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Impedance Based Image Analysis of Field Distribution inside a Closed Phantom Using EIDORS

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Abstract

Electrical Impedance Tomography (EIT) is a non invasive medical imaging technique which constructs the electrical impedance distribution image of the cross section of a body based on current excitation and voltage measurement from an array of electrodes.

This paper describes the implementation of electrical impedance tomography in the field of biomedical engineering which involves the development and performance evaluation of EIT system in detecting foreign object like non hardening clay and metal object in the water bath contained in plastic object. This system uses electrode in differential mode encircling a water container which is used for voltage injection and voltage measurement. This voltage data is used to reconstruct the conductivity profile of image by using Electrical Impedance and Diffuse Optical Reconstruction Software (EIDORS) package available in MATLAB.

Keywords: Electrical Impedance Tomography, EIT, Biomedical, EIDORS, and MATLAB.

Introduction

One of the non-invasive medical imaging techniques that have been widely in use today is the Electrical Impedance Tomography (EIT). The EIT image provides significant information regarding the physiological and pathological issues based on the electrical property of the tissue inside the human body [11]. The image quality heavily depends on the performance of the applied current, such as frequency, current accuracy and stability, therefore, the design of a steady and highly accurate signal source is of great significance. In this technique an image of the conductivity or permittivity of part of the body is inferred from surface electrical measurements.

Typically, conducting electrodes are attached to the skin of the subject and small alternating currents or voltages are applied to some or all of the electrodes. The resulting electrical potentials are measured, and the process may be repeated for numerous different configurations of applied current or voltage. A basic EIT system consists of array of electrodes for attaching to the subject's body, a voltage or a current source, a measurement circuit, an analog to digital converter, and a storage medium. A minimum data set is acquired for several values of currents or voltages & image can be reconstructed using these values [3].

The data processing portion of EIT has been developed extensively in the medical field. The work of Polydorides [6] was of particular importance to the project because this is extensively addressing the data processing issue of soft-field tomography, and eventually contributed to the development of the MATLAB toolkit called EIDORS (Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software) [2]. EIDORS is a MATLAB program package developed collaboratively by EIT research groups in order to help advance the field of EIT as a whole. The data processing portion of this experiment was accomplished with the EIDORS V3.0 toolkit [5]. The toolkit was essential because of the challenges in solving an EIT inversion problem. The EIT inversion problem is a nonlinear, ill-posed problem that is very intensive computationally. The basis of the EIDORS package is that it utilizes a finite element model for forward calculations and a

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regularized nonlinear solver to obtain a unique and stable inverse solution [4]. The package is equipped with a mesh generator, several standardized EIT methods, a graphical output, and supports two-dimensional and three-dimensional EIT systems [4] [8].

Electrical impedance tomography is a radiation free technique. It is safe, non invasive, portable and affordable medical imaging technique. Its applications include detection of breast cancer, imaging gastric emptying and gastric secretion pulmonary monitoring, thermal monitoring of hypothermia, intraventricular hemorrhage.

The EIT System

Figure 1 depicts a block diagram of the proposed EIT system:

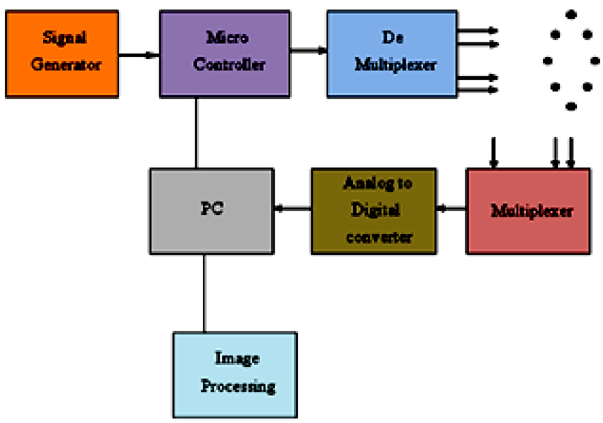


Figure 1: Block diagram of the EIT System

The EIT system consists of

- An array of electrodes, attached to the surface of the patient or the conducting medium, to maintain an electrical contact with the imaging media.
- A measurement circuit, which applies an alternating current to the medium to be imaged and measures resultant voltage distribution on the surface of the object.
- An image reconstruction algorithm, which reconstructs images of spatial resistivity distribution from the voltage measurements.
- An image processing algorithm consisting of several filtering and enhancement algorithms to improve the image quality.
- Image analysis software to improve the diagnostic value of the images.
- A user interface (display, hardcopy, keyboard, storage facilities, etc.) to enable an easy user access to the image analysis. The first two parts are referred as the data acquisition hardware and the last four are referred as the image acquisition software that is performed on a computer.

Data Processing and Collection

Image processing and reconstruction is performed using sophisticated reconstruction software, with the help of a computer .The reconstruction software used in this work is EIDORS Package which is an acronym for Electrical Impedance and Diffuse Optical Reconstruction Software and MATLAB as programming tool [2][8]. EIDORS provides flexibility in analyzing the system using finite element models and MATLAB provides good graphical support for display of reconstructed images [7].

