Using Polynomial Curve Fitting Method to Improve Image Quality in EIT

Jianjun Zhang , Guizhi Xu, Quanming Zhao and Weili Yan

***Abstract*—The Polynomial Curve Fitting Method (PCFM) is used firstly on Electrical Impedance Tomography (EIT) to find out the polynomial function of boundary potential distribution according to the measured data in this work. The potential values calculated from the polynomial function can be regarded as measured data. So enough data can be provided to satisfy the requirements of various algorithms. The potential distribution within the domain is obtained approximately according to the equipotential property. Without adding the electrode number and changing data collection strategy, more data can be obtained and regarded as measured data by using the PCFM. With these enough data, the quality of reconstructed image is improved obviously.**

I. INTRODUCTION

IMPEDANCE distribution is very useful in many researches for function analysis. Electrical impedance tomography (EIT) has many advantages over other imaging modalities, especially it identifies information of electrical properties of the tissue. This kind of information can not provided by other imaging techniques [1], [2]. However, it is difficult to use the tomographic image in clinical practice. But EIT reveals great significant latent value and applied prospect. Many groups in the world study the data collection system and reconstructed algorithm especially the solution of the inverse problem presently.

A severe limitation of EIT is its few collected data because of the limitation of the number of electrodes. For this reason, only by improving the algorithm can improve the quality of reconstructed image to some extent, but the defect of the image resulted due to the lack of quantity of information can not be eliminated. Prior information must be used to obtain more useful data.

Since the boundary potential distributes continuously and regularly, each of the measured data is not isolated from the others. Some relevant connotative information can be obtained from the locations of the data and relationship among them.

The Polynomial Curve Fitting Method (PCFM) is used to find out the function of boundary potential distribution from the measured data. The potential values calculated from the function are regarded as measured data. Therefore, enough data can be used by various algorithms.

The potential distribution within the domain is obtained approximately according to the equipotential property. The reconstructed image is improved by using the PCFM method.

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II. THE POLYNOMIAL CURVE FITTING METHOD

The mathematical model of EIT is given by Maxwell's equations. Given the resistivity distribution ρ inside the subject, the boundary voltage u satisfies the Laplace equation

$$\nabla \cdot \rho^{-1} \nabla u = 0 \qquad in \quad \Omega \tag{1}$$

with boundary conditions

$$\begin{cases} u = u_0 & in\, \Gamma_1 \\ \rho^{-1} \dfrac{\partial u}{\partial n} = -J & in\, \Gamma_2 \end{cases} \tag{2}$$

where u_0 is the measured peripheral voltage vector, J denotes the current intensities on the boundary and n is the outward normal.

Many algorithms are put forward and improved. But it is limited to improve the quality of reconstructed image only by changing the algorithm because of the limited information.

Though the reactance character of biology tissue is complicated，it shows resistance mainly. So the potential distribution is continuous on the boundary when current injected into the model. Because the shape of the model is usually regular, the potential distribution is regular.

The potential of measuring electrodes on the boundary of a circle model with 16 electrodes when current is injected through the adjacent electrodes is shown in Fig.1. The x-axis shows the number of electrodes and y-axis shows the potential of them.

As shown in Fig.1, the potential distribution is very regular. It can be inferred that the function of potential distribution in the boundary must be shown as a continuous curve which cross every point.

PCFM is used to find the coefficients of a polynomial $p(x)$ of degree n that fits the measured data

$$p(x) = p_1 x^n + p_2 x^{n-1} + \cdots + p_n x + p_{n+1} \tag{3}$$

where the degree n can be selected according to the requirement of errors by the algorithm. The function can describe the potential distribution on the boundary. From the function we can get infinite data. PCFM can take advantage of the limited measured data to get more useful information, which is used to reconstruct the tomographic image.

Therefore, enough data can be provided to satisfy the requirement of various algorithms.

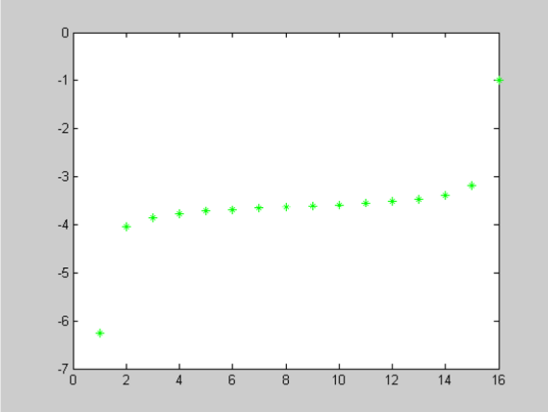


Fig. 1. The potential of electrodes.

The contrast of the fitting polynomial curve and the calculating potential curve is shown in Fig.2. The red line is the fitting polynomial curve (n =15) and the green line is calculating potential curve. As shown in Fig. 2, two curves largely overlap except the section between the injecting and its adjacent electrode.

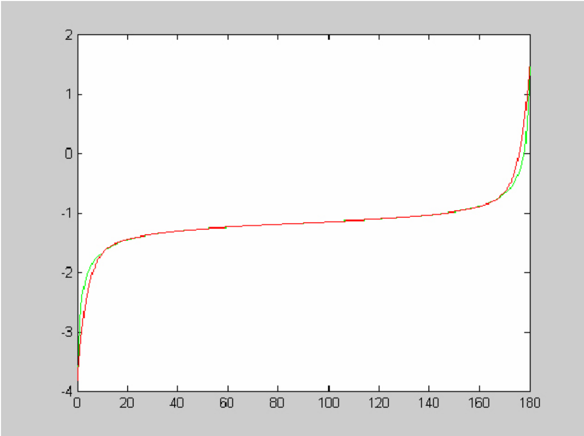


Fig. 2. Contrast of the polynomial and the calculating curve.

Dynamic EIT is a technique to obtain the image of the impedance changes by measuring potentials of electrodes on the boundary in two different moments. Impedance change of any point within the domain can be obtained approximately by fitting the polynomial function and calculating the location on the boundary of the equipotential line through the point.

III. Simulation Result

The circle model is used in the simulating experiments, as shown in Fig. 3, where the red dots denote the electrodes. The domain is meshed into triangular elements, and the numbers of nodes, elements and electrodes are 1051, 1908, and 16 respectively. The bipolar injected current patterns are adopted and the potential differences are computed among all electrodes with respect to one reference [3].

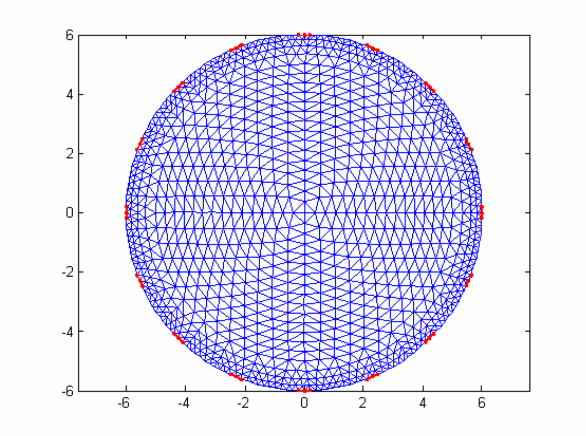


Fig. 3. Circle model for simulation.

The potential distribution is computed by using Finite Element method (FEM), as shown in Fig.4. The length of every line shows the value of potential. For the contrast, the potential distribution computed by using PCFM is shown in Fig.5. The difference of potential of every node by using the two methods is calculated, as shown in Fig.6. The profile chart for the potential difference is shown in Fig.7.

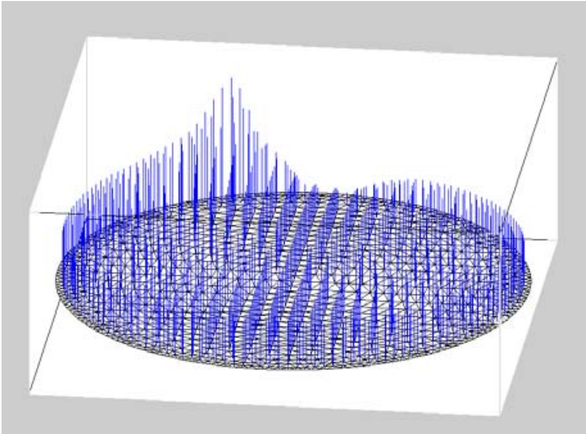


Fig. 4. Potential distribution computed by using FEM.

Potential errors of nodes near the injecting electrodes are more than that of other nodes, as shown in Fig.6 and Fig.7. It is because of the larger errors in the section between the

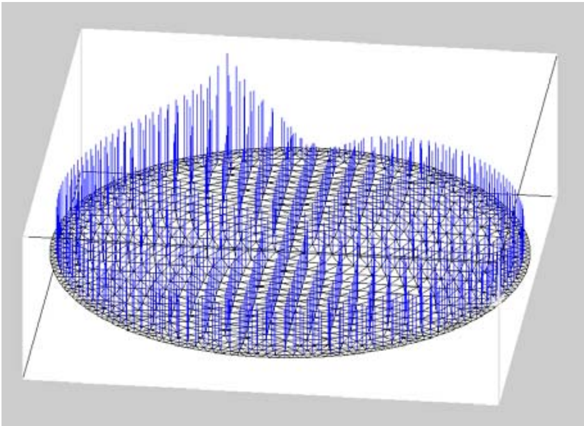


Fig. 5. Potential distribution computed by using PCFM.

injecting and its adjacent electrode, as shown inFig.2. Tetrapolar method is usually used in EIT. Since measuring electrodes are separated from injecting electrodes, the data are just not be used in computing. So it has no bad effect in the image reconstructing[4].

