Chapter 26
Unified Wavelet Transform Analysis Adapted to Different Biomedical Applications

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ABSTRACT

In biomedical signal processing, wavelet transform has gained an edge over other existing methods due to its highly efficient transforming capabilities. Relative wavelet energy is a technique used to extract meaningful and concise information from wavelet coefficients for signal classification. The possibility of classifying large datasets combined with the simplicity of the process makes this technique very attractive for many applications. The focus is on testing and validating the use of this technique on different signals keeping in view the specific needs for various biomedical applications. The importance of this unified technique is highlighted with statistical results and validation on several benchmark datasets.

1. INTRODUCTION

Feature transformation is used to obtain a new feature space from the raw biomedical signals. There are various transformations which are applied to the biomedical signals (Hu, Wang, Ren, 2005; Ciaccio, Dunn, & Akay, 1993; Tsipourasemail, & Fotiadis, 2004). In order to obtain an efficient feature space, biomedical signals require time-frequency transformation. Discrete Wavelet Transform (DWT) and Wavelet Packet Transform (WPT) are the most efficient and frequently used time-frequency based techniques for feature transformation of biomedical signals. The DWT is attractive primarily because the Mallat algorithm (Mallat, 1997) is a computationally efficient implementation of the WT and, depending on the mother wavelets; it can be used as an orthogonal or bi-orthogonal transform.

DOI: 10.4018/978-1-5225-3158-6.ch026

The coefficients derived from the DWT decomposition are too large (usually the same as the number of samples in the biomedical signal) to be used as feature space for classification; therefore many algorithms have been proposed for extracting relevant features from the wavelet coefficients (Khadra, Al Fahoum, & Al-nashah, 1997; Englehart, Hudgins, & Parker, 2001; Subasi, & Gursov, 2010). The statistical measures like standard deviation, mean, chaotic measures, etc. have been used extensively for this purpose (Dastidar, Adeli, & Dadmehr, 2007). The major problem with these measures is the lesser consensus among them. The other commonly used techniques for wavelet features extraction are Principal Component Analysis (PCA) (Hu, Wang, Ren, 2005) and Linear Discriminant Analysis (LDA) (Subasi, & Gursov, 2010), but these are not optimal for biomedical signal processing because the features extracted by these methods only utilize the averaged feature variations over time, and ignore the detailed status in each time slot, frequency band and the feature variation, and thus may lead to inaccurate results. The other reasons due to which these methods are avoided for this study are:

- PCA does not take into account the vector's classes so it cannot look at the classes' separability.
- PCA assumes linear transformation which is inappropriate for nonlinear biomedical data.
- LDA involves eigen decomposition and matrix inversions which may lead to computationally expensive programs and numerical instability respectively.
- LDA suffers from small sample size problem. It shows poor generalization ability and degrades the classification performance when the sample dimensionality is larger than the number of available training samples per subject, which is normally the case for biomedical signals.

The direct use of DWT coefficients results in inaccurate classification not only because of the large number of coefficients but also due to much discussed disadvantage of wavelet transform known as shift invariance. The DWT coefficients of a signal are sensitive to the location of the signal, and the energy distribution of wavelet coefficients of two signals may be quite different even if the two signals just differ by a time (or space) shift. In literature the problem is addressed by finding a best set of DWT coefficients among all time (or space) shifts to represent the signal (G. Wang, Z. Wang, Chen, Zhuang, 2006). Wang et al. (Garg, Singh, Gupta, Mittal, & Chandra, 2011) reported that the feature set constructed using energy of wavelet coefficients within each sub band can provide features with translational invariant property. Thus the energy representation of the wavelet coefficients overcome the problem of shift invariance as well as produce a reduced and efficient representation of the feature set. Based on the above observations, we are motivated to test the energy representation (of wavelet coefficients) method for the following solutions:

- A general feature extraction approach for performing classification on datasets of different origin and applications.
- A method which extracts non redundant and robust features from high dimension biomedical signals while retaining the diagnostically important information.
- Consistent performance for different problems.

In our previous works (Garg, Singh, Gupta, Mittal, Chandra, 2011; Garg, Singh, Gupta, Mittal, 2012) the energy representation method was used for feature extraction of EEG signals in sleep scoring and epilepsy detection. This paper will examine Relative Wavelet Energy (RWE) as a generalized feature extractor for harnessing the diagnostically important information from different biomedical signals. The

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