RR-Interval variance of electrocardiogram for atrial fibrillation detection

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Abstract. Atrial fibrillation is a serious heart problem originated from the upper chamber of the heart. The common indication of atrial fibrillation is irregularity of R peak-to-R-peak time interval, which is shortly called RR interval. The irregularity could be represented using variance or spread of RR interval. This article presents a system to detect atrial fibrillation using variances. Using clinical data of patients with atrial fibrillation attack, it is shown that the variance of electrocardiographic RR interval are higher during atrial fibrillation, compared to the normal one. Utilizing a simple detection technique and variances of RR intervals, we find a good performance of atrial fibrillation detection.

1. Introduction

Atrial fibrillation (AF) is a type of heart arrhythmia which is a serious problem of the heart. The problem is originated from the atrial of the heart. The estimation of AF prevalence of AF is estimated to 2.3 million in the United State and 4.5 million in the Europe [1]. A serious risk of AF is stroke [2] which leads to frequent hospitalization and increases mortality. During AF the atrial beats chaotically and irregularly.

Early detection of AF happening in a patient is necessary to conduct appropriate actions which might improve patient care and reduce healthcare costs [3]. These actions are also essentials to prevent the serious AF complications. Therefore, approaches have been proposed for early AF detection. Varied algorithms have been studied to find a sophisticated AF detection system accurately and quickly [4, 5]. Electrocardiographic features are often utilized for AF detection.

An AF detection approach using neural network has been proposed by [6]. The approach detection employs probabilistic neural network and a wavelet feature of electrocardiogram. A different strategy of an AF detection using neural network algorithm is proposed by (Mateo et al., 2013). This algorithm uses radial basis function (RBF) neural network and utilizes electrocardiographic features by cancelling the electrocardiographic QRST complex.

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The article explores electrocardiographic features for AF detection. The main explored-feature is variance of RR-interval of electrocardiogram. RR interval is the time interval between two consecutive R peaks of electrocardiogram. RR interval represents heart rate. Heart rate of the heart in patient with atrial fibrillation fluctuates, 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 presents a study of variance of electrocardiographic RR interval for atrial fibrillation detection. Firstly, we collect R peaks data of electrocardiogram provided by Physionet [7]. The electrocardiogram 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. 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 50%, 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 variance is defined by two definitions. The first definition, variance $\sigma$ is defined as

$$\sigma = \sqrt{\frac{\sum(x-\mu)}{n-1}}$$

The second definition, variance $\alpha$ is defined as the distribution of the data number in defined five ranges, from the lowest to the highest value of RR intervals in a segment. Specifically, we grouped RR intervals into a segment into five levels. The variance $\alpha$ is this article is defined as the difference of data number between the levels. For comparison of the detection performance, we use mean value of RR interval.

The detection performance is measured in terms of accuracy. Accuracy is the correctness of both atrial fibrillation and normal events.

![Figure 1](image1.png)

(a) (b)

(c) (d)

Figure 1. RR intervals pattern types of atrial fibrillation and normal. High and low levels of square signals indicate states of atrial fibrillation and normal, respectively.
3. Results

3.1. Description of RR interval during atrial fibrillation

We obtain RR intervals of electrocardiogram of all the patients. The patterns of RR intervals in the state of atrial fibrillation and normal of patients are presented in Figure 1. The line with square forms indicate normal and atrial fibrillation; low and high levels indicate normal and atrial fibrillation respectively. Thus, the most left part of the Figure 1a is normal and the most right part also indicate normal, which both parts are low levels. Figure 1a indicates that the RR intervals rise and decline more significantly during atrial fibrillation than the normal one. In the normal state RR intervals just make a ripple. The similar fact can also been seen in the other RR interval pattern, as presented in Figure 1b and Figure 1c. However, we need to provide attention that, in the normal state RR interval there is a small part in which RR interval also rise to a high magnitude and jump to a very low magnitude; it looks like sparks.

