A WEARABLE SYSTEM WITH REAL-TIME DIAGNOSIS OF ARRHYTHMIA BASED ON FUZZY ALGORITHM

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Abstract— Most arrhythmias are hard to detect in the early stage without regular health diagnostics, and often this leads to patients discovering arrhythmia after they had already reach a lethal stage. If one could diagnose and analyze the data in advance to start the treatment of arrhythmia, there would be less cases that fail to benefit from the golden treatment period. This paper develops an automatic recognizing arrhythmia electrocardiogram (ECG) signal measurement and monitoring system, using the light and wearable device to extract single-lead ECG signal and transmit through Bluetooth to the system receiver. The system uses Dynamic Threshold Crest Detection (DTCD) method to calculate ECG time sequence feature values then convert and analyze to acquire the average heart rate, QRS complex duration, and heart rate variability (HRV) for fuzzy system input parameter. The data are classified by fuzzy inference and degree of membership analysis. The inference of this system is not required to build complicated mathematical models and training samples, thus it possesses a simple and rapid advantage. According to the experiment results, this system can be effectively used to diagnose 5 types of cardiac arrhythmia and give feedback to users immediately. Data stored can be applied as the diagnostic assessment indicators for physicians in order to achieve the goal of disease prevention.

I. INTRODUCTION

According to the World Health Organization (WHO), cardiovascular disease has been the most common cause of death worldwide, with an average of more than 17 million deaths each year, accounting for 30% of the world's total deaths, of which 7.4 million People died of heart disease, 6.7 million people died of stroke, it is estimated that by 2030 the number of global deaths, will climb to 23.6 million per year [1, 2]. Heart disease has a high risk of recurrence and death, but premature death caused by cardiovascular disease is mostly avoidable, and heart disease is not caused by a short time, but the first arrhythmia (Arrhythmia) omen [3]. Therefore, how to use information technology and sensing devices in the daily monitoring and immediate diagnosis of the user's heart rhythm, is a very important issue.

Arrhythmia can lead to irregular heartbeat, mild patients will Arrhythmia can lead to irregular heartbeat, mild patients will have headaches, shortness of breath, chest pain or bleeding and other symptoms, severe cases may lead to stroke or even sudden death [4]. Most of the heart arrhythmia are not easy to detect the early abnormalities, if there is no usual detection of the habit, may lead to the patient found in the heart when the condition is already quite serious. Patients even learned that suffering from arrhythmia, due to the occurrence of the majority of its associated paroxysplasty, to the hospital during the emergency examination is difficult to present from the traditional ECG instrument symptoms, so patients in their daily lives must be monitored at any time Record the status of ECG. Most of today's medical use Hort 24-hour continuous ECG machine (Holter monitor) to record heart disease ECG signal, but the instrument in addition to the high price, wear more cumbersome, only for data recording action [5], patients still Must go to the medical unit in person for physicians or professionals to carry out manual diagnosis and treatment can not be pre-automatic analysis of information.The aim of this study was to provide a set of ECG monitoring system and to automatically identify arrhythmia. The use of low-cost, lightweight and low-power characteristics of the Bluetooth wearing device, to capture the user single-lead (single-lead) ECG signal, and single-lead ECG signal can be analyzed with limited effective characteristics of this study (QRS complex) [6], so the QRS complex wave can be used to know the RRI and QRS complex wave interval, and then the QRS complex wave (19) We can diagnose the normal sinus rhythm (NSR) and five arrhythmias: Sinus Bradycardia (SB), sinus tachycardia (sinus tachycardia) (ST), Premature Ventricular Contraction (PVC), Ventricular Tachycardia (VT) and Ventricular Flutter (VF). With the software system of this study, the user can immediately monitor the ECG signal and data storage analysis, keep abreast of their own rhythm situation. Can be safe to use home without the need to visit the medical unit, if the first time to find abnormal heart rate can quickly seek medical treatment, and thus achieve the purpose of disease prevention, storage of data can also assist physicians as diagnostic indicators.

