Matched Wavelets In Modern Pattern Recognition Techniques – Improvement of Feature Extraction Stage in Biomedical Data Classifier

Kostka P, Tkacz E
[1] Institute of Electronics, Div. of Microelectronics and Biotechnology,
Silesian University of Technology, Gliwice, Poland
pawel.kostka@polsl.pl

Abstract. The goal of presented work was to compare the usage of standard basic wavelet function like e.g. bio-orthogonal or dbn with the optimized wavelet created to the best match analyzing ECG signals in the context of P-wave and atrial fibrillation detection. A library of clinical expert evaluated typical atrial fibrillation evolutions was created as a database for optimal matched wavelet construction. Whole data set consisting of 40 cases with long term ECG recordings were divided into learning and verifying set for the multilayer perceptron neural network used as a classifier structure. Compared with other wavelet filters, the matched wavelet was able to improve classifier performance for a given ECG signals in terms of the Sensitivity and Specificity measures.

1 Introduction

The subject of multiscale signal representation/analysis has been studied by applied mathematicians for a number of years. The works of Daubechies [1] and Mallat [2] evoked the interest of signal processing community in the theory of wavelet transforms. These papers established the connection between wavelet transforms and the theory of multirate filterbanks. Matching a wavelet to class of signals can improve the feature extraction stage in classifiers based on time-frequency signal decomposition as well as can increase the signal to noise ratio during de-nosing process. In signal detection applications, the decomposition of a signal in the presence of noise using a wavelet matched to the signal would produce a sharper and more discriminating peak in time-scale space as compared to standard non-matched wavelets [1]. Described in literature wavelet design techniques developed by Mallat and Zheng [3], and Chen and Donoho [4], build nonorthonormal wavelet bases from a library of existing wavelets in such a way that some error cost function is minimized. These techniques are constrained by the library of functions used and do not satisfy the need for optimal correlation in both scale and translation.

Proposed method as a modification of Chapa [5] approach bases on the matching the basic wavelet separately for magnitude and phase of the signal spectrum. Finding an optimized wavelet is a crucial stage of time-frequency ECG signal decomposition (feature extraction stage) of the atrial fibrillation episodes classifier structure. The goal of presented work was to compare the usage of standard basic wavelet function like e.g. bio-orthogonal or db*n* with the optimized wavelet created to the best match analyzing ECG signals in the context of P-wave and atrial fibrillation detection.

The application field of presented multi-domain feature extraction is the trial of detection of atrial fibrillation (AF), which is a supraventricular tachyarrhythmia characterized by uncoordinated atrial activation with consequent deterioration of atrial mechanical function. Last researches report AF as a result of a fractionated atrial electrical activity mainly due to the shortening of atrial refractory period, which allows multiple waves pass through the atrial mass. These changes ultimately reduce the inward calcium current, and this in turn reduces the action potential duration. If the action potential duration shortens, the refractory period shortens too, and the cell can be ready for reactivation earlier. On the electrocardiogram (ECG), AF is described by the replacement of consistent P waves by rapid oscillations or fibrillatory waves that vary in size, shape, and timing, associated with an irregular, frequently rapid ventricular response when atrio-ventricular conduction is intact. Because of disturbed haemodynamic, atrial fibrillation and atrial flutter are between of the most usual causes of thrombi-embolic events. So it is very important to diagnose and to treat these arrhythmias.

2 Methods

2.1 Atrial fibrillation detection problem identification:

- No P waves, fibrillating chaotic F waves around baseline
- Approximate atrial rate: 350 – 600 [bpm] (or no regular pattern discernible),
- Ventricular rate: 100 – 180 [bpm]
- Ventricular rhythm: Irregular; R-R interval constantly varies, as does size of QRS complexes

A library of clinical expert evaluated typical atrial fibrillation evolutions (see example presented in Fig.1) was created as a database for optimal matched wavelet construction.

Fig 1. 12 lead atrial fibrillation events (indicative of atrial fibrillation with a fast ventricular response) as a reference pattern in created library for matched wavelet design.

2.2 Matched wavelet construction algorithm

An algorithm introduced by Chapa e al. [5] were modified to obtain optimal wavelet basis function for AF detection. According to this optimized method, wavelet basis function matching is performed separately for magnitude and phase of the signal spectrum. To obtain a single wavelet that could provide the best match, the signal of interest is projected onto the different orthonormal wavelets.

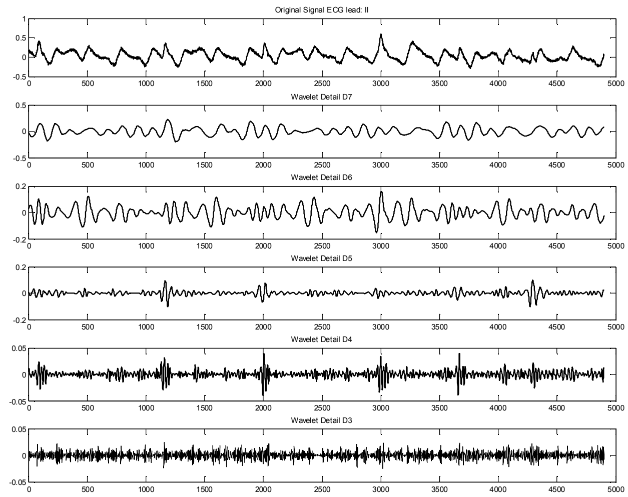

Fig.2 An example of multilevel Mallat decomposition components (details: d3-d7 with original ECG signal) of II ECG lead of patient with AF.

