The Development Prospects of Heart Rate Monitor

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ABSTRACT
Nowadays, heart rate monitors are common to be seen in daily life. However, current monitors are simple and sometimes provide inaccurate results. Thus, a sophisticated heart rate monitor is critical for researchers to invent. This paper focuses on the development of a heart rate monitor. This paper mainly discusses the improvement of ECG(electrocardiogram) and PPG(photoplethysmography). Researchers can use second-order difference minimum and first-order difference zero crossing in ECG and analyze the skin optical model of rPPG signal in PPG, in order to make previous data more precise. This improvement can be used on heart rate monitors which collect more detailed information. Most of the resources in this paper are from professor Lingyun Zhun and professor Bingxun Li.

Keywords: *ECG, PPG, Heart rate monitor, Future improvement.*

1. INTRODUCTION

Nowadays, cardiovascular disease remains the most common cause of death in Europe, accounting for 45% of all deaths, equivalent to 4 million deaths per year. [1] In addition, coronary heart disease is the most common cause of death, causing 19% of men and 20% of women to die. The number of deaths is far greater than that of female breast cancer (2%) and male lung cancer (6%).[2] The current wireless heart rate monitor is one of the best devices to remind people of cardiovascular disease. This is because that wireless heart rate monitor is worn near blood vessels or the heart so they can detect abnormalities in the body more quickly. However, current heart rate monitors cannot satisfy everyone's needs. Thus, the future development of heart rate monitors seems important. This paper introduces methods of improving PPG recording and ECG recording which also assist in heart rate monitors development. Plus ECG will use second-order difference minimum and first-order difference zero crossing, and PPG will know the blind source separation method and the wavelet threshold denoising method and VMD-ICA algorithm in theory. Therefore, this development can provide fundamental assistance for future heart rate monitors.

2. ANALYSIS OF THE PRINCIPLES OF THREE METHODS FOR MONITORING HEART RATE

In the current state, heart rate monitoring is based on three methods, which are ultrasonic inspection, PPG recording and ECG recording. The heart rate monitoring instrument is based on Doppler ultrasound technology and uses the principle of the Doppler effect to detect moving organs and blood flow. Also, the Doppler ultrasonic technology is mainly applied to fetal.[3] In daily life, it is common for people to see ECG recordings. An electrocardiogram records the electrical signals in people's heart. It's a common and painless test used to quickly detect heart problems and monitor people's heart health. ECG uses electrodes attached to the skin to monitor electrical impulses in the heart.[4] The heart is in every cardiac cycle-pacemaker point, atrium, ventricle is excited successively, accompany the change of cardiac muscle cell action potential, the change of this biological electricity is namely cardiac electricity. Bioelectrical signals are captured and digitally processed to produce accurate, detailed information about heart health. ECG is the most accurate way to measure heart rate in medical devices. Some smart wearables have sensors that measure electrical signals from the heart muscle contractions to determine a user's heart rate, similar to an ECG, which can be relatively accurate. However, ultrasonic inspection is mainly used for fetal inspection which is seldom use for personal heart rate monitoring.

PPG stands for photoelectric volumetric pulse wave, which can be used to monitor heart rate. [5]The principle is to irradiate blood vessels for a period of time through the green LED lamp of a smart wearable device with a photosensitive photodiode. Because red blood can reflect red light and absorb green light, when the heart beats, the blood flow increases, and the absorption of green light increases accordingly. There is less blood flow between beats, and less green light is absorbed. This allows PPG technology to measure heart rate based on the absorbance of blood. Specifically, when a light beam of a certain wavelength hits the skin surface, it is transmitted through transmission or reflection to the photoelectric receiver. During this process, the light beam is absorbed by the skin muscle and blood, resulting in attenuation, and the intensity of the light detected by the detector is reduced. Among them, the reflection of the skin, bone, muscle and fat of the human body to light is a fixed value, and the volume of capillary and arteries and veins is under the action of the heart with the pulse constantly changing larger and smaller. When the heart contractions, the peripheral blood volume is the largest, the amount of light absorption is also the largest, the light intensity detected is the smallest; However, when the heart diastole, the situation is just the opposite, so that the light intensity received by the light receiver subsequently shows a fluctuating change, thus reflecting the heart activity. In the next part, the author will introduce two ways of improving PPG and ECG.

