A projected image reconstruction algorithm for electrical impedance tomography using time difference data

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Abstract. This work develops the projection image of conductivity from 3D to 2D. The new proposed method has four electrodes, which we call driving electrodes. There are used to inject current into the object. The other electrodes are the voltage sensing electrodes placed between the driving electrodes, which we called the voltage-sensing electrodes. Based on the derived voltage-current relation, we produce images of conductivity changes within a local region underneath the voltage-sensing probe. We describe the new image reconstruction algorithm and its numerical simulation results.

1. Introduction

In conventional electrical impedance tomography (EIT), the electrodes attached around an imaging object. For instance: image of the human chest or image of abdomen and so on. The electrodes on boundary for injection of currents are designed also to measure induced voltage distributions (Adler *et.al* 2009), (Cheney *et.al* 1999), (Holder 2004), and (Brown *et.al* 1985). Sometimes, practically it is not continent and impossible to attach electrodes around a boundary of chosen region. Therefore it is important to focus only in interested region. About it related previous studies to use a planar array of electrodes (Boverman *et.al* 2009) and (Sadleir *et.al* 2009). They used some or all of the electrodes for current injections and voltage measurements and adopted conventional EIT image reconstruction methods. Rabbani *et.al* proposed focused impedance measurement (FIM) using two pairs of current injection electrodes and one pair of voltage-sensing electrodes (Rabbani *et.al* 1999). By adding two voltage measurements subject to two orthogonal current injections, they could enhance the sensitivity of the tetra-polar surface impedance measurement to the admittivity of the internal local region underneath the voltage-sensing electrodes. In this paper, we propose a new EIT image reconstruction algorithm for the electrode configuration of the PHI shown in figure 1.

2. Mathematical model and electrode configuration

The time difference Dirichlet data is used to investigate admittivity change of human's organs such as insult to subsurface cortical blood vessels of stroke, lung monitoring and the human abdomen. In this work observation is the admittivity distribution in the human abdomen. Let the human body satisfies a three-dimensional domain Ω with its boundary $\partial\Omega$. The complex admittivity is depending of time t, and position $\mathbf{r} = (x, y, z)$ in Ω denoted by

$$\gamma(t, \mathbf{r}) = \sigma(t, \mathbf{r}) + i\omega\epsilon(t, \mathbf{r}),$$

where $\sigma(t, \mathbf{r})$ is conductivity, $\epsilon(t, \mathbf{r})$ is permittivity, and ω is angular frequency. We attach two pairs of driving electrodes $\mathcal{E}_1^{\pm}$ and $\mathcal{E}_2^{\pm}$ to the surface to inject current and a sensing probe occupying Γ to measure the resulting voltages. When we apply a sinusoidal voltage of $V_0 \sin \omega t$ using a chosen pair of electrodes $\mathcal{E}_j^{\pm}$, the resulting complex potential $u^j(t, \mathbf{r})$ satisfies the following mixed boundary value problem: $j = 1, 2$

$$\left\{ \begin{array}{ll} \nabla \cdot (\gamma(t, \mathbf{r})(\mathbf{r}) \nabla u^j(t, \mathbf{r})) = 0 & \text{in } \Omega \\ u^j(t, \mathbf{r})|_{\mathcal{E}_j^-} = 0, \qquad u^j(t, \mathbf{r})|_{\mathcal{E}_j^+} = V_0 & \\ (\gamma(t, \mathbf{r})(\mathbf{r})) \frac{\partial u^j(t, \mathbf{r})}{\partial \mathbf{n}} = 0 & \text{on } \partial\Omega \setminus (\mathcal{E}_j^- \cup \mathcal{E}_j^+) \end{array} \right. \tag{1}$$

where $\mathbf{n}$ is the unit outward normal vector to the boundary $\partial\Omega$. Through the probe Γ we measure the time varying boundary voltage

$$f^j(t, \cdot) := u^j(t, \cdot)|_{\Gamma} \qquad \text{for } j = 1, 2. \tag{2}$$

