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Spectral of electrocardiographic RR intervals to indicate atrial fibrillation

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Abstract. Atrial fibrillation is a serious heart disease, which is associated with the risk of death, and thus an early detection of atrial fibrillation is necessary. We have investigated spectral pattern of electrocardiogram in relation to atrial fibrillation. The utilized feature of electrocardiogram is RR interval. RR interval is the time interval between two consecutive R peaks. A series of RR intervals in a time segment is converted to a signal with a frequency domain. The frequency components are investigated to find the components which significantly associate to atrial fibrillation. A segment is defined as atrial fibrillation or normal segments by considering a defined number of atrial fibrillation RR in the segment. Using clinical data of 23 patients with atrial fibrillation, we find that the frequency components could be used to indicate atrial fibrillation.

1. Introduction

Atrial fibrillation is a serious heart disease, which is associated with the risk of death. It is the problem in the heart atrial. During atrial fibrillation, the heart atrial beats chaotically and irregularly. A serious risk of AF is stroke [1]. This situation could increase mortality.

Early detection for atrial fibrillation is important to conduct appropriate actions which might reduce healthcare costs and improve patient care [2]. These actions are also necessary to prevent the serious complications of atrial fibrillation. Therefore, approaches have been investigated to detect atrial fibrillation early. Varied algorithms have been studied to find a sophisticated atrial fibrillation detection system accurately and quickly [3, 4]. Electrocardiographic features are often utilized for atrial fibrillation detection.

Neural network for an atrial fibrillation detection has been investigated by [5]. The approach detection employs probabilistic neural network and a wavelet feature of electrocardiogram. A neural network algorithm for atrial fibrillation is also investigated by (Mateo et al., 2013). This approach uses radial basis function (RBF) neural network and utilizes electrocardiographic features by cancelling the electrocardiographic QRST complex.

This article presents spectral features of electrocardiographic RR intervals for atrial fibrillation detection. RR interval is the time interval between two-consecutive R peaks of electrocardiogram [6]. RR interval represents heart rate. Heart rate of the heart in patient with atrial fibrillation fluctuates,

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opposing the normal heart which beats stably. This happen as a result of that the atrial of the heart beats chaotically and irregularly.

2. Method
This article explores a study of the spectral of electrocardiographic RR interval for atrial fibrillation detection. Firstly, the data of electrocardiographic R peaks are obtained from Physionet [7]. The electrocardiograph is recorded from 23 patients. The recording is 10 hours in duration for each patient with sampling rate of 250 samples per second.

From the R peaks, RR interval is defined. It is the time interval between two consecutive R peaks. RR intervals is then segmented or windowed with a defined length. The length of segment is 60 RR intervals. A segment is defined as atrial fibrillation or normal by considering the number of atrial fibrillation happening in the segment. If the number of atrial fibrillation is more than a defined number, the segment is defined as atrial fibrillation. The other situation is defined as normal. The number of atrial fibrillation refers to the number of RR interval which is defined as atrial fibrillation.

The spectral of RR interval is defined from the defined segment. The spectral is obtained using fast Fourier transform (FFT). FFT computes Discrete Fourier Transform (DFT) defined as [8]:

\[ X(k) = \sum_{n=0}^{N-1} x(n)e^{-j2\pi kn/N} \]

Using FFT, frequency components of the segment are presented. The amplitude of the components are investigated. The amplitude of the component is used to identify the related segment is associated to atrial fibrillation or non-atrial fibrillation. The identification (or the detection) is conducted using comparing the amplitude with a defined threshold. The performance of the detection is presented in term of accuracy. The accuracy is defined as the number of correct detection divided by the total number of data. In the other words, the accuracy is the correctness of both atrial fibrillation and normal events. Moreover, a segment is defined as atrial fibrillation or normal by considering the number of atrial fibrillation beats in the segment.

![Figure 1. RR intervals pattern types of atrial fibrillation and normal. The high and low levels of square signal indicate the states of atrial fibrillation and normal, respectively.](image)

3. Results

3.1. RR intervals during atrial fibrillation
We have obtained electrocardiographic RR intervals of all the patients of the MIT-BIH Atrial Fibrillation Database [9]. The RR intervals in the state of atrial fibrillation and normal of patients are presented in Figure 1. In the square signal, the high and low levels indicate the atrial fibrillation and normal states, respectively. In the atrial fibrillation state, the amplitudes of RR intervals are higher and fluctuate sharper than the normal one. The RR intervals of normal state appear as a signal with a relative small ripple. This indicates that the RR intervals are more stable in a certain value than that the atrial fibrillation one. However, in the normal state, sometimes it happens that RR intervals rise to a high magnitude and jump to a very low magnitude; it looks like a spark [10].

