# Is it Possible to Detect Atrial Fibrillation by Simply using RR Intervals?

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### Abstract

*Atrial fibrillation is the most common sustained arrhythmia in clinical practice worldwide. Several algorithms have been developed to detect atrial fibrillation, which either rely on atrial activity analysis or are based on the irregularity of RR intervals. This paper is addressed to study the latter type of algorithms. The main question is whether there is sufficient information in the sequence of RR intervals for reliable detection of atrial fibrillation and whether the atrial fibrillation can be differentiated from other significant ECG arrhythmias.*

*We have tested various types of algorithms existing in the technical papers utilizing MIT-BIH databases.*

*Except the atrial fibrillation all other arrhythmias have some regularity, self-similarity and some degree of predictability. Consequently, algorithms utilizing only the values of RR intervals without their order may misclassify other irregular rhythms as atrial fibrillation. The best algorithms use the scatter plot of successive RR differences or Sample Entropy. The error rate was about 5%.*

*It is possible to create a robust atrial fibrillation detection algorithm relying only on RR intervals considering their places in the sequence.*

## 1.     Introduction

Several algorithms have been developed to detect atrial fibrillation, which either rely on atrial activity analysis or are based on the irregularity of RR intervals. This paper is addressed to study the latter type of algorithms.

Atrial fibrillation is the most common sustained arrhythmia in clinical practice worldwide. It is a cardiac arrhythmia with uncoordinated irregular atrial activation. Its main characteristic is the presence of irregular and chaotic atrial activation, the fibrillatory f-waves instead of distinct repetitive P-waves. Atrial activity analysis is essential for unquestionable diagnosis of the atrial fibrillation. But a stable, high quality signal without extensive noise is required for the analysis, which is hardly achievable by the ambulatory ECG monitoring, the most widespread tool for atrial fibrillation screening. In addition, high HR and QRS complexes make it even more

difficult to identify atrial activities. Irregular ventricular response, however, is commonly caused by atrial fibrillation, which makes the detection easier.

So an irregular ventricular rhythm may raise suspicion for atrial fibrillation. However the irregular QRS complexes are just a secondary phenomenon, at the same time there are also other cardiac arrhythmias with irregular heartbeats. Furthermore, in the case of the third-degree AV block the rhythm is completely ventricular and it is no related to atrial activities.

The main question is whether there is sufficient information in the sequence of RR intervals for reliable detection of atrial fibrillation and whether the atrial fibrillation can be differentiated from other significant ECG arrhythmias.

## 2.     Methods

The existing algorithms can be classified by several aspects. A part of the methods only uses the values of RR intervals, whilst others apply their places in the sequence too. Certain algorithms are based on differences between consecutive RR intervals, while others use only the values themselves. We have tested several of these types of algorithms existing in the technical papers utilizing MIT-BIH databases [6].

We examined the following methods: Shannon entropy, Root Mean Square of Successive RR Differences, other statistical methods, different run tests, turning point ratio, various scatter plots and Sample entropy [1–4].

### 2.1.     Disadvantages of statistical methods

The statistical methods using only values of RR intervals, but not their order cannot be successful in differentiating of atrial fibrillation from the other type of arrhythmias. Let's see a very simple example!

A typical RR trend and scatter plot of an atrial fibrillation is shown in the upper part of Figure 1. The result of a rearranged RR sequence is illustrated in the lower part of the figure. The statistical parameters of RR intervals (mean value, standard deviation, etc.) remained the same, although the RR sequences are totally different. The second sequence is a bigeminy-like RR series. We

cannot differentiate these two sequences from each other merely by applying statistical parameters.

On the contrary, the run tests and the turning point ratio methods utilize only the order of the relative values of RR intervals. The result is not better than the results of previous methods. They cannot differentiate the atrial fibrillation from other type of arrhythmias. For example the expected number of turning points for the random sequences is equal to the turning point ratio for the trigeminy. We cannot distinguish between them.



Figure 1. Upper picture – atrial fibrillation, lower picture – the RR intervals are rearranged.