The other the RR interval pattern is a little different, indicated in Figure 1d. The figure shows that in the atrial fibrillation state the RR intervals pattern is similar with the previous figures. In the normal state, the RR intervals fluctuate more steeply, but it is still less steeply than in the atrial fibrillation. In other words, the difference of atrial fibrillation and normal is that RR interval pattern more fluctuates that the normal one. In addition, the fluctuation in the atrial fibrillation state is more steeply.

![Figure 1. RR intervals pattern types of atrial fibrillation and normal.](image)

Figure 1. RR intervals pattern types of atrial fibrillation and normal. The

The other RR interval patterns show a different pattern as indicated in Figure 2. The pattern show that the normal RR interval fluctuate with ‘fluctuated baseline’. Thus, for the normal state, the difference of this RR interval pattern with the previous one is the fluctuation of the baseline.

Variance of RR interval presented using $\alpha$ and $\sigma$ are indicated in Table 1. Variance ($\sigma$) is higher in atrial fibrillation than that in the normal one, but variance in terms of $\alpha$ is higher in the normal situation than that in the atrial fibrillation. This might be as a result of the difference formulation of variance. In general the two variance indicate different values between atrial fibrillation and normal, which might be used for input or feature of atrial fibrillation detection technique. For addition feature of RR intervals, average of RR interval is presented. The data shows that the average is lower in atrial fibrillation than that in normal one, which is confirmed by previous study [8].

![Figure 2. RR intervals pattern types of atrial fibrillation and normal.](image)

Figure 2. RR intervals pattern types of atrial fibrillation and normal. The

|                  | Atrial Fibrillation (mean ± std, ms) | Normal (mean ± std, ms) |
|------------------|--------------------------------------|-------------------------|
| Variance ($\sigma$) | 5136.4 ± 3579.76                    | 1557.68 ± 3160.48       |
| Variance ($\alpha$) | 126.80 ± 37.28                      | 47.38 ± 75.25           |
| Average          | 646.84 ± 134.88                     | 799.76 ± 156.08         |
3.2. **A simple atrial fibrillation detection using RR interval variance with a threshold**

A simple detection for atrial fibrillation using each of the three features are created. The detection method is based on a threshold. In this study the threshold is varied and the accuracy of the different threshold is presented in Figure 3.

![Graph showing accuracy vs. threshold for different variances](image)

**Figure 3.** Accuracies of atrial fibrillation detection using different RR interval features – variance $\sigma$, variance $\alpha$ and mean – with different thresholds.

| Maximum Accuracy        |
|-------------------------|
| Variance ($\sigma$)    | 84.70 %               |
| Variance ($\alpha$)    | 78.62 %               |
| Average                | 71.67 %               |

Table 1. Maximum accuracies obtained by the detection which use variance $\sigma$, variance $\alpha$ and mean of RR interval.

In general, different threshold could provide different accuracies and therefore an optimal threshold is necessary to find an optimal accuracy. The maximum accuracies of the three approaches are presented in Table 2. Figure 3a shows the accuracy of the detection using variance $\sigma$ with different thresholds; the maximum accuracy of this approach is 84.70%. Figure 3b shows the accuracy of the detection using variance $\alpha$; this approach provides maximum accuracy of 78.62%. Figure 3c indicates that the maximum accuracy obtained by which use mean of RR intervals is 71.67%. Thus, among the three approaches, the detection which utilizes variance $\sigma$ provide the highest accuracy. Conversely, the lowest is which use the mean. It might imply that variance of RR interval is a better parameter to indicate atrial fibrillation than the mean.

4. **Conclusion**

A study of atrial fibrillation detection using variance of RR interval is presented. For comparison, the detection which utilize mean of RR interval is compared. Using the variance, the accuracy is higher than which uses the mean. We uses two types of variances: variance $\alpha$ and the proposed variance $\sigma$. The proposed variance $\sigma$ indicates the different number of RR intervals in a certain range with the others.
The proposed variance $\sigma$ provides higher performance than the variance $\alpha$. Using $\sigma$ the atrial fibrillation detection provide 84.70%.

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