2.3 Classifier system structure with matched wavelet analysis used as a feature extraction tool.

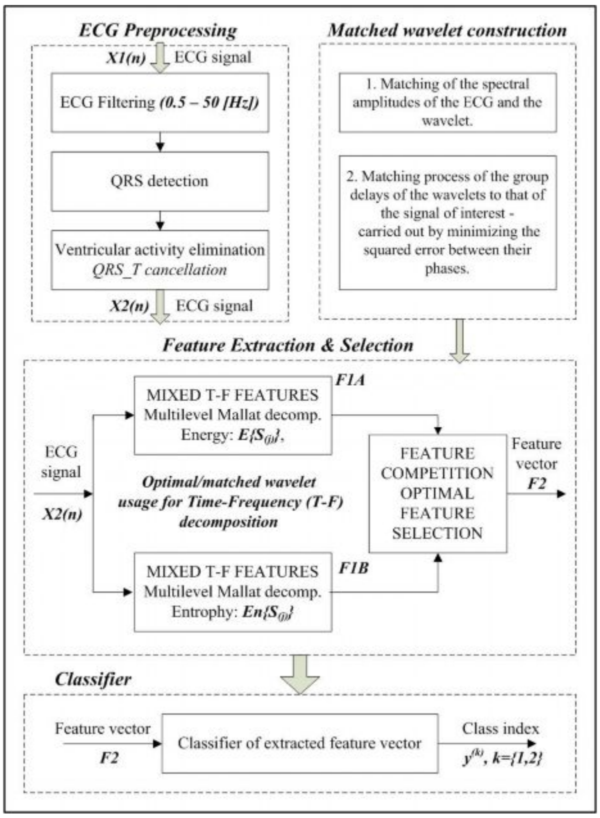

Fig 2. Structure of presented method with a matched wavelet construction (right upper 'channel') and normal AF detection from ECG data path (left upper 'channel').

Before a normal performance of presented classifier (Fig.2 'left channel') a matched wavelet is created for a library of representatives AF templates (Fig.2 'right channel').

The optimized basic wavelet is a crucial point of Time-Frequency analysis of ECG signal in order to create the most representative feature vector, consisting of set of energies $E\{S_{(j)}\}$ and entropies $E\{S_{(j)}\}$ of chosen ECG wavelet analysis decomposition components ($j=n..m$), which correspond to filter bank with definite frequency ranges. So instead of original ECG raw data a lower dimension feature vector *F2* is put as an input to final classifier.

3 Results

To verify presented method, ECG signals clinically evaluated by experts, taken from MITBIH database containing AF episodes were used. Whole data set consisting of 40 cases with long term ECG recordings were divided into learning and verifying set for the multilayer perceptron neural network used as a classifier structure.

Table 1. A comparison of AF classifier performance for matched wavelet and standard wavelets on feature extraction stage.

WAVELET TYPE OF T-F DECOMPOSITION	SENSITIVITY [%]	SPECIFICITY [%]
db 4	81	78
bior 2.4	82	77
optimized/matched basic wavelet	88	85

In the context of presented method a comparison of constructed matched wavelet and two types of standard wavelets often used for ECG analysis like *db4* and *biorthog.* basic function is presented in term of classifier quality measures: *Sensitivity* and *Specificity* in Tab.1.

4 Discussion

Selection of appropriate wavelet and the number of decomposition levels is very important in analysis of signals using the wavelet transform. Usually, tests are performed with different types of wavelets and the one which gives maximum efficiency is selected for the particular application. In this work we designed an own wavelet based on best matching algorithm for problem of atrial fibrillation (AF) detection. Results indicate that a matched wavelet, that was able to capture the broad ECG features, could be obtained. Such a wavelet could be used to extract ECG features such as QRS complexes and P&T waves with greater accuracy.

5 Conclusions

Many applications of signal representation, adaptive coding and pattern recognition require wavelets that are matched to a signal of interest. Presented algorithm can be considered as a universal method, which can be applied to different types of biomedical signals by adjusting the process of matched wavelet creation, conditioned by the specific character of studied signals.

6 References

[1] Daubechies I. Ten Lectures on Wavelets. Philadelphia, PA: SIAM, 1992, ch. 3-5.

[2] Mallat S. A theory for multiresolution signal decomposition, *IEEE Trans. Pattern Anal. Machine Intell.*, vol. 11, no. 7, pp. 674–693, Jul. 1989.

[3] Mallat S.G, Zhang C. Matching pursuit with time-frequency dictionaries, IEEE Trans. Signal Processing, vol. 41, pp. 3397–3415, Dec. 1993.

[4] Chen S, Donoho D. Basis pursuit. Proc. IEEE 28th Annu. Asilomar Conf. Signals, Syst., Comput., Nov. 1994.

[5] Chapa M. Rao R. Algorithms for designing wavelets to match a Specified signal, IEEE Transactions on Signal Processing, 2000, pp. 3395-3406.

[6] Unser M. Aldroubi A. A review of wavelets in biomedical applications *Proc. IEEE*, vol. 84, no. 4, pp. 626–638, Apr. 1996.

[7] Tewfik A. H. Sinha D. Jorgensen P. On the optimal choice of a wavelet for signal representation, *IEEE Trans. Inform. Theory*, vol. 38, no. 2, pp. 747–765, Mar. 1992.