The evaluation of this type of algorithms confirmed the considerations above.

## 2.2. Ectopic beat filtering

Some algorithms applying a statistical approach have tried to eliminate the problems cited above using ectopic beat filtering before starting the algorithm itself.

However, there are many problems with this. We just want to decide if it is a regularly or irregularly irregular rhythm. We do not possess a mean RR value yet. The prematurity does not make sense at this step of the algorithm. During atrial fibrillation SVES and SVESC beats do not exist. On the other hand, wide QRS complexes are often aberrant beats (Ashman phenomenon).

Since the algorithms have to differentiate between atrial fibrillation and other irregular rhythms we have not used ectopic beat filtering before starting our algorithms.

## 2.3. Algorithms applying both values and order of RR intervals

We have chosen two quite promising algorithms: sample entropy and scatter plot analysis.

### 2.3.1. dRR Lorenz Plot

There are numerous applications of Lorenz plot in the analysis of physiological time series. It represents very well not only the values in the time series, but their relationship as well. Instead of the conventional Lorenz plot we have picked out the dRR scatter plot. In this case the differences of RR intervals are plotted against the previous differences. Advantages of this scatter plot are the independence from HR changes. Moreover, this type of scatter plot takes into account simultaneously three RR intervals.

Lorenz plot of different rhythms is shown in Figures 2 – 10. The differences between them are apparent.

There is not enough room for a detailed description of the algorithm, so we only describe the principles applied in our algorithm.

The algorithm breaks up the ECG record into non overlapping segments of 80 beats and creates the Lorenz plot of the differences between the consecutive RR intervals.

We have divided the plot into fields of 50*50 ms and examined the quantitative distribution of the points.

Main features of atrial fibrillation:

- RR intervals of atrial fibrillation are uncorrelated
- RR interval changes are unpredictable
- Scatter plots do not have any patterns or regularities
- Points are more or less uniformly scattered in the center with larger radius than normal sinus rhythm or sinus arrhythmia
- There are just a few points in the individual fields
- There are many empty fields
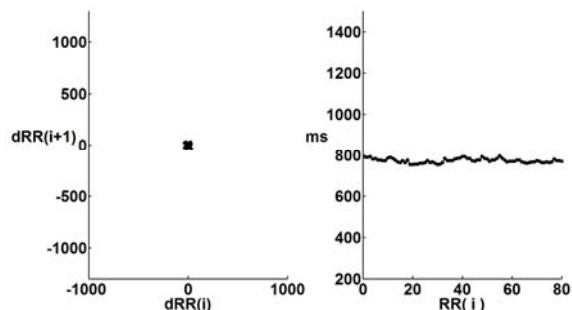- The radius of the cluster is the function of the mean RR interval
-



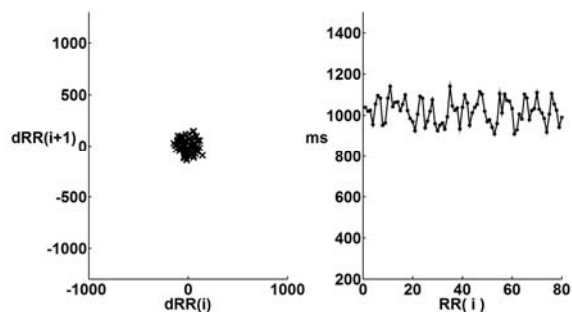Figure 2. Normal sinus rhythm with low HRV.



Figure 3. Normal sinus rhythm.

