HEART RHYTHM – DIFFERENTIATION OF ATRIAL FIBRILLATION AND FLUTTER FROM OTHER ARRYTHMIA USING WAVELET TRANSFORM AND ARTIFICIAL NEURAL NETWORK

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Abstract: The automatic detection method of heart arrhythmias such as both atrial fibrillation and flutter is presented. The coupling of both artificial neural network and wavelet transform has been applied. At present a new trend of combining together methods from different area of signal processing can be observed. Such an approach creates new possibilities by extracting most useful features coming out from each and particular method and apply them effectively to sort out sophisticated computational or classification problem.

Introduction

The main task of cardiovascular system is to provide all the tissues with oxygen and nutritive products.

The heart is taking up the central point; its quasi-synchronous work guides to constant translocate of blood from vein reservoir (low pressure 0 kPa) to system with high pressure – artery system (24 kPa). The human heart is build of cardiac muscle (myocardium). Exploring muscular coat the different fibres from the main muscle can be observed. Concentration of this specific tissue make the cardiac conduction system. This system consists of sinoatrial node, AV node, His bundle and Purkije fibres.

In the cardiac conduction system impulses causing the heart contraction have been generated. The sinoatrial node has initially any constant static potential. Instantly after end of repolarization the potential of the velum is changing to the positive value. When the value (velum potential) reaches the threshold the next excitation of the cell is coming up. This occurrence is known as slow static depolarization. AV node has got low value minus static potential. There is no slow static depolarization – no automatism, small amplitude of potentials. Owing to this, the conduction velocity on this area is slower, less than 5cm/s. Conduction system generates impulses in the heart, without any external stimulus. This system is responsible for so called automatism of the heart.

Changes of potentials or difference of potentials In the time measured on the surface of body is a basic diagnostic tool – ECG.

Cardiac arrhythmias detection is important because they determines the emergency conditions (risk of life). Special kind of arrhythmia: atrial fibrillation and flutter have both their special pattern on the shape of ECG, they perturb the electrocardiogram and in the same time complicate automatic detection of other kinds of arrhythmia. Automatic detectors/analyzers of fibrillation and flutter usually are as a part of other arrhythmia detectors, for differentiate.

Materials and Methods

The database of flutter and fibrillation will be used to develop this study. The signals have been taken from PhysioNet database.

The Research Resource for Complex Physiologic Signals, to which PhysioNet belongs, is a cooperative project initiated by researchers at Boston's Beth Israel Deaconess Medical Center/Harvard Medical School, Boston University, McGill University, and MIT, under the auspices of the National Center for Research Resources of the National Institutes of Health.

The problem has been described as a *challenge* by both Computers in Cardiology and PhysioNet.

One of standard methods for construction of continuous representation of heart rate (HR) is the application of Fourier transform. But mathematical simplification and limits however should be taken into consideration. Such an approach is justified due to some physiological interpretations which fortunately allow for the mentioned simplifications.

One of mathematical methods without restrictions of the Fourier transform is wavelet transform (WT). Similarly to Fourier transform, a wavelet transform can be continues and discrete. In both cases there are some useful properties available which makes possible to use that signal processing tools effectively.

The HR signal should moved by *'b'* and scaled by *'a'* for further analysis:

$$\psi(ax-b) \tag{1}$$

Integral WT has the following form:

$$W\psi\{f(x)\}(b,a)=\frac{1}{\sqrt{a}}*\int_{-\infty}^{\infty} f(x)*\psi\left(\frac{x-b}{a}\right)dx \tag{2}$$

Analogously the discrete WT is predetermined by wavelets collection:

$$\psi(2^j x-k) \quad j,k\in Z \tag{3}$$

and wavelet factor:

$$c_{j,k} = W\psi\{f(x)\}\left(\frac{k}{2^j}, \frac{1}{2^j}\right) \qquad (4)$$

Based on (3) and (4) the wavelet series can be described:

$$f(x) = \sum_{j,k=-\infty}^{\infty} c_{j,k}\,\psi(2^j x - k) \qquad (5)$$

Authors have used a wavelet transform for data pre-processing to extract a classifier features allowing to differentiate both atrial fibrillation and flutter from the normal rhythms. Next step was to determine structure and train an artificial neural network (ANN).

