Segmental Spectral Decomposition as a Time Persistent Method of BioImpedance Spectroscopy Feature Extraction

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Abstract: BioImpedance Spectroscopy (BIS) have been investigated in many research areas as a method to detect changes in living tissues. However, BIS measurements are known to be hardly reproducible in clinical applications. This article proposes segmental spectral decomposition as a method of extracting reproducible parameters from raw BIS. The efficiency of this method is then compared to conventional Cole-Cole parameter extraction in a classification task.

1 Introduction

BioImpedance Spectroscopy (BIS) is a safe, non-invasive method to explore various changes of the composition or functionality of a living tissue. In spite of widespread range of methods and models introduced by researchers, BIS measurements don't seem to be reproducible enough to be considered as a diagnosis tool [1]. Practically, researchers fit each measured spectrum, $Z(f)$ to Cole-Cole model, using a nonlinear regression algorithm. Four fitting parameters are then used to represent the information content of BIS measurements. These parameters are informative and useful for explaining the physiology of tissues. However, they can be easily affected by experiment setup and condition, which is difficult to control over time, especially from one experiment session to another. In a set of longitudinal BIS data, the information contents related to tissue response at different frequencies are highly correlated, while noise information could be viewed as uncorrelated to tissue's frequency response. Therefore, applying Principal Component Analysis (PCA) in frequency domain could be a promising candidate to cancel the effect of variations of experiment conditions and extract time persistent features from measured spectra. Although PCA has been employed to analyze BIS data in a few specific applications [2], it has never been considered as a general BIS feature extraction method to represent the information content of a set of longitudinal BIS measurements. In this paper, the measured spectra are decomposed and mapped on most significant eigenvectors. Moreover, this decomposition is modified to be delimited in specific frequency ranges to decrease the computational cost. A BIS classification task over different experiment sessions is also investigated to show the advantage of proposed method over Cole-Cole parameter extraction in representing BIS data.

2 Method and Results

We performed a set of measurements using a Solartron 1255 Frequency Response Analyser and 1294 Impedance Interface, with tetra-polar system and frequency range of 5-200 kHz with 5 kHz steps. Four subjects were involved in three different experiment sessions, and their forearm BIS was measured in three different positions: horizontal, vertical pointing downward and vertical pointing upward. Cole-Cole parameters were extracted based on the state-of-the-art method introduced in [3]. For the sake of testing the reproducibility of extracted features in this longitudinal data, each arm position is considered as a class and a classification task is implemented. Different classifiers were tested using 1-leave-out validation method. Using Cole-Cole parameters, best classification accuracy was obtained by a KNN (n=3).

In order to decompose the BIS spectra, the total covariance of spectral data is estimated as sum of the covariance matrices of real and imaginary parts. Eigenvectors are then computed from this covariance matrix. In this experiment, more than 97% of the total variance lies on the first principal component. Therefore, each 80-dimentional vector (real and imaginary in 40 frequencies), is reduced to a 2-dimensional one by mapping real and imaginary parts onto the first eigenvector. In addition, by assessing the coefficients of the first eigenvector for each arm position, we found that different frequencies don't have equal impact on this mapping. So, we delimited the measurements and feature extraction to the frequency range with highest coefficients in the first eigenvector. Restricting the frequency segments decreases the computational cost of analysis which is very important in clinical use. When the above mentioned classifier is fed with the features extracted with proposed method, the classification accuracy improves, which is shown in Table 1. Therefore, this method is extracting the reproducible information from raw data of different experiment sessions more effectively than Cole-Cole method.

3 Conclusions

This paper proposes that segmental spectral decomposition can be considered as an effective feature extractor to overcome the reproducibility issue of BIS measurements. This method is carried out by mapping the measurements on the eigenvectors with highest variance. This mapping is delimited in frequency segments corresponding to highest coefficients of most significant eigenvectors, resulting in a far lower computational cost than nonlinear curve fitting. The proposed method has the potential to be generalized in future works as a general BIS and EIT feature extraction method.

References

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Table 1: Comparing different BIS feature extraction methods in arm position classification task

Feature extraction method	Cole-Cole parameter extraction [3]	Spectral decomposition	Segmental spectral decomposition
Classification Accuracy	75%	87.5%	95.5%