Main features of premature beats, bigeminy, trigeminy
- Significantly different RR intervals, but their order is determined in advance
- RR intervals follow repetitive patterns
- A few premature beats do not change the main picture
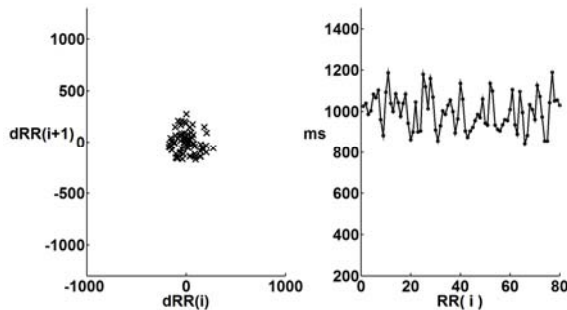- Many premature beats produce several distinct clusters far from the center
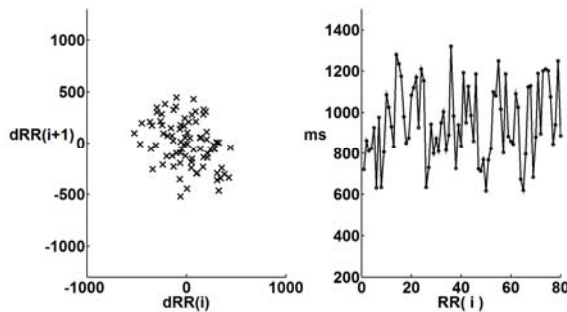

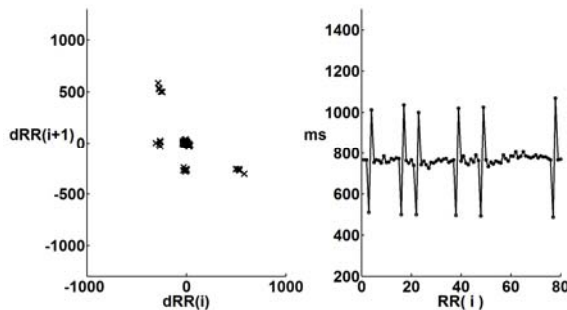Figure 4. Sinus arrhythmia.


Figure 5. Atrial fibrillation.


Figure 6. Premature contractions
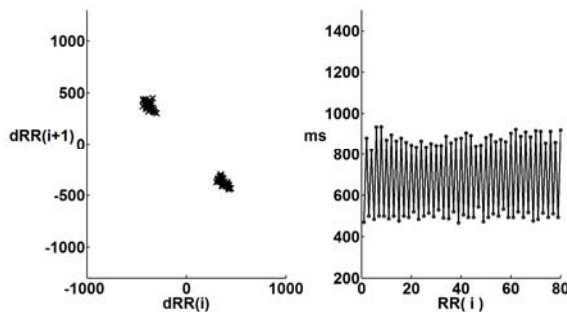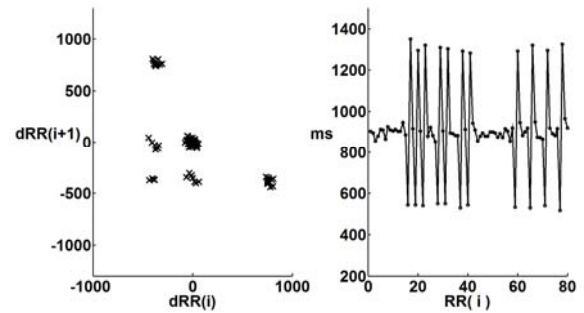

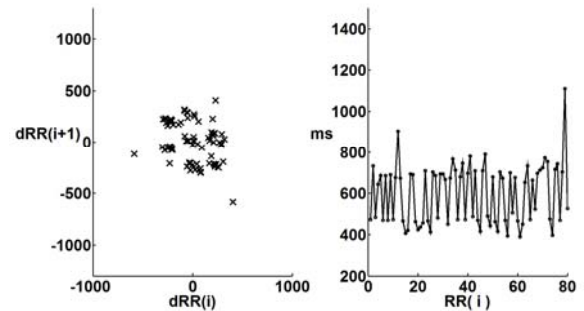Figure 7. Bigeminy


Figure 8. Trigeminy
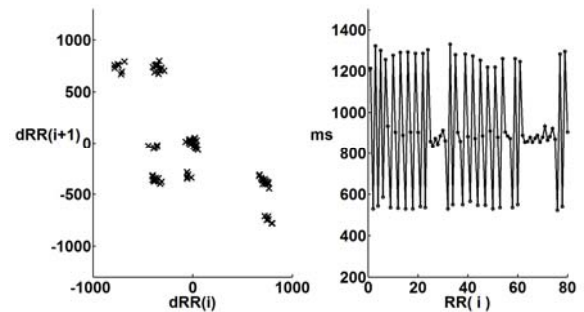

Figure 9. Complex arrhythmia.