3. METHODS FOR THE IMPROVEMENT OF ECG RECORDING AND PPG RECORDING

3.1 Methods for the improvement of ECG recording

Nowadays, the main problem of ECG recording is its precision. So, enhancing the precision is vital to improve ECG recording. There is a method introduced by Lingyun Zhun. [6] Firstly, aiming at the limitation of the traditional difference threshold method to detect the QRS group, a real-time detection algorithm is proposed to accurately locate the QRS group of ECG signal by using second-order difference minimum and first-order difference zero crossing. The algorithm improves the signal-to-noise ratio of the second-order and first-order differential signals by four-point smoothing filtering and is more conducive to the detection of signal feature points. The setting of detection threshold with adaptive and self-learning functions improves the accuracy of accurate detection and location of QRS wave groups and enhances the anti-jamming ability and robustness of the algorithm. Secondly, rough set theory is used to extract ECG signal characteristic information. At present, the extraction of ECG signal characteristic information is based on experience and subjective assumptions of researchers, there is no theoretical basis for reference. Rough set theory has been a methodology of database mining or knowledge discovery in relational databases. In its abstract form, it is a new area of uncertainty mathematics closely related to fuzzy theory. People can use a rough set approach to discover structural relationships within imprecise and noisy data. [7] A knowledge representation system based on rough set theory can be used. ECG information is taken as a conditional attribute of the ECG knowledge representation system, and the diagnostic results of the ECG signal are taken as decision attribute to establish the ECG information decision table. In addition, ECG signal is extracted and processed by multi-domain feature information. In view of the current ECG signal characteristic information extraction only depends on the time domain, frequency domain or wavelet domain information. The union of the multi-domain characteristic subset is regarded as ECG characteristic information set. It can reflect disease information represented by ECG signal comprehensively, objectively and fully, and improve the accuracy and completeness of characteristic information. Finally, the method of automatic classification of arrhythmias based on support vector machine (figure 1) is studied. In view of the shortcomings of current ECG automatic classification methods, a support vector machine (SVM) is proposed to realize ECG signal automatic recognition and classification. The results show that ECG classification based on SVM is better than the other two classification algorithms and more suitable for automatic diagnosis of heart disease.

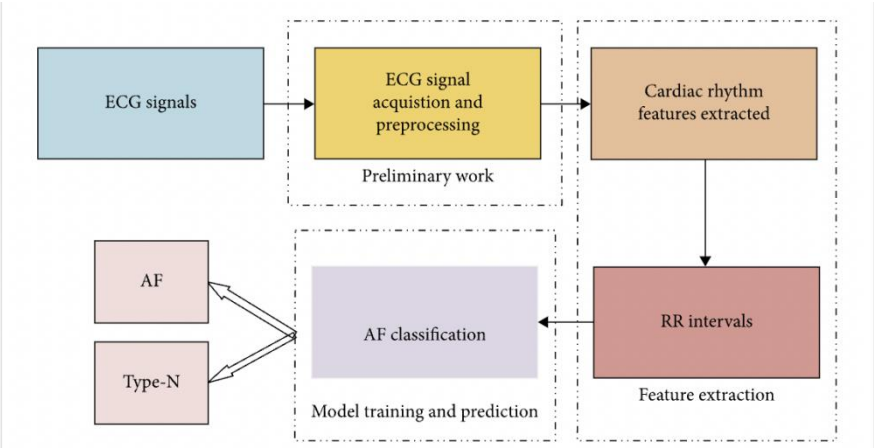

Figure 1. The process of identification and analysis of AF in wearable ECG monitoring equipment.[8]