II. SYSTEM DESIGN

The system is divided into two parts in Figure 1: wearing device and receiver system. The first part is responsible for the capture and transmission of ECG signal. The ECG signal in the device will pass through the high-pass filter (cut-off frequency = 0.5 Hz), signal amplifier, A / D converter (16 bit), Notch filter (center

frequency = 50 Hz & 60 Hz), low pass filter (cutoff frequency = 100 Hz), and then through the Bluetooth module HC-06, wavesen, Inc., China) Transfer ECG data to the second part .The receiver system receives data packets from the Bluetooth receiver. The second part is the focus of this research, the received continuous packet disassembly to obtain the original signal (raw data), digital signal processing (DSP) such as software signal amplification, moving average filtering (moving average filtering) So that the signal high-frequency noise filter to facilitate the subsequent waveform analysis. The Q, R and S peak positions were found by dynamic Threshold Crest Detection (DTCD). The ECG timing features such as RR Interval (RRI), QRS complex duration (QRS complex duration) And its related computing data storage. Finally, the rhythm of the arrhythmia is deduced by the fuzzy algorithm.

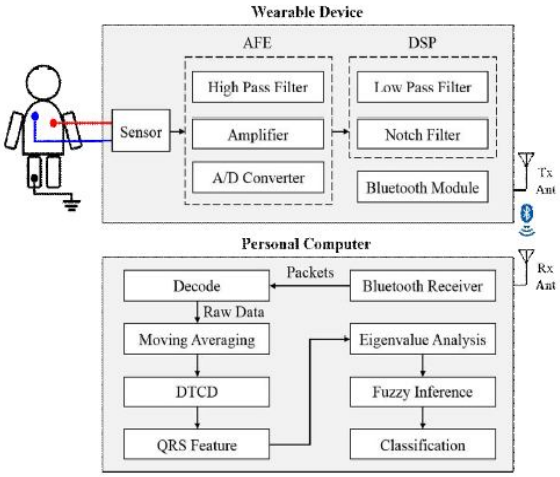


Figure 1. System architecture

A. Fuzzy System Design

In this study, we used fuzzy algorithm to classify the arrhythmia data. Figure 2 is the design flow of the fuzzy system in this study, which is divided into the establishment of input and output variables, the establishment of related terms, the definition of membership function (MF), the establishment of fuzzy rules rule database, fuzziness, and Defuzzification. Finally, the six rhythms are classified according to the degree of membership of the system output.

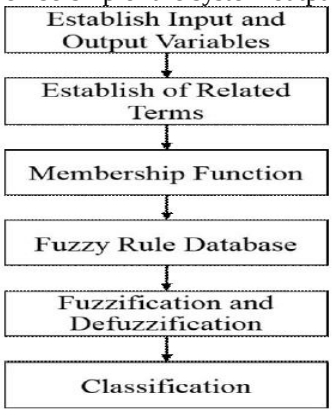


Figure 2. The fuzzy system design process

B INPUT AND OUTPUT VARIABLES

In this study, the eigenvalues analyzed by the measured data are taken as the input of the fuzzy system. The output is the degree of arrhythmia, and the system is classified according to the degree. The parameters of the fuzzy system are shown in Figure 3. The input parameters have the total mean heart rate (HR), the average QRS complex (QRS) and the heart rate variability (HRV), and the output is six rhythms (SB), sinus tachycardia (ST), ventricular contraction (PVC), ventricular frequency (VT) and ventricular flutter (VF) were measured, including normal sinus rhythm (NSR), sinus bradycardia (SB) The The fuzzy inference within the system is the minimum and minimum synthesis (Min-Min-Max) proposed by Mamdani in 1975. De-fuzzification uses the Center of Gravity (COG) to solve the explicit output (Crisp).

The fuzzy system will output the membership of the six rhythms, the values are between 0-1, the representative of the degree of the rhythm, the system finally according to the output of the membership of the data classification. This study has been tested repeatedly to set the membership threshold of the classification to 0.7, and it is determined that this threshold has the best classification accuracy. If the six memberships have a maximum greater than 0.7, their data will be classified into the results; if the six membership values are no greater than 0.7, then the data will be classified into the seventh category "ELSE" category, that the data can not Interpretation or may be other arrhythmia.

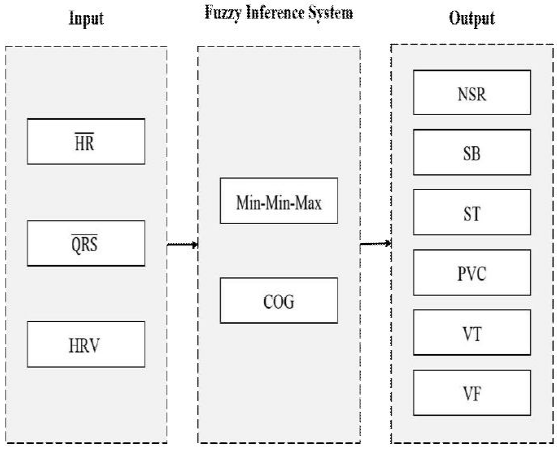


Figure 3. Parameter design of the fuzzy system

C LINGUISTIC TERMS AND MEMBERSHIP FUNCTION

The term established for each parameter is usually at least three, for example, "large, medium and small". In this study, the input parameter (HR) is divided into five levels: "L", SL (slightly lower), M (middle), SH (slightly higher), H (high), (QRS) 6, the output parameters NSR, SB, ST, PVC, VT, VF are divided into "UL (very low), VL (super)," Low (low), SL (slightly lower), M (middle), SH (slightly higher), H (high), VH (ultra high), UH (very high) nine levels.

Table 1. The 6 kinds of rhythms characteristics in this paper [7]

HR \ QRS	< 120ms	> 120ms
< 60 bpm	SB	
60-100 bpm	NSR	PVC
> 100 bpm	ST	VT
150-300 bpm		VF

After the term is established, it is necessary to define its membership function for each term. The function graphs are triangular (Trimf) and trapef (Trapmf) fuzzy numbers. Each rhythm has its own characteristics, such as normal sinus rhythm (NSR) HR is usually in the range of 60-100 bpm, and QRS Complex Duration will be less than 120 ms [8]. Based on this rhythm feature table, this study defines the knowledge and experience of arrhythmia, defines the terms and membership functions of the fuzzy system.

D EXPERIMENTAL AND RESULTS

In the actual measurement experiment, the feasibility of the whole operation of the system was tested in the non-arrhythmia subjects. In order to verify the correctness of the algorithm, the experiment took MIT-BIH arrhythmia database data. MIT-BIH arrhythmia database is one of the internationally recognized standard ECG database, which has been widely used by many related research institutions [9].

E ACTUAL MEASUREMEN

In the system measurement (actual measurement), the experiment will continue to measure the same non-arrhythmia subjects (male, age 25 years, height 175 cm, weight 73 kg), each measurement time of about 30 seconds, and ECG data storage statistics and analysis, as shown in Figure 10, the results of this study, in this study diagnosis of arrhythmia of the three eigenvalues available (HR)¯70 bpm, (QRS)¯103 ms, HRV is 86 ms. The three parameters as a fuzzy system input, through the fuzzy inference, the membership output can be obtained in the NSR 0.84 the highest, exceeding the system classification threshold of 0.7, the system will be the measurement data classified in the NSR category, and in the comments column to inform the user Heart rhythm is a normal sinus rhythm (NSR). In this study, 15 experiments were performed in this way. Fifty-nine data were correctly classified in the NSR category. Therefore, in the system, the system was 100% accurate in the diagnosis of NSR.

CONCLUSION

With the change of social patterns and the improvement of people's health awareness, the use of wear-type devices to monitor the physiological signals, and thus prevent the occurrence of disease has become the direction of today's wisdom of medical care. This study uses a low-cost, lightweight wearing device, the construction of a set of ECG signal monitoring system, and can be objective and automated identification of arrhythmia. In this study, we use fuzzy algorithm to ECG timing characteristics as the basis of inference and classification of arrhythmia, do not need to construct complex mathematical model and a large number of sample training, so it has the advantages of fast, for the wearing device in the sensing data in real-time transmission And the operation has a great advantage. Experiments through the actual measurement and access to MIT-BIH database data to verify the system, the results confirmed that the system can effectively diagnose the user's rhythm is normal or abnormal, and can identify five arrhythmia, immediate feedback users may suffer There is the type of arrhythmia, even if the symptoms are not recognized by the type of system, can still be diagnosed with abnormal heart rhythm. Nowadays, the development of the wearable device is not yet reached, but it has not yet reached the point of absolute precision. It still needs a long course of development. Although the wearable system of this study is not ideal, it can effectively diagnose the abnormal health condition and use it , And then early treatment, to achieve the purpose of preventing disease deterioration.

In addition to the immediate monitoring of ECG signals, through the data storage analysis, users can keep abreast of their own heart rhythm. In the algorithm part, the future can add more ECG eigenvalues as a basis for arrhythmia identification, increase the system accuracy and diversity. At present, the system only supports Windows operating system, the future can go to Android and iOS platform development, the system built on the smart device, increase its carrying convenience, so that the measurement is not subject to location restrictions, and with other sensors, such as Acceleration and gyroscope, the sensing data analysis and action to identify the azimuth, and then achieve the movement monitoring and health management, to provide users with more applications.

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