Rational functions in biomedical signal processing

Executive summary

The analysis of physiological signals by means of mathematical transforms proved to be an effective method in various respects. The main idea for the project was to represent the signal by simple rational functions. The construction is adaptive and the shape of the basic rational functions used are similar to the natural components of the signal. In case of ECG signals they are the P,Q waves and the QRS complex. Similarly to wavelet decompositions both time and frequency information are preserved. Taking advantage of the high adaptivity of these systems, we can achieve a good representation of the electrocardiogram (ECG). Recently, the project was extended to electroencephalograph signals (EEG) as well.

Challenge overview

Biomedical monitoring of the human body have become one of the most important tools for making patient's diagnosis. Additionally, it is also a principal device for proactive prevention of diseases as well. For instance long term recordings such as Holter or sleep-deprived EEG are widely used to monitor the heart and brain functioning during a 24 hours period. These experiments generate a large amount of data which is usually transferred via channels with limited bandwidth like smart-phones. In this case the compression of data is inevitable. Another issue to be considered is the distortion of diagnostic information. The challenge was to develop a transformation method that leads to good compression and approximation as well. The parameters of the transform should carry direct diagnostic information to help in making the diagnosis. Our primary subject is the detection and classification of abnormalities, and also the reduction of diagnosis time.

Implementation of the initiative

The project has started in 2007 as a cooperation with the former Pannon ZRt, now Telenor Hungary. The telecommunication company was interested in innovation of mobile devices such as mobile ECG. A group of three professors at Faculty of Informatics of ELTE has started the research. Then PhD, and MSc students joined the group who implemented several applications and performed the necessary experiments. The joint work with the Department of Signal Processing at Tampere University of Technology on EEG modeling started in 2012.

The problem

The model represents the digital signal as a finite linear combination of rational functions. One of the main problems was to find the basic rational functions by means of which a compressed representation with desired accuracy can be given. This involves an optimization process with respect to the poles of the basic functions. In order to keep the parameters in the proper range the modification of such optimization algorithms like Nelder-Mead, PSO was necessary. For this purpose we used the hyperbolic metric and geometry of the Poincaré model. After having set the system an effective orthogonalization or construction of a biorthogonal system was needed. The problem of discretization had to be addressed too. Controlling the stability, error, diagnostic distortion, etc. was also a challenging task.

Results and achievements

The model we developed enjoys several good features like orthogonality, analytic representation, low computational complexity. Thanks to the free parameters the representation of a signal is highly adaptive. It means that one can obtain both compact and accurate approximation as well. This is demonstrated in Fig. 1. Recently we are concerned with utilizing the rational model in classification tasks including arrhythmia detection in ECG and seizure classification in EEG processing. We could increase the accuracy of EEG seizure detection comparing to the state-of-the-art methods. A MATLAB Toolbox called RAIT was developed to ease and illustrate the computations with rational functions. The library is available at the following website: http://numanal.inf.elte.hu/~locsi/rait/

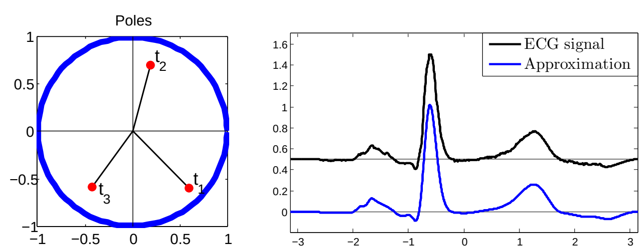

Figure 1: Rational approximation with 16 coefficients.

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