3.2 Methods for the improvement of PPG recording

PPG recording has the same problems as ECG recording which is the precision of collected data. This method is provided by Bingxun Li. [9]About PPG recording, firstly, the skin optical model of rPPG signal is analyzed. (Figure 2) Based on this model, the PPG signal is analyzed in terms of signal generation principle and signal composition, and the characteristics of the PPG signal are studied, and the processing methods of the PPG signal are analyzed according to the unique characteristics of the PPG signal. It provides a basis for the research and selection of PPG signal processing methods. Second, the human face video is filmed and the original PPG signal is detected from it. Through the comparison of the characteristics of PPG signal, adaboost algorithm realized the detection and location of human face ROI region in MATLAB, and completed the detection of original PPG signal by averaging the pixel space of RGB three channels of human face ROI region image, and analyzed the inaccuracy of previous blind source separation methods in processing the optical characteristics of PPG signal. Then vmD-ICA combined denoising algorithm was applied to PPG signal denoising and motion artifact elimination. The algorithm principle and flow of VMD-ICA joint noise reduction algorithm are analyzed PPG signal decomposition and the significance of the concept, and expounds the flow chart of the algorithm and the specific steps, from rPPG signal characteristics on the principle and algorithm on rationality, feasibility and superiority of the proposed algorithm, and the original G channel PPG signal as the input signal to realize the algorithm, got the periodic good, smooth remote PPG signals. Finally, the detection results of rPPG signal detection methods are compared. To know the blind source separation method and the wavelet threshold denoising method and VMD - ICA algorithm in theory and the signal characteristics are analyzed, and the PPG signal of heart rate estimation as an evaluation standard of PPG signals, to mean a clip-on pulse measuring instrument for the standard heart rate value, selected the heart rate estimation method and error calculation method for finished results contrast. First in the four kinds of signal noise reduction algorithm of eliminating the motion artifact results and comparison of the advantages of the proposed algorithm is verified, and then studied under the condition of different light sources and heart rate estimation results under different imaging equipment, light conditions are discussed and the impact of imaging equipment for rPPG signal detection and some of the possible, finally discussed the detection method through the experiment of stability Qualitative, practical and inadequate. On the basis of previous work, rPPG signal detection methods are studied and analyzed in this paper, a new method of signal noise reduction and motion artifact elimination is proposed for the optical properties of rPPG signal, and the detection results generated by different conditions in rPPG signal detection are studied and discussed, in order to provide some reference and suggestions for the development of non-contact physiological information detection methods in the future.

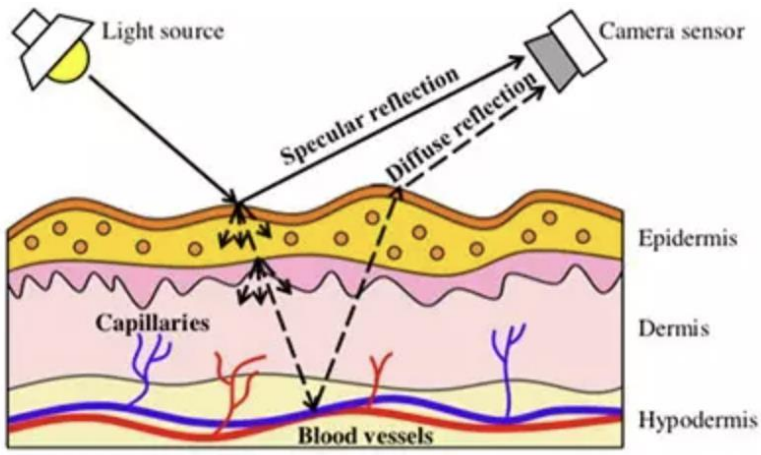

Figure 2. The skin reflection model that contains specular and diffuse reflections, where only the diffuse reflection contains pulsatile information [10]

4. CONCLUSION

In the current state, scientists can focus on developing ECG recording and PPG recording. For ECG recording, researchers can use second-order difference minimum and first-order difference zero crossing. For PPG recording, researchers can use skin optical of rPPG signal. These methods can both enhance the precision of monitoring data. However, the heart rate monitor can also be more accurate. Since different person have different body structures, researchers can invent personal heart rate monitor based on different person, which can make the data more accurate.

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