A Comparison of Two Regularization Methods Based on the Sussex EIM MK4 System

Xiaolin Zhang[1] Chris Chatwin[1] and Wei Wang[2]
[1]University of Sussex, Brighton, UK, xz68@sussex.ac.uk
[2]Micro Image UK Ltd, UK, w97wang@yahoo.co.uk

Abstract: A comparison of two regularization methods: the general regularization method and the Sheffield method using the voltage ratio rather than the difference.

1 Introduction

The Sussex MK4 is a 3D EIT system for breast cancer detection, using current excitation and voltage measurements. The data acquisition is completed by a planar electrode array at the bottom of the tank in the MK4. In experiments, two groups of measurements are collected: the reference measurements which are from a tank of saline and the actual measurements which are from a patient with a breast placed in the tank. For detailed information of the MK4, please refer to [1] (page 44-49). The aim of this paper is to compare the two regularization methods shown in Section 2.

2 Methods

The vector c_0 denotes the initial conductivity, which is the saline in the tank; the vector V_0 denotes the measurements of the saline; the vector c_{ref} denotes the reference conductivity, which could be c_0 or the conductivity with some known anatomical features; the vector C denotes the actual conductivity, with a breast in the tank; the vector V_m denotes the actual patient measurements. Defining $\Delta c = C - C_{ref}$, $\Delta V = V_m - V_{ref}$, the general regularization method for the EIT inverse problem is:

$$\begin{cases} \Delta c = (S^*S + \alpha^2 I)^{-1}\left(S^*\Delta V + \alpha^2 I(c_{ref} - c_0)\right) \\ c = c_{ref} + \Delta c \end{cases} \quad (1)$$

where S is the Jacobin matrix, α is the regularization parameter, I is the identity matrix. For the details, please refer to [1] page 62-65 and [2] page 21. The Sheffield group uses the logarithm of the voltage ratios rather than the difference to do image reconstruction.

$$\begin{cases} \Delta lnc = (F^*F + \alpha^2 I)^{-1}\left(F^*\Delta lnV + \alpha^2 I(lnc_{ref} - lnc_0)\right) \\ lnc = lnc_{ref} + ln\Delta c \end{cases} \quad (2)$$

where $\Delta lnV = \left[\ln\left(\frac{V_{m1}}{V_{01}}\right); \cdots; \ln\left(\frac{V_{mM}}{V_{0M}}\right)\right]$, $\Delta \ln c = [\ln\left(\frac{c_1}{c_{ref1}}\right); \cdots; \ln\left(\frac{c_E}{c_{refE}}\right)]$, $F_{ij} = \frac{1}{V_{refj}} . S_{ij} . C_{refi}$, M and E indicate the number of measurements and the number of the mesh elements (refer to [1] page 65-67 and [2] page 370).
To compare the two algorithms, a cylindrical model is employed in Figure 3. The conductivity of the object is 0.8 mS/cm and the conductivity of the surrounding saline is 0.5 mS/cm. The SNR of the simulated measurements is 60dB. The L-curve is employed to decide α. α at the global corner is the optimized trade-off between the noise and image quality (Figure 1, 3), thus the optimized α for (1) and (2) are $\alpha^2 = 2$ and $\alpha^2 = 0.08$. The results corresponding to the optimized α are shown in Figure 2, 4. The images from left to right indicates the bottom, middle and top reconstructed conductivity.

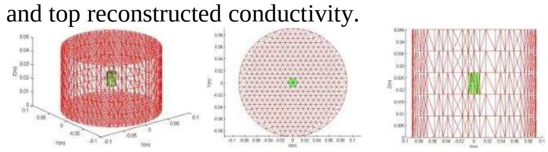

Figure 3: Model: 3D view, XY view and XZ view

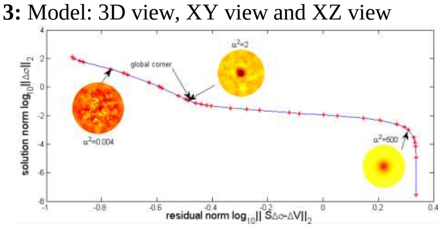

Figure 4: L-curve of the general regularization method

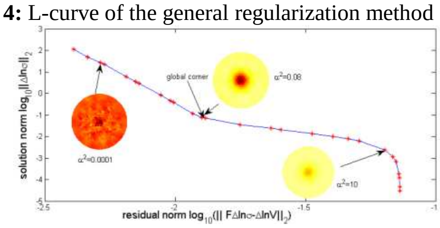

Figure 5: L-curve of the Sheffield method

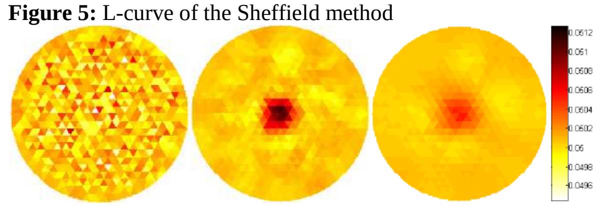

Figure 6: Result from Equation (1), $\alpha^2 = 2$.

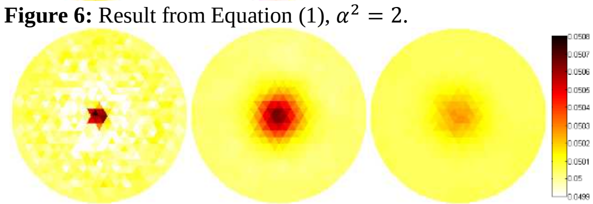

Figure 7: Result from Equation (2), $\alpha^2 = 0.08$.

3 Conclusions

For the Sussex MK4 system, at an optimised α, the general regularization method gives a better performance in distinguishing the object from the background but has less noise tolerance. The Sheffield algorithm is more robust to noise.

References

[1] G. Sze, “Detection of breast cancer with electrical impedance mammography,” Doctoral thesis, Engineering and Design, University of Sussex, 2012.

[2] D. C. Barber, "EIT: The view from Sheffield," Electrical impedance tomography : methods, history and applications, D. S. Holder, ed., pp. 348-371, Bristol: Institute of Physics, 2005.