A microscopic electrical impedance tomography using a novel design with two injection current

Eun Jung Lee[1], Tong in Oh[2], Tae Eui Kim[2], Eung Je Woo[2] and Jin Keun Seo[1]
[1]Department of Computational Science and Engineering, Yonsei University, Seoul, KOREA
[2]Department of Biomedical Engineering, Kyung Hee University, Gyeonggi-do, KOREA
E-mail: eunjunglee@yonsei.ac.kr

Abstract. An enhanced microscopic electrical impedance tomography (micro-EIT) system which aims to produce cross-sectional admittivity images of a biological tissue sample or cells inside a small hexahedral container is proposed. The proposed micro-EIT system enhances the originally suggested electrode configuration in Lee *et al* (2011) and Liu *et al* (2011). On both ends of the container nine pieces of gold-coated solid electrodes for source and sink current injection are placed. The 360 voltage sensing electrodes are located on the side walls for voltage measurements. The top of the container is open for sample manipulations. In terms of the image quality, the new micro-EIT system is advantageous over a conventional EIT method adopting multiple current injection patterns.

1. Introduction

The culture of cells in vitro provides a platform for studying cell and tissue physiology and to grow regenerative tissue outside of the organism. Traditional cell culturing has been doing on two dimensional substrates. However, in vitro cells in 2D exhibit unnatural behavior. Recently, biologists and bioengineers have investigated three dimensional cell culture and monitoring methods. Cultured in three dimensional environments have become popular as mimics of the native microenvironment.

Electrical impedance tomography (EIT) has been developed to visualize internal admittivity distributions of human body by utilizing boundary current-voltage data sets subject to multiple injection current patterns. It has a potential to monitor of cell growth, proliferation, differentiation, migration and apoptosis based on microscopic admittivity distribution and changes. It is nondestructive, non-invasive, label-free, multi-dimensional (space, time and frequency) and direct imaging method even though the spatial resolution is very poor. For last few decades, microelectrode systems using conventional EIT techniques have been used to investigate the growth and migration of cell. Most micro-EIT systems proposed so far have much in common with a standard medical EIT system using conventional approaches. It has a technical difficulty from EIT such as the ill-posedness of the inverse problem and the nonlinearity between admittivity and boundary voltage measurements and so on.

Recently, a new micro-EIT system design using a miniaturized hexahedral sample container with projected image reconstruction algorithm was introduced (Liu *et al* 2011, Lee *et al* 2011). It provides a unique electrode configuration and associated data collection method by separating driving and sensing electrodes. In this paper, we enhance the proposed model in Liu et al (2011) to overcome some difficulties occurred by the secondary driving electrode and achieve better admittivity distribution image of interior of the container.

2. Enhance micro-EIT : KHU Mark2

In order to mitigate the troubles that were introduced in the first model (Liu *et al* 2011, Lee *et al* 2011), we relocate the driving electrodes. The container has size of $4.8 \times 2.4 \times 2.4$ cm^3.

There are several choices in choosing the primary, $\mathcal{E}_{1\pm}$, and secondary driving electrodes, $\mathcal{E}_{2\pm}$. Any combination of nine electrodes can be driving electrodes. Let P_k, k = 1,…,9 and k = 11,…,19, be the metal plates placed on both ends (left and right) of the container as driving electrodes. Typically we choose $\mathcal{E}_{1+} = \cup_{\{k=1\}}^{9} P_k$ and $\mathcal{E}_{1-} = \cup_{\{k=11\}}^{19} P_k$ to induce a primary current so that we can create a uniform parallel current density distribution inside the container when it is filled with homogeneous saline. For the secondary current injection, we choose the solid metal plates on both ends more carefully so that the dominant direction of the secondary current is linearly independent to the primary current. For instance, we can choose $\mathcal{E}_{2+} = P_1 \cup P_2 \cup P_3$, $\mathcal{E}_{2-} = P_{17} \cup P_{18} \cup P_{19}$ for front and back sides of image reconstruction and $\mathcal{E}_{2+} = P_1 \cup P_4 \cup P_7$, $\mathcal{E}_{2-} = P_{13} \cup P_{16} \cup P_{19}$ for bottom side of image reconstruction. Total 24X15 (360) sensing electrodes are placed on side walls.

3. Experimental results

We fill the container with saline of 0.4 S/m conductivity. Pieces of carrot with 0.029 S/m conductivity are placed in the container at different positions.

Using the projected image reconstruction algorithm introduced in Lee *et al* 2011, three images of admittivity on front, back, and bottom sides are obtained then back-projecting method is used to construct three dimensional image of the interior.

Test 1

We place a cubical piece of carrot with 8 × 8 × 8 mm^3 size to three different positions, left, right, and center-position.

