes the physiological phenomenon of fluctuations in the interval between consecutive heartbeats [3].

Feature extraction is one of the most important steps in the classification scheme. The Pan-Tompkins algorithm [4] can extract the QRS part of the ECG signal and extract statistical characteristics such as mean, variance and standard deviation.

The transfer function of the second-order recursive low-pass filter used in the algorithm is as follows:

$$H(z) = \frac{1 - 2z^{-6} + z^{-12}}{1 - 2z^{-1} + z^{-2}}. \quad (1)$$

The high-pass filter is defined:

$$H(z) = \frac{-1 + 32z^{-16} + z^{-32}}{1 + z^{-1}}. \quad (2)$$

The QRS complex is characterized by the steepest gradient (rate of voltage change) of the signal. Because the rate is given by a derived operator, Pan and Tompkins suggested using this operation as the basic operation for detecting the QRS complex. This procedure suppresses the P and T wave components and amplifies the QRS complex components.

Subsequent squares make the result positive and amplify the components of the QRS complex.

After applying the derivative and squaring operators, the output signal shows a large number of peaks during the QRS complex. Therefore, the smoothing process is performed using a sliding window type integral filter specified:

$$y(n) = \frac{1}{N}\left[x\big(n - (N-1)\big) + x\big(n - (N-2)\big) + \dots + x(n)\right], \quad (3)$$

where N is the width of the window.

The choice of the window width is based on the following considerations: if the window is too wide, the complex and the T-wave will be combined, and if the width is too small, there will be several peaks in one QRS complex.

The threshold search method adapts to the changes in the ECG signal by calculating the motion estimates of the peaks associated with the signal.

This method was chosen for the project because the definition of the QRS complex is very accurate and easy to implement.

The index of activity of regulatory system

In order to display the level of health in the project, the PARS (activity index of regulatory systems) method was used [5]. These indices are calculated in coefficients according to a unique set of rules, which takes into account the facts of statistical signs, histogram signs and spectral evaluation of cardio-intervals. PARS was proposed in the early 80's (Baevsky R.M. (1964)) and proved to be very effective in assessing the adaptive abilities of the organism.

PARS values are presented in the form of ranking from 1 to 10. On the basis of the evaluation of PARS values, the following practical states can be diagnosed:

- state of optimum regulatory system anxiety necessary to maintain a stable body-environment balance (PARS = 1-2);
- state of moderate anxiety about the regulatory device, while the structure desires further practical reserve to adapt to environmental conditions. This state occurs within the method of adapting to work, accompanied by intellectual pressure, or under the influence of environmental hazards (PARS = 3-4);
- level of perceived regulatory system anxiety associated with active mobilization of defense mechanisms, which include increased sympathetic and pituitary-adrenal system activity (PARS = 5-6);
- state of inordinate regulatory system anxiety, characterized by loss of protective and adaptive mechanisms, lack of ability of the body to adequately respond to environmental factors. At the same time, inordinate activation of the regulatory device is now not supported by the corresponding practical reserve (PARS = 7-8);
- state of depletion (malaise) of the regulatory mechanism, in which the efficiency of the regulatory mechanism decreases (lack of regulatory mechanisms), characteristic symptoms and symptoms of pathology appear. Here, positive modifications are absolutely successful compared to non-unique ones (PARS = 9-10).

The calculation of PARS is performed step by step using a set of rules that takes into account the next 5 criteria:

- total effect of regulation by pulse rate (HR);
- total change in regulatory mechanisms through the same old deviation - SD (or through total spectrum energy - TP);
- autonomic stability according to a hard and fast set of signs: In, RMSSD, HF, IC;
- activity of the vasomotor center, which regulates vascular tone, according to the energy of the first-order gradual waves (LF) spectrum;
- activity of the cardiovascular subcortical nerve of the middle or suprasegmental levels of the law through the energy of the spectrum of gradual waves of the second order (VLF).

To fully assess the parameters of coronary heart disease variability, R. M. Baevsky proposed a method of calculating the efficiency index of regulatory systems (PARS) in accordance with 5 criteria.

