Developing An Atrial Activity-based Algorithm For Detection Of Atrial Fibrillation

Steven Ladavich, MSc and Behnaz Ghoraani, PhD
Biomedical Engineering Department, Rochester Institute of Technology, Rochester, NY

Objectives:
In this study we propose a novel atrial activity-based method for AF identification that detects the absence of normal sinus – rhythm (SR) P-waves from the surface ECG.

Methods:
Dataset and ECG Records: The MIT-BIH AF Database from Physiobank was used for validation of the proposed AF detection algorithms. The dataset includes 25 long-term (10 hrs.) ECG recordings with AF (23 paroxysmal and 2 persistent) and contains 299 AF episodes (about 93.4 h). Out of the total 23 paroxysmal recordings, this study uses only the 20 recordings that contain sufficient SR data to construct a training set.

R-wave Detection and P-wave Extraction: A third-order butterworth bandpass filer is applied with poles at 0.5 Hz and 50 Hz to reduce baseline wander and powerline noise. Then R-wave detection and P-wave extraction are performed in two steps. First, R markers are placed at the point of maximum absolute derivative on the QRS complex. Then, P onset and P offset points are manually chosen from the segment preceding the R-wave marker, and the supposed P-waves are extracted from the ECG recording.

Classification: Test set evaluation begins with P-wave feature extraction as shown in Figure 1B. The classifier determines if the feature vector constitutes PWA or AF. A pScore was defined in such a way that it reflects the likelihood that a feature vector extracted from the segment preceding the QRS complex is also a P-wave.

\[
pScore(f) = \sum_{j=1}^{6} \exp \left( \frac{\ln (1 / x)}{2} \right) M_j^f
\]

A pScore of 1 reflects a near absolute certainty of a P-wave, while a PScore of 0 reflects a near absolute certainty of not a P-wave.

Results:

Figure 2 - The receiver operating curves (ROC) for the best performing record (Record 04936), the worst performing record (Record 06905), and all the patients with area under the curve of 0.99, 0.86 and 0.94, respectively. The circles on the graph locate the optimum threshold for each patient.

Table 1 - Performance results with various majority voter sizes and thresholds set to the static threshold value.

Table 2 - Performance results with various majority voter sizes and thresholds set to the optimal threshold values.

Conclusions:

- In this study, we proposed a novel rate-independent based approach that detects AF through statistical analysis and classification.
- The proposed algorithm achieves a sensitivity of 99.28% and a specificity of 96.70%, which is comparable to other RRI-based detection algorithms.
- In addition, the proposed method is rate-independent and is capable of making an AF determination in as few as seven beats, whereas the majority of RRI algorithms utilize 50 to 100 beats.
- It provides a patient specific detection of AF using a simple classifier that is more appropriate for ambulatory devices.
- The rate-independent nature of the proposed algorithm could provide clinicians with a reliable tool to detect the SR-AF transition that will happen over a few beats with no limitations for patients with rate-controlled drugs or pacemakers.

Background:
Atrial fibrillation (AF) is the most common cardiac arrhythmia. It affects an estimated 2.3 million United States citizens, and this number is only expected to increase as the general population ages. Automatic detection of AF can provide cardiologists with significant information for accurate and reliable diagnosis and monitoring of AF and is crucial for clinical therapy. However, monitoring AF remains an open area of research when the heart rate is controlled.

Conclusions: