Abstract

Electrical impedance tomography (EIT) is a powerful tool for mapping the electrical property of the estimated objects. The quality of impedance image is limited by the number of electrodes. In this paper we proposed a pseudo electrode driven patterns for electrical impedance tomography. By changing the measuring sites of the physical electrodes we can obtain the expanded pseudo electrodes. The modified adjacent method is also proposed to increase more independent measurement. The singular value plot of the adjacent method and pseudo electrode is provided to show the improvement of pseudo electrode scheme. The result shows that the pseudo provides the better image quality in EIT data collection. We hope the pseudo electrode scheme will bring some help in electrical impedance tomography.

Keywords: Electrical impedance tomography, pseudo electrode driven patterns, modified adjacent method

1. Introduction

Electrical impedance tomography (EIT) is a powerful tool for mapping the electrical property of the estimated objects. The cross-section distribution of impedance of object can be accessed from the measurement made on its surface. Electrical impedance tomography could provide a low cost, real time and portable imaging tool. Because of several potential advantages, the EIT technique has been developed in many industrial applications, such as the fields of process tomography, non-destructive testing, geological studies and medical image [1-3]. It has few commercially EIT systems available. This is because impedance image unable to achieve the essential spatial resolution and this technique has an intrinsically poor signal to noise ratio[4].

The quality of impedance image is limited by the number of electrodes[5]. We may improve the performance of EIT system by increasing the number of electrodes. For a conventional N electrodes EIT system, we could obtain at most N(N-1)/2 independent measurement data to reconstruct the impedance distribution. According to reciprocity theorem, the truly independent measurements are only half of total measurements. For example, the voltage on the electrode pair (3, 4) with driving electrode pair (1, 2) was equal to that on electrode pair (1, 2) with electrode driving pair (3, 4). Both measurements can only be regarded as a single independent measurement. Therefore the total of independent measurement is N(N-3)/2. Adjacent method is the popular drive patterns in most EIT studies. In order to eliminate the influence of contact impedance, the measurements on the driven electrodes pair are ignored. Then the total of independent measurement are reduced to N(N-3)/2. A demonstration of the current injecting and the boundary voltage collecting in adjacent method is shown in Figure 1.

2. Measurement method

For a conventional N electrodes EIT system, we could obtain at most N(N-1) individual measurement data to reconstruct the impedance distribution. According to reciprocity theorem, the truly independent measurements are only half of total measurements. For example, the voltage on the electrode pair (3, 4) with driving electrode pair (1, 2) was equal to that on electrode pair (1, 2) with electrode driving pair (3, 4). Both measurements can only be regarded as a single independent measurement. Therefore the total of independent measurement is N(N-1)/2. Adjacent method is the popular drive patterns in most EIT studies. In order to eliminate the influence of contact impedance, the measurements on the driven electrodes pair are ignored. Then the total of independent measurement are reduced to N(N-3)/2. A demonstration of the current injecting and the boundary voltage collecting in adjacent method is shown in Figure 1.

2.1 Pseudo electrodes driven patterns

In order to increase the number of independent measurement, Pseudo electrodes driven patterns was proposed in this work. In this pattern measuring sites are expended by the pseudo electrodes, which are achieved by rotating the physical electrodes. As shown in Figure 2, for a
16 electrodes EIT system, we rotate the physical electrodes 5 times. The electrodes inside the boundary of tank perform the position and index of pseudo. The electrodes outside the boundary of tank make the real position of physical electrodes. Even, there are 80 measurement sites available, we provide more choices to obtain driven patterns and get more measurement data.

However, not every pseudo electrode pairs combination (driving or measuring pair) are practical. For example, if we choose measuring pair as pseudo electrode (1,2) and driving pair as pseudo electrode (3,4). This driven pattern is impossible, because pseudo electrode (1,2,3,4) are all mapping to the same physical electrode 1. To simplify the data collection process, we proposed an easy driven pattern. By applying data acquiring procedure of adjacent method, we could obtain 16x(16-3)/2=104 independent impedance measurements. Next, the angular orientation of the scanning device is incremented 1 stepping angle (0.018°), and a second data acquiring procedure of 104 impedance measurements is available. Thus, by moving electrodes from the original location to next electrodes location, we could increase the independent measurements further.

2.2 Modified Adjacent data collection method

The modified adjacent method is proposed to increase more independent measurement. The idea of modified adjacent method is achieved by combining the adjacent method and the interleaved method. In the interleaved method, the current electrodes are adopted adjacent electrodes but the voltage electrodes are adopted interleaved electrodes. The boundary voltage collection is shown in Figure 3. For the interleaved method, the total of independent measurement is N(N-4)/2. By combining the adjacent method and the interleaved method, we can gather more independent measurement and improve the image quality of EIT. The total of mo modified adjacent method can be derived as N(2N-7)/2. For the 16-electrodes rotational EIT system, if we apply adjacent method we will obtain 16(16-3)/2=104 independent measurements. If we apply pseudo electrodes driven patterns(5 rotations), we will obtain 104x5=520 independent measurements. If we apply pseudo electrodes driven patterns with modified adjacent method, we will obtain 5x 16(2x16-7)/2=1000 independent measurements. Compared with the adjacent method, the proposed method is about 10 times the total data of adjacent method.

3. The design of measurement system

In order to assess the performance of the proposed system, a rotational EIT system is applied to acquire the boundary measurement of measured object. Figure 4 depicts the experimental setup and an overhead view of the rotational EIT system. The rotational EIT is equipped with movable electrode pairs attached to electrodes that move to a new measurement site so as to acquire more data. Figure 5 shows the vertical view of the assembled rotational EIT. The rotational EIT system can be divided into three subsystems, movement scheme, switching network and measurement.
system. The movement scheme includes a phantom equipped with movable electrodes and a stepping motor to drive the electrodes. The switching network is constructed from several solid state relays. These switches are used to change the current path to different electrodes and to pick up the voltage measured from each electrode. For the measurement subsystem, we adopt a four-electrode system to measure the impedance of sample. The four-electrode method can eliminate the influence of contact impedance. A constant current source injects the fixed current (Ic) into the estimated object at a specific frequency. The Lock-in amplifier picks up the potential (Vm), which is a response to the injecting current, and filters out unwanted components from the measured signal.

4. Result

By applying the modified adjacent data collection method, we obtain more measurements data. Figure 6 is the boundary voltage profile of the Modified Adjacent method. Figure 6 includes two groups of data. The first 14 measurements are obtained by adjacent method and last 12 measurements are obtained by interleaved method. In interleaved method, the distance of measurement pair is larger than adjacent method. Thus, interleaved method induces higher measurement voltage.

A graph of the singular value provides a guide to the number of degree of freedom in the image. For EIT, we typically plot the normalized singular value ($\sigma_i/\sigma_0$) on a logarithmic scale. The singular decomposition is a valuable tool in studying ill-posed problem. The eigenvalues indicate how well the basis image amplitudes are defined by the data, basis images with smaller eigenvalues are more sensitive to data noise. In order to illustrate the degree of ill-conditioning, the singular values are plotted. Figure 7 shows the eigenvalues chart of adjacent method and pseudo electrodes method. Compared with their singular values, it is clear that increasing the number of measurements could obtain more and greater singular values. Figure 8 shows the eigenvalues chart of the modified adjacent method and pseudo electrodes method. The modified adjacent method could reduce ill-posed problem further.
Figure 7 the eigenvalues chart of adjacent method and pseudo electrodes method

Figure 8 the eigenvalues chart of pseudo electrodes method and modified adjacent method

Figure 9 show the impedance image of T-shape metal object reconstructed by different data collection methods. Figure 9(a) illustrated the phantom tank with T-shape metal object. This indicates shape and the location of the measured T-shape metal object. Figure 9(b) shows the impedance image reconstructed by conventional adjacent method. Because the conventional adjacent method only acquire 104 measurement data, the reconstructed impedance image suffer serious ill-posed problem. Figure 9(c) shows the impedance image reconstructed by pseudo electrodes without modified adjacent method. The pseudo electrodes method improves the ill-posed problem substantially. Figure 9(d) shows the impedance image reconstructed by pseudo electrodes with modified adjacent method. The modified adjacent method could improve the quality of impedance image further.
5. Conclusion

The idea of pseudo electrode driven pattern is proposed in this paper. The scheme of pseudo provides several advantages in EIT data collection. (1) The expanded measurement sites could increase the independent measurement data and improve the spatial resolution. (2) Pseudo electrode could decrease the number of physical electrodes and simplify the design of the EIT system. However, the great number of measurement data obtained from pseudo electrode driven pattern will cause serious problem in image reconstruction. We hope the pseudo electrode scheme will bring some help in electrical impedance tomography.

6. References