Multi-frequency Electrical Impedance Tomography Using Principal Component Analysis to Determine Reference Signal Automatically

Yang Pu[1], Tao Dai[1] and Andy Adler[2]

[1]Sealand Technology (Chengdu), Ltd., Chengdu, China, tdai@eitchina.net
[2]Systems and Computer Engineering，Carleton University, Ottawa, Canada

Abstract: A reference signal calculation method is proposed for multi-frequency EIT difference imaging. The 1st principal component calculated by using PCA technique is selected as reference.

1 Introduction

Multi-frequency electrical impedance tomography (mfEIT) is expected to show promise for detecting tumors in the breast. It has been discovered that malignant breast tumors have significantly different impedance spectra than benign tissue [1], and could provide a better imaging contrast. Moreover, frequency response of different tissues could be obtained by analysing mfEIT images, which provides a reasonable way to identify and characterize tumors.

Generally, difference EIT imaging is utilized in mfEIT, but it's difficult to manually select one measurement at a specific frequency as a suitable reference signal to obtain relative changes with respect to measurements at other frequencies. If a noisy signal is mistakenly selected as a reference, image reconstruction may yield uninterpretable artefacts. In this paper, principal component analysis (PCA) is used to analyse the measured raw data at each frequency point, and the 1st principal component can be automatically obtained as a reference.

2 Methods

We suppose the measured raw data at each frequency point as a vector $\mathbf{v_i}, i = 1,2\ldots n$, where n is the total frequency points. A data frame matrix can be obtained as $\mathbf{V} = [\mathbf{v}_1^T, \mathbf{v}_2^T \ldots \mathbf{v}_n^T]$. Then PCA technique is applied to calculate the 1st principal component $\mathbf{v_0}$. Therefore, difference signal $\mathbf{y_i} = \mathbf{v_i} - \alpha_i\mathbf{v_0}$ is obtained, where α_i is a scaling factor defined as [1]

$$\alpha_i = \frac{<\mathbf{v_i}, \mathbf{v_0}>}{<\mathbf{v_0}, \mathbf{v_0}>} \qquad (1)$$

where $<\cdot,\cdot>$ is the standard inner product of two vectors.

Moreover, shape distortion and contact impedance changes are compensated [2]. An ℓ_1 norm iterative method, which has the merits of reducing sensitivity to data outliers and avoiding edge blurring, is applied as well [3].

2.1 Numerical Simulation

Sixteen electrodes were located surrounding the medium outer surface. Inside the medium, there were two targets with different frequency responses. Gaussian white noise was added to the simulation data with 1% noise level. Results were shown in Fig.1.

2.2 Saline Phantom Measurement

Small biological tissues such as potato, apple and porcine liver were statically suspended in the 0.9% saline solution. Reconstructed images demonstrated frequency response of each tissue.
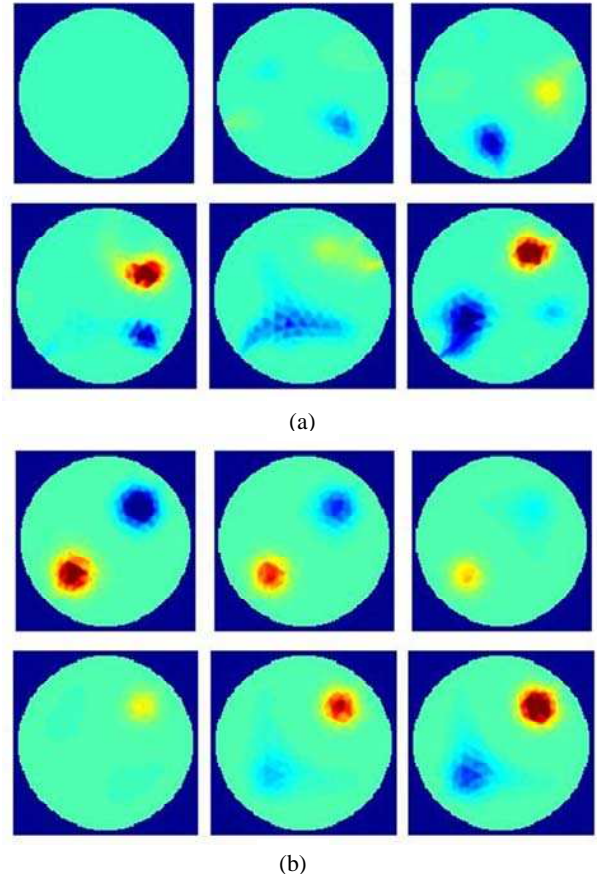

(a)

(b)

Figure 1: Images reconstructed from simulation data using (a) the 1st frequency; (b) the 1st principle component as reference respectively. Colour changes indicate frequency responses.

2.3 *In vivo* Human Measurement

The mfEIT data were acquired from female patients with malignant breast tumors using Zscan™ diagnosis system (Sealand Inc., in Chengdu, China). Preliminary results showed that the proposed method has a potential to be adopted for tumor detecting.

3 Conclusions

One key advantage of the proposed method is that the reference signal can be calculated automatically without manual selection. Considering PCA is robust to data noise and outliers, this method is expected to show improvement of artefact resistance (as shown in Fig.1).

References

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