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A Robust LPC Filtering Method for Time-Resolved Morphology of EEG Activity Analysis

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A Robust LPC Filtering Method for Time-Resolved Morphology of EEG Activity Analysis

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INTRODUCTION

This paper introduces a new time-resolved spectral analysis method based on Linear Prediction Coding (LPC) method that is particularly suited to the study of the dynamics of EEG (Electroencephalogram) activity. The spectral dynamic of EEG signals can be challenging to analyse as they contain multiple frequency components and are often heavily corrupted by noise. Furthermore, the temporal and spectral resolution that can be achieved is limited by the Heisenberg-Gabor uncertainty principle [1]. The method described here is based on a z-plane analysis of the poles of the LPC which allows us to identify and estimate the frequency of the dominant spectral peaks. We demonstrate how this method can be used to track the temporal variations of the various frequency components in a noisy EEG signal.

METHODS

The LPC method provides a method for estimating the coefficients $\{a_i\}$, $(i = 1,2,\ldots,p)$, where p is the order of LPC, that characterize the frequency response $H(z)$ of the corresponding LPC filter. Most researchers to date have used the roots (i.e. the poles) of $H(z)$ to directly estimate the dominant spectral features (i.e. the formants) of the response. However, here we propose an algorithm that further processes these poles to produce a more accurate and more robust estimate of the formants. The new pole processing algorithm is as follows:

1. Obtain the set of poles of LPC filter $H(z)$, i.e. $z = \{z_1, z_2, \cdots, z_p\}$.
2. Partition the poles into different frequency bands. As each pole z_i is complex, we can write of $\gamma_i e^{j2\pi f_i}$, $(i = 1,2\ldots,p)$, then we can get the magnitude of poles $|z_i|$ and the corresponding pole frequency f_i.
3. Organise the poles of each frequency band into the dominant pole and local non-dominant poles. The LPC pole with the largest magnitude $argmax(|z_i|)$ is classified as the dominant pole, other poles are the non-dominant poles.
4. Calculate the spectrum response for each of the dominant poles z_i. The dominant pole and local poles where in a frequency range Δf around the dominant pole, are used to form a new filter transfer function $\tilde{H}_i(z)$.
5. Using a minimisation technique to find the spectral peak of $\tilde{H}_i(z)$.

RESULTS

The EEG signal used in our experiment comes from the public dataset BCI2000 [2]. The parameters of the experiments are: the sampling frequency $f_s = 160Hz$, the order of LPC $p = 20$, the time interval $\Delta t = 0.5s$, the search range $\Delta f = 2Hz$, the signal is separated into 6 EEG bands $(\delta, \theta, \alpha, \mu, \beta, \gamma)$, Figure 1 compare the spectral response between the original LPC method and our new method.

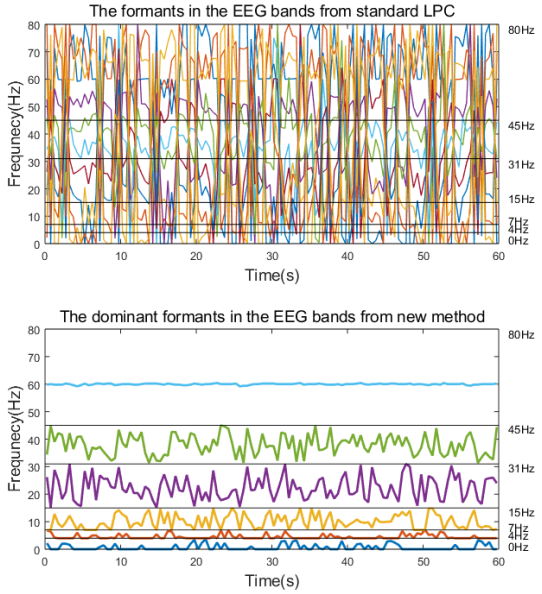

Figure 1 Comparing time-resolved spectral between the standard method and the new method.

The standard LPC method directly generates many formants as it does not distinguish between the dominant and non-dominant poles. On the other hand, our method allows us to extract the dominant frequency component in each of the EEG bands.

DISCUSSION

The research work of this paper proposes a new robust time-resolved method to extract the dominant frequency components in the different EEG frequency bands. The main advantages of this method are that it is robust and capable of producing a time-resolved analysis of multi-frequency signals. Furthermore, as it is a parametric method, it can support further processing of the EEG signal using machine learning techniques.

REFERENCES

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