The criteria for evaluation of individual states and characteristics of cardiac rhythm regulation system according to its mathematical analysis are presented below [6] (table 1).

Table 1

Criteria for evaluation of conditions and characteristics of the heart rhythm regulation system

Characteristics of the regulatory system	**Criteria for their evaluation**		
Cumulative effect of regulation		rNN	
+ 2 Severe tachycardia		< 0.66	
+1 Moderate tachycardia		< 0.80	
0 Normocardia		0.8…1.0	
-1 Mild bradycardia		> 1.00	
-2 Severe bradycardia		> 1.20	
Cardiac automatism	SDNN	dX	CV
+2 Stable rhythm	< 0.02	< 0.10 M	< 2.0
+1 Severe sinus arrhythmia	> 0.10	> 0.30 rNN	> 8.0
0 Moderate sinus arrhythmia		0.1 rNN…0.3 rNN	
-1 There is a moderate arrhythmia disorder		> 0.45 rNN	
-2 Severe automatic disorder	> 0.10	> 0.60 rNN	> 8.0
Autonomic homeostasis	dX	AMo	ИН
+2 Significant prevalence of SNA	< 0.06	> 80	> 500
+1 Moderate prevalence of SNA	< 0.15	> 50	> 200
0 Autonomic homeostasis intact	0.15…0.3	30…50	50…200
-1 Moderate prevalence of PSNS	> 0.30	< 30	< 50
-2 Significant prevalence of PSNS	> 0.50	< 15	< 25
Stable regulation		CV	
+2 Dysregulation		< 3.0	
0 Sustained regulation		3.0…6.0	
+2 Dysregulation		> 6.0	

Subcortical nerve centers activity	VLF/TF	LF/TF	HF/TF
+2 Significant increase of PNC activity	> 70 %	> 25 %	< 5 %
+1 Moderate increase of PNC activity	> 60 %		< 20 %
0 Normal VPC activity	40...60 %		20...30 %
-1 Moderate weakening of PNC activity	< 40 %		> 30 %
-2 Significant weakening of PNC activity	< 20 %		> 40 %

The obtained values are summed up and the result is a PARS score.

Next, a simple application was developed that determines the signs of QRS complex from the incoming ECG signal and then determines PARS (Figure 1).

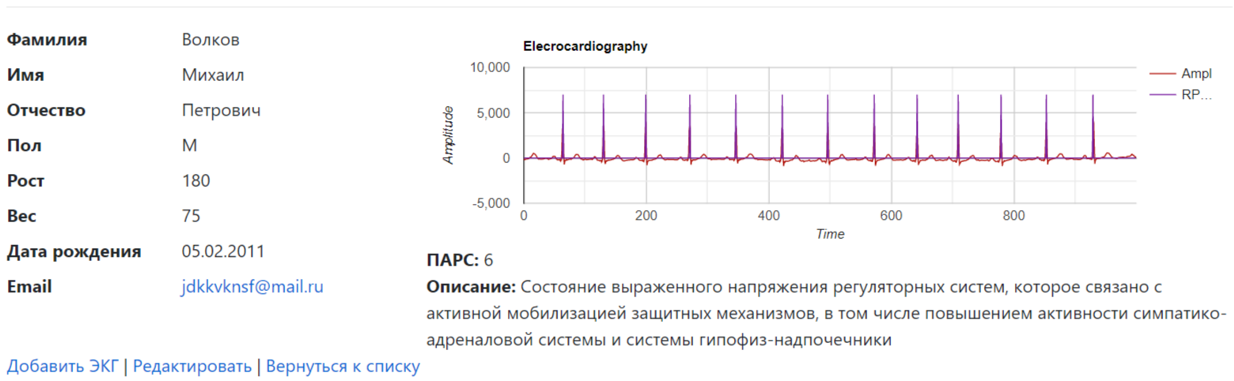

Fig. 1. Finding a fragment of a scene in a video file

Conclusion

This work was implemented as part of the graduate qualification work. The goal of determining a health index based on heart rate variability was achieved by writing an application that finds R-peaks on the output ECG signal and calculates the overall health level based on the PARS.

References

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