Figure 10. Complex arrhythmia

## 2.3.2.  Sample Entropy

Sample entropy is the negative logarithm of the conditional probability that two sequences similar for m points remain similar at the next point, where self-matches are not included in calculating the probability. It quantifies the unpredictability of fluctuations in a time series [2]. Thus, a higher value of entropy indicates irregularity and unpredictability in the series of RR interval and the lack of repetitive patterns which is typical for atrial fibrillation.

Selecting dimension and tolerance is a crucial step of the algorithm. The tolerance must be larger than the fluctuation of RR intervals at normal sinus rhythm.

We have chosen dimension equal to two. Usually the tolerance is chosen accordingly to the standard deviation of the time series. In our case we modify the tolerance accordingly to the alteration of the mean RR interval.

The average test result of the algorithm was very close to the results of the Lorenz plot. Nevertheless, the sample

entropy algorithm was more sensitive to sinus arrhythmias.

## 3. Results

For the evaluation of the algorithms the MIT-BIH arrhythmia, atrial fibrillation and long-term atrial fibrillation databases were utilized.

First of all, we had to determine which parameters best characterized the power of atrial fibrillation detection. As the theory shows the positive predictive value is not intrinsic to the performance of the algorithms and considerably depends on the prevalence. The prevalence of the MITDB, AFDB and LTAFDB is 9,45 %, 39,94 % and 52,96 % respectively. So we used sensitivity, specificity, error rate and kappa value for the assessment of the algorithms.

We tested the algorithms accordingly to ANSI/AAMI standards. We did not exclude short atrial fibrillation segments and did not align the start and end point of atrial fibrillation segments to the inspected part.

The results are presented in Table 1 and 2.

Table 1. Results of dRR Lorenz plot algorithm

| Database | Se (%) | Sp(%) | Error rate (%) | Kappa |
|---|---|---|---|---|
| MITDB | 95,79 | 95,26 | 4,69 | 0.76 |
| AFDB | 92,59 | 98,27 | 4.00 | 0.92 |
| LTAFDB | 93,94 | 95,61 | 5,28 | 0,89 |
| Overall | 93,79 | 95,91 | 5.18 | 0.90 |

Table 2. Results of Sample Entropy algorithm.

| Database | Se (%) | Sp(%) | Error rate (%) | Kappa |
|---|---|---|---|---|
| MITDB | 94,85 | 94,32 | 5,64 | 0,72 |
| AFDB | 89,67 | 99,53 | 4,41 | 0,91 |
| LTAFDB | 94,31 | 96,16 | 4,82 | 0,90 |
| Overall | 93,93 | 96,56 | 4,79 | 0,89 |

Except for the atrial fibrillation all other arrhythmias have some regularity, self-similarity and some degree of predictability. Consequently, algorithms utilizing only the values of RR intervals without their order misclassify other irregular rhythms as atrial fibrillation. The best results are achieved using the scatter plot analysis of successive RR differences and Sample Entropy. The error rate was about 5 %. It is better than published results for 12-lead computerized decision software [5]. GPs and nurses performed less well.

## 4. Discussion and conclusions

It is possible to create a robust atrial fibrillation detection algorithm relying only on RR intervals considering their places in the sequence.

The quality of QRS detector is an important issue for algorithms relying on RR intervals. However infrequent mistakes do not influence the performance of our algorithms.

The detection accuracy can be improved by combining the two algorithms, since they failed at the different parts of ECG records.

Further improving of specificity is possible using atrial activity analysis, excluding the ECG signal, having well detectable distinct P waves, from the atrial fibrillation candidates.

## References

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