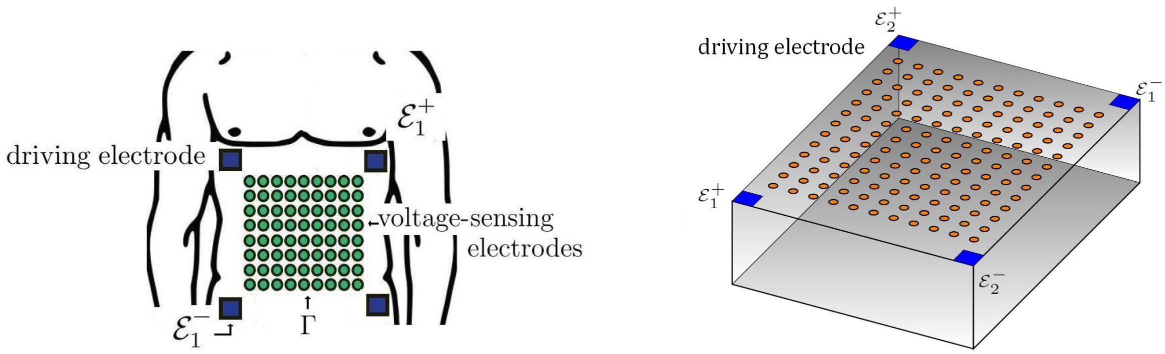

Figure 1. Electrode configuration: human torso model and simple tank model

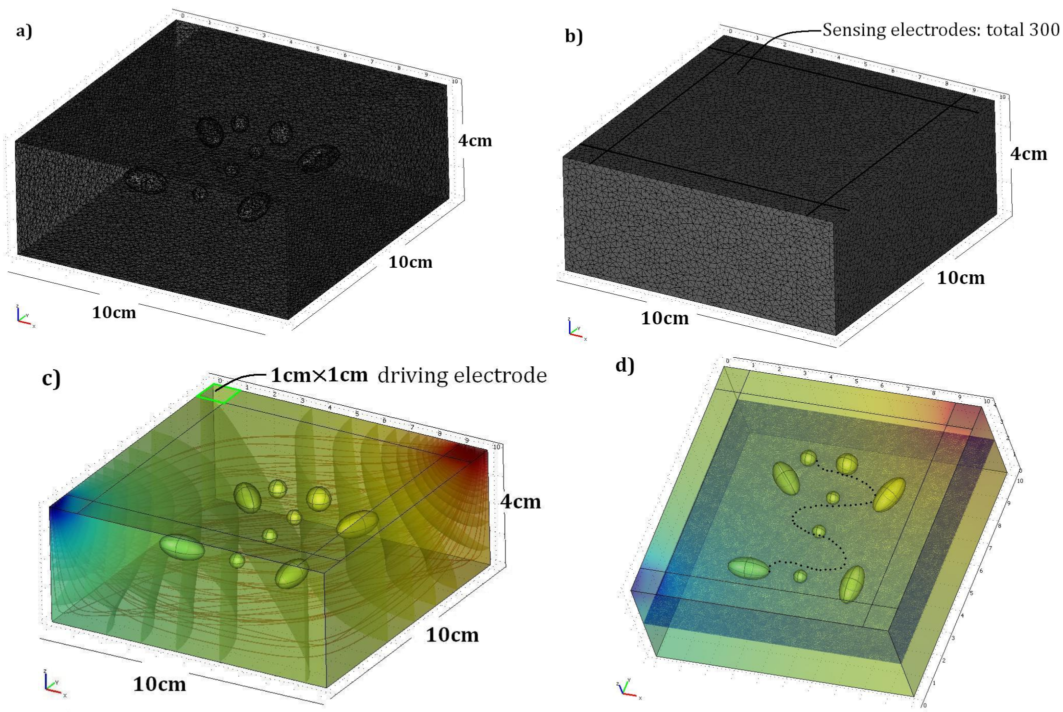

Figure 2. a) The tetrahedrons of model b) Sensing electrodes c) Current and voltage distributions d) The trajectory of moving ball

The goal is to reconstruct time change of the complex admittivity $\frac{\partial}{\partial t}\gamma(t, \mathbf{r})$ underneath the probe Γ using time difference voltage data $\frac{\partial}{\partial t}f^j$ on Γ. We use the algorithm introduced in (Lee *et.al* (2011)). Figure 1 shows proposing electrode configuration for planar EIT.

3. Numerical simulations

We observe simple tank with sizes $10cm \times 10cm \times 4cm$ and background conductivity set to $1s/m$. In Figure 2, we placed 8 objects with conductivity $3s/m$, which are static. One ball is moving in sinusoidal trajectory with conductivity $4s/m$. The reconstruction

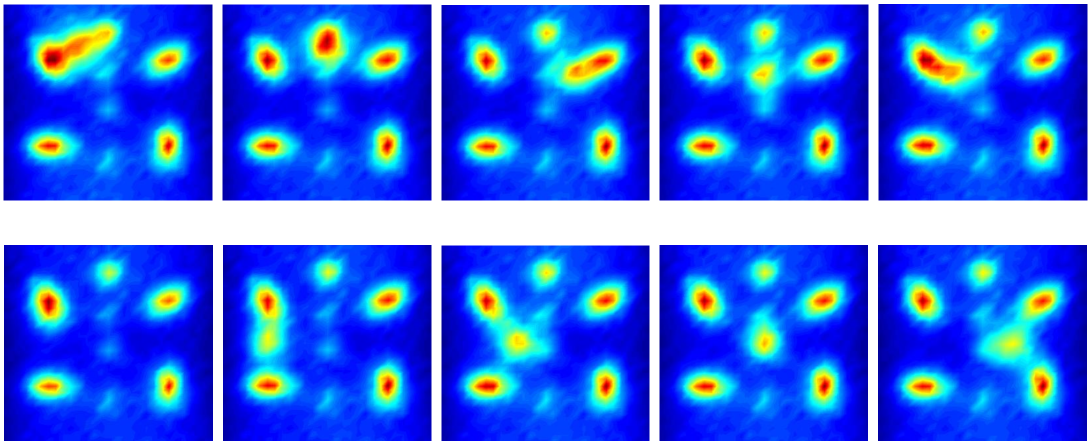

Figure 3. The reconstructed images at time period $t_1, t_2, ...t_{10}$

images shown Figure 3 at times $t_1 = 0.1, t_2 = 0.2, ...t_{10} = 1$.

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