The standard perceptron with back propagation algorithm has been chosen.

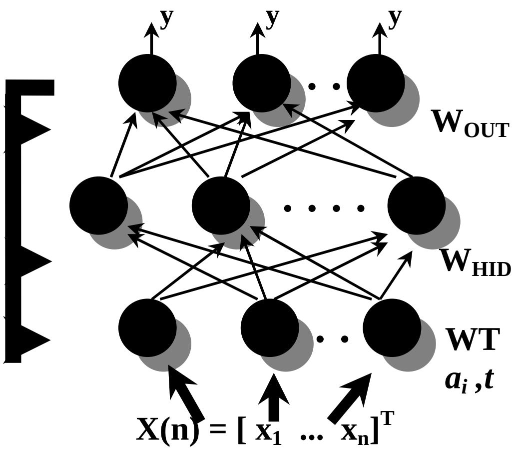

Figure 1: Perceptron model of ANN with back propagation algorithm.

Coupling of two methods: signal preprocessing by WT and analysis by ANN gives a structure of wavelet neural networks (WNN) with following advantages:

- multidimensional signal decomposition,
- time-frequency signal representation,
- signal analysis possibility,
- multi-types of basis wavelets,
- parallel method of data processing,
- different types of activation functions,
- analysis possibility of line and non-line correlation between input and output signals.

The last step was to evaluate the above mentioned database to obtain the results of classification from the experienced cardiologist participating in the challenge.

The learn the WNN each parameters first has been given *a priori*. The parameters have to be changing each step.

$$\Delta w_{i,j} = l_r * \frac{\partial E}{\partial w_{i,j}} * p^T \qquad (6)$$

$$\Delta b_i = l_r * \frac{\partial E}{\partial b_i} \qquad (7)$$

$$\Delta a_i = l_r * \frac{\partial E}{\partial a_i} * p^T \qquad (8)$$

$$\Delta t_i = l_r * \frac{\partial E}{\partial t_i} * p^T \qquad (9)$$

where *p* – input vector for given layer.

The following learn algorithm has been used:

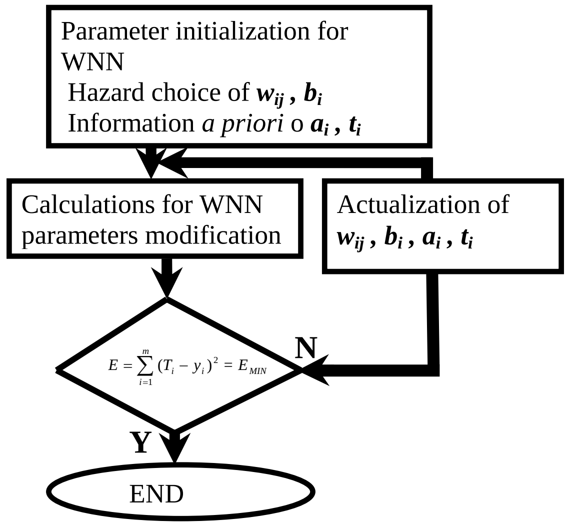

Figure 2: Algorithm of WNN.

As result of above described methods the fully controlled correlation operation can be obtained. The output of this operation returns a clear single peak function, which is extremely easy for detection and further recognition when the signal episode is similar to the template established, whereas in case when the signal episode is significantly different than established templates the output is totally undetectable. This fact can be easy applied to differentiate normal sinus rhythm from both atrial fibrillation or flutter.

Results

This work should be considered as a preliminary study. Therefore authors have concentrated first of all upon the method choice, decision rules elaboration, parameters modification and finally wavelet template construction. However, first results are quite promising and are worth of further investigation.

Conclusions

Existing algorithms and methods still have a place for both development and improvement. Lot of ways have been chosen [1,2,3,4]. Author’s hypothesis is based on coupling of mathematical signal pre-processing using wavelet transform, indicate and differentiate from others arrhythmia and further application of neural network, which is trained on real signals. The initial results obtained up to now are quite promising. However, further investigations are absolutely necessary.

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