3.2. Frequency components of RR intervals during atrial fibrillation

The frequency components of the electrocardiographic RR intervals have been obtained. The frequency components are obtained from each segment. Each segment of RR interval has a set of the associated frequency components, which has 10 components. The mean amplitude of the frequency components are summarized in Table 1. The first component is far higher than the other components, for both atrial fibrillation and normal. The amplitude of the first component in the normal state is higher than in the atrial fibrillation state. Conversely, the amplitude of the second and so forth components are higher in the atrial fibrillation than in the normal one, as presented in Figure 1.

| Amplitudes for the | Amplitudes for the |
|-------------------|-------------------|
| 1st Component | 1567.70 | 1989.10 |
| 2nd Component | 72.50 | 24.88 |
| 3rd Component | 70.07 | 27.49 |
| 4th Component | 68.06 | 28.23 |
| 5th Component | 68.26 | 24.87 |
| 6th Component | 55.30 | 21.34 |
| 7th Component | 68.26 | 24.87 |
| 8th Component | 68.06 | 28.23 |
| 9th Component | 70.07 | 27.49 |
| 10th Component | 72.50 | 24.88 |
3.3. A simple atrial fibrillation detection using RR interval frequency components with a threshold

A simple detection or identification for atrial fibrillation using frequency components of RR intervals is explored. The detection method is based on the amplitude of the components. For the 1st components, the amplitudes which are higher than the threshold are defined as normal, and the lower one is defined as atrial fibrillation. Conversely, the other components, the amplitudes which are higher than the threshold are defined as atrial fibrillation, and the lower one is defined as normal. The threshold of the amplitude is varied. Figure 3 presents the accuracies of the detection using different components, which are the 1st, 2nd, 3rd and 4th components. The pattern for the other components are similar. The accuracies find the maximum value at certain thresholds and different components could have different threshold.

Among the single components, the detection using the 10th components find the highest accuracy, which is 78.99%. The lowest accuracy happen at which uses the first component; that is 72.72%. The detection which utilizes the mean of the 2nd to the 10th components find a significant higher than the other components, which is 82.23%. It implies that each component could contribute positively to improve the accuracy and when all the components are utilized the performance could find the higher. Note that the first component is not included to the mean value. The reason is that the amplitude of the 1st component is far higher than the other components and the characteristic is different. The difference is that the normal state associated the higher amplitudes, which is the opposite of the other components.
Figure 3. The accuracies of atrial fibrillation detection using the 1\textsuperscript{st}, 2\textsuperscript{nd}, 3\textsuperscript{rd} and 4\textsuperscript{th} frequency components with different thresholds, as shown in part a, b, c and d, respectively.

Table 2: The maximum accuracies of the atrial fibrillation identification using the different frequency components of RR intervals during atrial fibrillation and normal states (values are in term of average)

| The frequency components | Accuracy (%) |
|--------------------------|--------------|
| 1\textsuperscript{st} Component | 72.72        |
| 2\textsuperscript{nd} Component | 78.33        |
| 3\textsuperscript{rd} Component | 78.00        |
| 4\textsuperscript{th} Component | 77.72        |
| 5\textsuperscript{th} Component | 78.80        |
| 6\textsuperscript{th} Component | 75.44        |
| 7\textsuperscript{th} Component | 78.80        |
| 8\textsuperscript{th} Component | 77.72        |
| 9\textsuperscript{th} Component | 78.00        |
| 10\textsuperscript{th} Component | 78.99        |
| Mean of the 2\textsuperscript{nd} to the 10\textsuperscript{th} components | 82.23        |

4. Conclusion

A detection of atrial fibrillation utilizing the frequency components of RR intervals are presented. For the study, the detection approaches which utilize different components are compared. Each of the component has shown a positive contribution for the performance of the detection. The detection
approach finds the highest performance when it utilizes mean the components. Using clinical data of the patients with atrial fibrillation, the highest accuracy found is 82.23%.

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