IMPROVED SPECTRAL ANALYSIS OF EEG SIGNALS

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Abstract

Removal of low frequency trends is often a preliminary step to estimating a spectrum and failure to do so can result in serious distortion in the spectrum. In this paper, we use a 'quasi-detrending' method for classification of EEG spectrum where the level of detrending or differencing is made to vary. Differencing in time domain acts as a high pass filter in the frequency domain. Therefore the low frequency values in the delta range can be ignored and this is a saving in computation time since delta range values do not correspond to any normal conscious human mental tasks. We also show that using discrete PSD values in the range below 30 Hz gives better classification results than using the delta, theta, alpha and beta power band values used by some authors.

Keywords: Spectral Analysis, Stationary, Quasi-detrending, EEG, Tukey, Wiener – Khintchine theorem

1.0 Introduction

Stationary transformation through the removal of low frequency trends is often a preliminary step to estimating a spectrum and failure to do so can lead to misleading power spectrum. Linear trends can be removed by first and second differencing while logarithmic differences are used for cyclical trends. In this paper, we use a 'quasi-detrending' method proposed by Nerlove [4]. In his paper, Nerlove has suggested of transforming the original time series into quasi-detrended time series by

$$z(n) = x(n) - kx(n-1)\,, \qquad (1)$$

where *x(n)* is the original time series, *z(n)* is the transformed series, *n* is the sampling point and *k* is the quasi-detrending factor. Higher level detrending would remove too much power from the signal in the low frequency range and might serve to worsen the spectral estimation. As such, an optimal value of *k* would give the least distortion while also removing linear trends in the power spectrum. In this paper, we have investigated the performance of the spectrum with different values of *k*.

Fig. 1 shows an example where 0.5 quasi-detrending removes low frequency cycles but maintains the spectral peak as before detrending thereby improving the quality of the spectrum.

2.0 Method

We have applied this method for EEG signals where the level of detrending is made to vary. Detrending in time domain acts as a high pass filter in the frequency domain. Therefore the low frequency values in the delta range (0-3 Hz) can be ignored and this is a saving in computation time since delta range values do not correspond to any normal conscious human mental tasks. The EEG power spectral densities (PSD) are extracted using Wiener - Khintchine theorem with Tukey window smoothing with 25% truncation point for frequencies up to 30 Hz. The EEG signals extracted are from 6 channels: C3, P3 and O1 from the left hemisphere and C4, P4 and O2 from the right hemisphere, in the standard 10-20 positioning scheme. The subjects are seated in an Industrial Acoustics Company sound controlled booth with dim lighting and noiseless fans for ventilation. The electrodes are connected through a bank of amplifiers and bandpass filtered from 0.1--100 Hz. The data was sampled at 250 Hz with a 12 bit A/D converter mounted on a computer. Four subjects are studied with two different mental tasks namely a complex multiplication task and a visual task imagining an image being rotated about an axis. These two tasks were chosen since they elicit different hemispheric responses [3]. Data was recorded for 10 seconds during each task. With a 250 Hz sampling rate, each 10 second trial produces 2,500 samples per channel. Each EEG signal is segmented with a half-second window and a quarter-second overlap. A Fuzzy ARTMAP (FA) [1] classifier is used to classify these 6 channels of EEG. Vigilance parameter for Fuzzy ARTa module was fixed at 0.9. For all the experiments, 50% of available patterns are used for training while the rest 50% are used for testing.

3.0 Results

The results show that 'quasi-detrending' improves the FA classification performance from 83.97% to 91.67% across all four subjects as compared to FA classification without detrending and with all other parameters fixed. The complete results are shown in Table 1. We can also see from this table that any quasi-detrending improves the performance with *k*=1 giving the best results for subject 1,2 and 4, while *k*=0.75 gives the best results for subject 3. Table 2 shows the results of another experiment. This table shows improvement of using discrete PSD values in the range below 30 Hz rather than using the delta, theta, alpha and beta power band values used by some authors [2-3].

4.0 Conclusion

The results show that quasi-detrending gives improved performance than without detrending and that discrete PSD values below 30 Hz perform better than using band power values. The results also show that it is possible to discriminate accurately between different mental tasks using the improved EEG spectrum and this can be used as a form of communication for paralysed patients [3].

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References
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Table 1: Fuzzy ARTMAP classification for quasi-detrended signals

6 channels of PSD	1st user	2nd user	3rd user	4th user	All users
k=0; No detrending	84.62	74.36	94.88	74.4	83.97
k=0.25 detrending	84.62	79.49	94.88	76.92	84.62
k=0.5 detrending	84.62	89.74	94.88	76.92	91.03
k=0.75 detrending	92.31	87.18	97.44	79.49	84.62
k=1.0 detrending	97.44	89.74	94.88	76.92	91.67

Table 2: Fuzzy ARTMAP performance for discrete PSD values and band power values

	1st user	2nd user	3rd user	4th user	All users
4 to 30Hz PSD (without detrending)	84.62	74.36	94.88	74.4	83.97
4 band power values (without detrending)	69.23	66.67	94.88	74.36	78.85

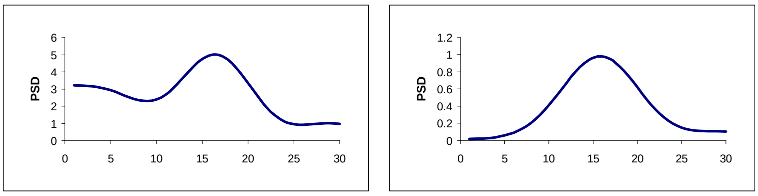

Figure 1: PSD (a) without detrending (b) with 0.5 quasi-detrending

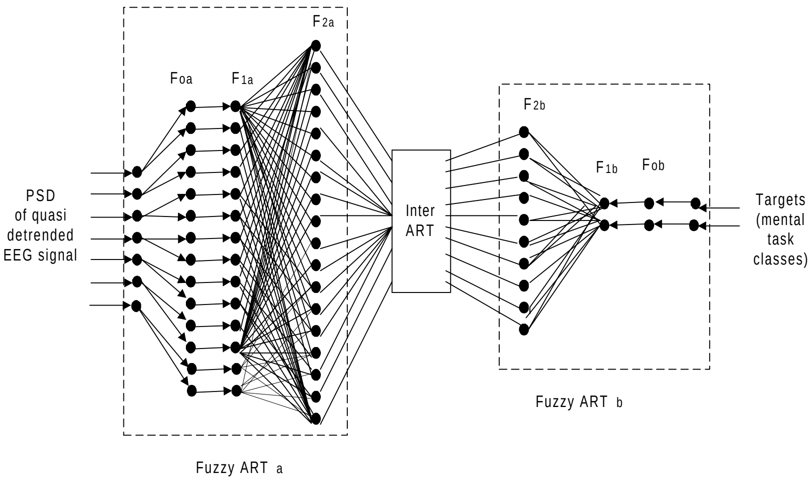

Figure 2: Fuzzy ARTMAP network structure as used in this paper