A Modified Landweber Iteration Algorithm using Updated Sensitivity Matrix for Electrical Impedance Tomography

Lifeng Zhang, Department of Automation, North China Electric Power University, Baoding, China

ABSTRACT

Electrical impedance tomography (EIT) is a technique to reconstruct the conductivity distribution of an inhomogeneous medium by injecting currents at the boundary of an object and measuring the resulting changes in voltage. The sensitivity matrix of EIT is calculated with a selected reference conductivity distribution, which is time-consuming. However, the sensitivity matrix will change with the media distribution, which results in the quality of the reconstructed image reduction. A modified Landweber iterative algorithm based on updated sensitivity matrix was presented in this paper. The reconstructed image based on conventional Landweber iteration was selected as the initial image for sensitivity matrix update, and the reconstructed images after sensitivity matrix update using different initial images were compared. The effect on the quality of reconstructed images for different times of sensitivity matrix update was also analyzed. Simulation and static test were carried out. Experimental results showed that reconstructed images with higher quality can be obtained.

Keywords: Conductivity Distribution, Electrical Impedance Tomography (EIT), Image Reconstruction, Modified Landweber Iteration Algorithm, Sensitivity Matrix Updating Strategy

1. INTRODUCTION

Electrical impedance tomography (EIT) is a new functional imaging technique which can generate cross-sectional images of electrical properties inside the human body which are related to functional changes in tissues or organs (Shi, Dong, Shuai, You, Fu, & Liu, 2006). A safety Sinusoidal current (<5 mA) is applied to a set of electrodes attached on the body surface and the voltages between adjacent electrode pairs are measured. An image reconstruction algorithm is used to estimate the conductivity distribution based on the measured boundary voltages (Halter, Hartov, & Paulsen, 2007).

Conductivity imaging has been employed in a number of different medical applications including imaging brain function, pulmonary activity, gastric emptying, and ischemia in transplant organs (Tidswell, Gibson, Bayford, &...
EIT has been studied to generate images of various parts of the human body, such as the human lungs, head, heart and stomach (Holder, 1992; Vonk Noordegraaf et al., 1997; Mangnall et al., 1987). Although the resolution of an EIT image is lower than that of an x-ray, CT or MR image, the possibility of long-term monitoring without harmful side effects on the human body seems to make EIT a promising technique capable of continuous monitoring (Otten & Rubinsky, 2000; Shuai et al., 2008).

Image reconstruction in EIT is a nonlinear optimization problem in which the solution is obtained iteratively through the forward and inverse solvers (Kim, Kim, Kim, & Kim, 2004). Various reconstruction algorithms have been developed to estimate the internal conductivity distribution of the object, among most of which the sensitivity matrix was used to fulfill image reconstruction (Cheney, Isaacson, Newell, Smike, & Goble, 1990; Hua, Woo, Webster, & Tompkins, 1991; Vauhkonen, Karjalainen, & Kaipio, 1998; Kim, Kim, Kim, Lee, & Vauhkonen, 2001). Usually, the sensitivity matrix is calculated with a selected reference conductivity distribution, assuming that the media distribution doesn’t affect the electrical potential distributions (Wang, 2002). In fact, there exists ‘soft-field’ effect, that is, the media distribution will greatly affect the electrical potential distributions. Even more, for different electrodes and locations, this affection is different. As a result, the sensitivity matrix will change with the media distribution and needs to be updated. However, the calculation of sensitivity matrix is time-consuming. In industrial multiphase flow applications, the flow regimes vary quickly. To obtain real-time reconstruction images, the sensitivity matrix is hardly to be updated. In this case, reconstructed images with high quality cannot be obtained. To enhance the quality of the reconstructed images, sensitivity matrix updating strategy is considered in this paper.

In principle, sensitivity matrix should be updated according to the true media distribution, which is unknown (Xie et al., 1992). Therefore, sensitivity matrix can only be updated according to the reconstructed image by some reconstruction algorithms, say, Landweber iterative algorithm (Li & Yang, 2008). A modified Landweber iterative algorithm based on updated sensitivity matrix was presented in this paper. The reconstructed image based on conventional Landweber iteration was selected as the initial image for sensitivity matrix update, and the reconstructed images after sensitivity matrix update using different initial images were compared. The effect on the quality of reconstructed images for different times of sensitivity matrix update was also analyzed. Simulation and static test results showed that reconstructed images with higher accuracy can be obtained.

2. PRINCIPLE OF EIT

2.1. Mathematical Model of EIT

A typical 16-electrode EIT system can be shown in Figure 1. An EIT includes three parts: array electrode sensor, data acquisition system and image reconstruction. For a K-electrode EIT system, the independent measurement number is \(K(K-1)/2\). 120 independent measurements can be obtained using a 16-electrode EIT system. When electrical currents \(I_k = (1, 2, \ldots, K)\) are injected into a body \(\Omega \in R^2\) through the electrodes \(E_k\) and the conductivity distribution \(\sigma(x, y)\) is known for \(\Omega\), the corresponding electrical potential \(u(x, y)\) can be determined from a partial differential equation, which can be derived from the Maxwell equations:

\[
\nabla \cdot (\sigma \nabla u) = 0
\]

(1)
TB-WPRO: Title-Block Based Web Page Reorganization
[www.igi-global.com/article/wpro-title-block-based-web/59712?camid=4v1a](www.igi-global.com/article/wpro-title-block-based-web/59712?camid=4v1a)

A Multi-Agent System for Improving the Resource Allocation on Programmes in Higher Education
[www.igi-global.com/chapter/multi-agent-system-improving-resource/76783?camid=4v1a](www.igi-global.com/chapter/multi-agent-system-improving-resource/76783?camid=4v1a)