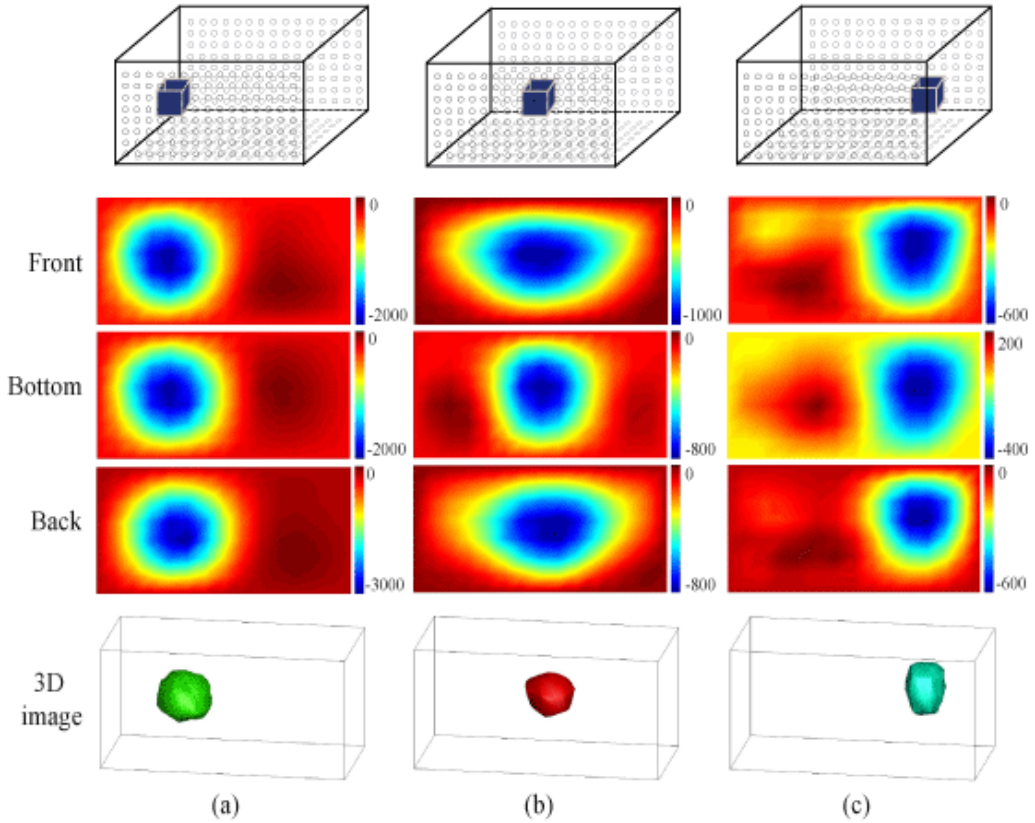

Figure 1 : First row-the exact position of objects; From second to fourth row-projected conductivity images on the front, bottom and back; Fifth row-three dimensional reconstructed image; (a) left object with 0.029 S/m conductivity and 8 × 8 × 8 mm^3 (b) center (c) right

Test 2

A cubical piece of carrot with 5 × 5 × 5 mm^3 size to three different positions, left, right, and center-position.

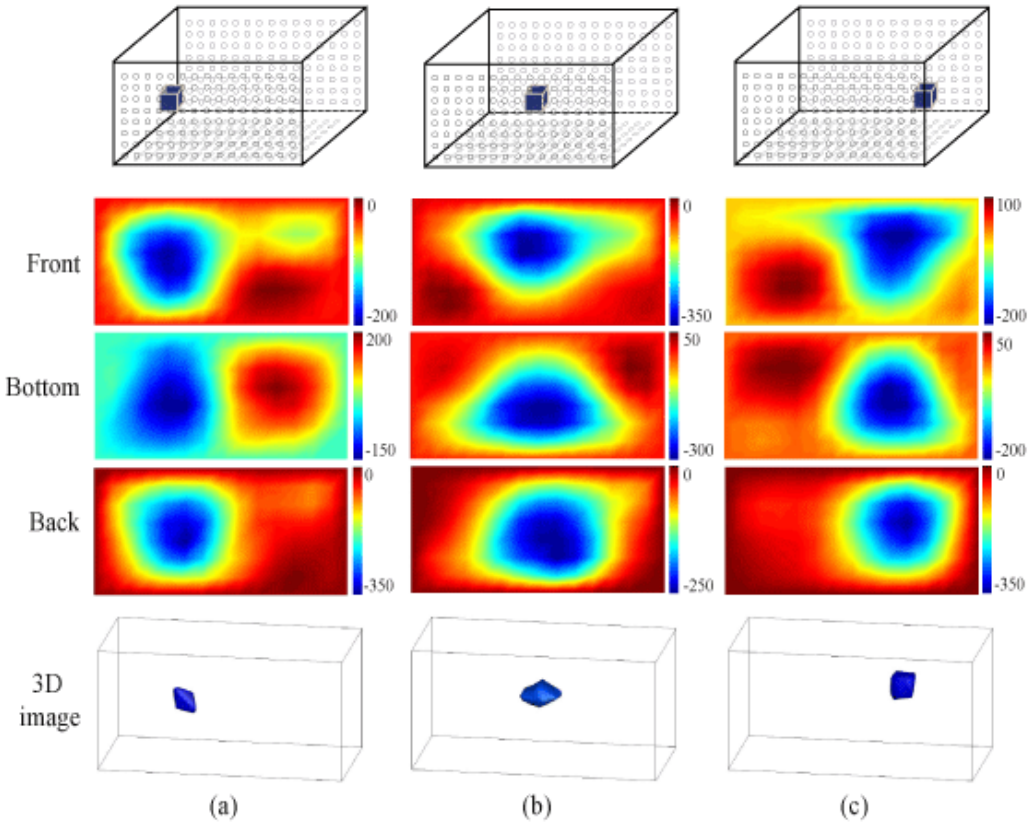

Figure 2 : First row-the exact position of objects; From second to fourth row-projected conductivity images on the front, bottom and back; Fifth row-three dimensional reconstructed image; (a) left object with 0.029 S/m conductivity and 5 × 5 × 5 mm^3 (b) center (c) right

References

Lee E J, Seo J K, Woo E J and Zhang T 2011 Mathematical framework for a new microscopic electrical impedance tomography system *Inverse Problems* **27** 1-19

Liu Q, Oh T I, Wi H, Lee E J, Seo J K and Woo E J 2011 Design of a microscopic electrical impedance tomography system using two current injections *Physiol. Meas.* **32** 1505-1516