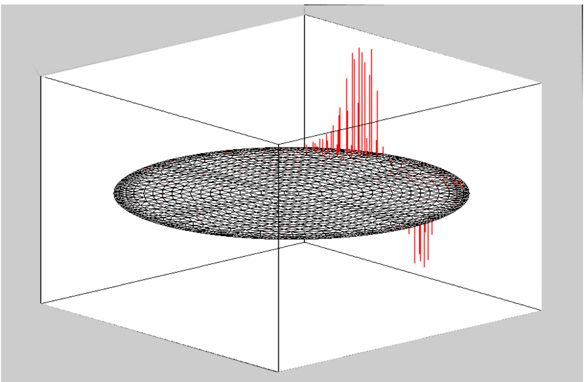


Fig.6. Potential difference of by using PCFM and FEM.

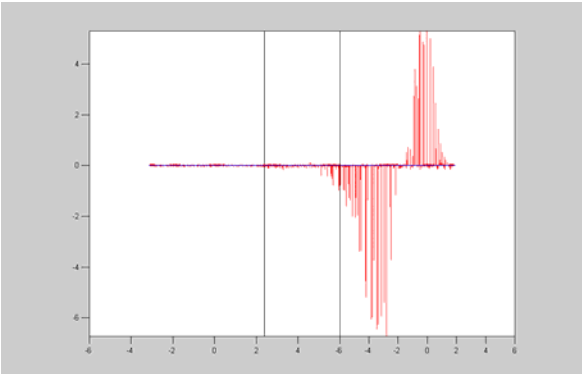


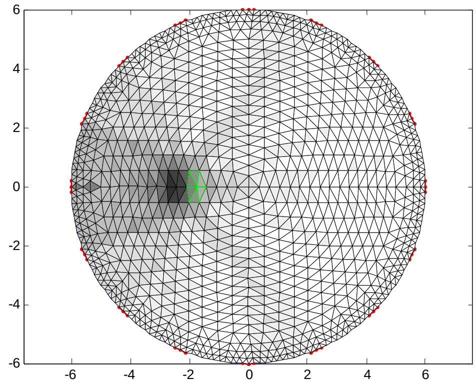
Fig.7. Profile chart for the potential difference.

The reconstructed result of single object models by using back-projection algorithm[5] is shown in Fig. 8(a), where the green region is the object location. The profile chart for the impedance distribution is shown in Fig. 8(b).

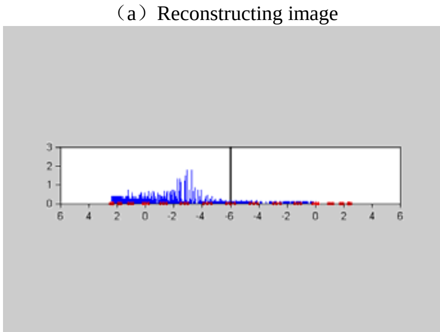
To obtain potential values of more points on the boundary can decrease the width of the equipotential regions. For the simplest example, potential values of 16 midpoints of adjacent electrodes are calculated. The reconstructed result of the equivalent 32-electrode-model is shown in Fig. 9(a). As shown in the figure the object is distinguished from the background more clearly. The location and the size of the object image are more correct and the edge is in focus. The contrast of the image is intensified obviously.

IV. Conclusion

Without adding the electrode number and changing data collection strategy, more data can be obtained and regarded as measured data by using PCFM. With these enough data, the quality of reconstructed image is improved effectively.

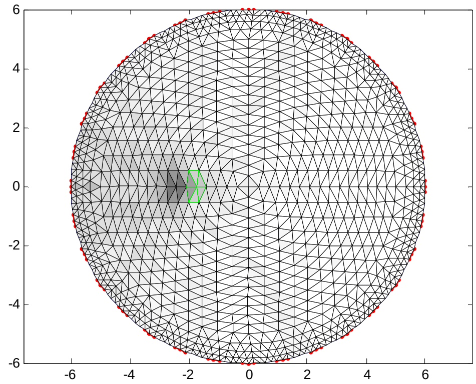


（a）Reconstructing image

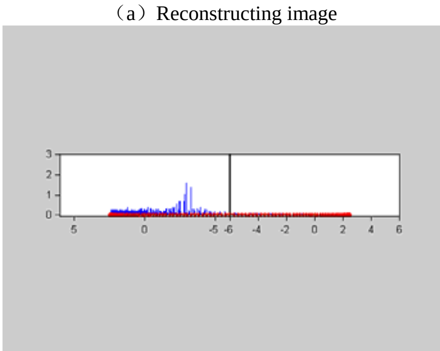


（b）Profile chart of impedance distribution

Fig.8. Reconstructing result



（a）Reconstructing image



（b） Profile chart of impedance distribution

Fig.9. Improving result

Simulation experiments on 2D circle model shows the validity of PCFM. This method can also be used to calculate the distributing function of curved surface to improve reconstructed image quality in 3D EIT.

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