The circuit consists of power supply, signal generator, relay system, microcontroller, electrodes and a phantom. The circuit setup is as shown in the Fig 2. First a plastic box is taken assuming it to be a closed phantom. Water is poured in it and electrodes are attached as shown in figure 2. Care is taken to ensure all electrodes are immersed properly in the water. The power supply is switched on to 12 volts and necessary voltages are given to microcontroller and relay system. The ac frequency is kept at 100 Hz. The supply from microcontroller drives a relay which in turn is connected to an electrode pair. The electrodes are numbered as 1a, 1b, 2a, 2b till 8a, 8b constituting a total of 16 electrodes. Depending upon the simulation pattern, one electrode pair is connected to relay at a time and the supply is provided. This electrode is considered to be the source and current through it measured using digital multimeter. Current across remaining pairs is measured accordingly. This process is repeated by switching the source till all the currents are measured. This data is used to reconstruct the image. The same setup can be used for testing other scenarios.

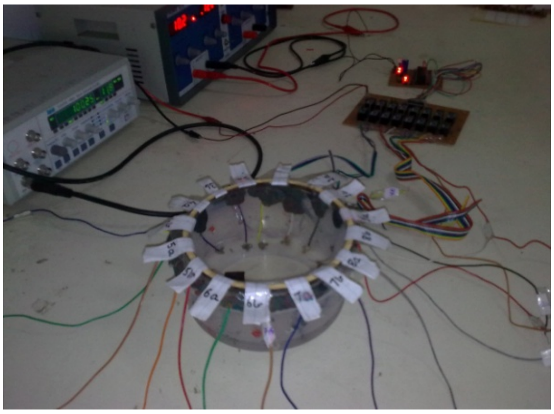


Figure 2: Experimental Setup

Results and Discussions

Most EIT systems apply current or voltages between a pair of electrodes at a time (an opposite drive configuration) [1]. The electrodes are placed by taking non-conducting circular ring as reference. The radial method is used for taking readings. Before taking readings on human tissue, the EIT procedure was performed on a phantom (papaya and watermelon) [9]. The tissue impedance of the phantom is as shown in figure 3.

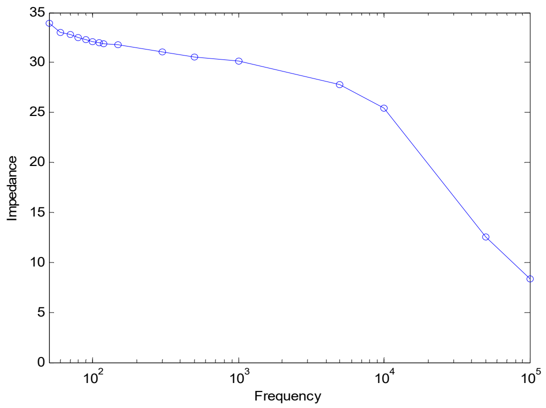


Figure 3: Impedance versus frequency

As the tissue impedance of the phantom is similar to the impedance of the human tissue, EIT procedure on phantom can be used.

EIT is applied on closed object hence experiment was performed on circular plastic box. Here pair wise method was used for taking the readings [1]. The box used had a diameter of 13cm. The electrodes were placed around the circumference of box, equidistant from each other at an angle of 22.5˚. Different cases were tried on this box by applying input ac voltage to the electrode pair 1 a-b; this acted as a source, while the readings were obtained from other electrode pairs.

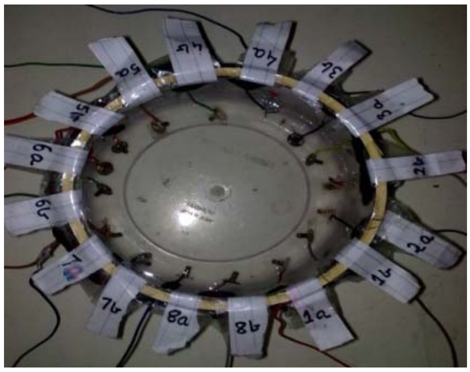


Figure 4: Electrodes arranged on a circular box

Clay, which is a non conducting material, was placed near the source (electrode pair 1 a-b). Clay acts like an obstruction and does not allow any current to pass through it. No current is taken up by the clay and this causes a rise in the current measured from the electrode pairs (8a-b, 2a-b) which were closest to the point where the clay was placed. However the current measured from electrode pairs (3, 4, 5, 6, and 7) which were farther away from the clay did not show much of a deviation when compared to the reference because the path taken by the current was free from any obstruction.

When clay was kept away from the source, near electrode pair 5a-b, the current measured from the electrode pairs close to the source did not show much of a deviation when compared to the reference. This happens because there is no obstruction to the path of current reaching these electrodes. However the current measured from electrode pair 5a-b, where the clay was placed, was seen to be raised. This happens because the clay does not absorb any of the current and thus the current reaching electrode pair 5a-b is more. Figure 5 shows the two scenarios.

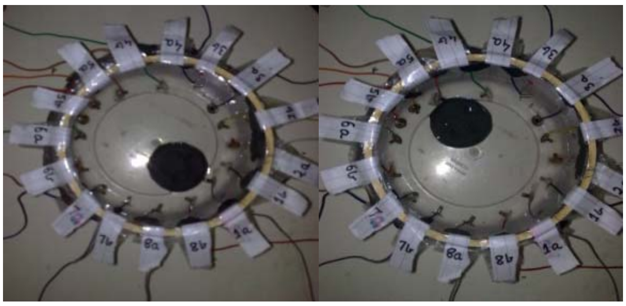


Figure 5: Clay placed near and away from source

Iron, which is a conducting material, was then placed near the source. The current obtained from electrode pairs 8a-b and 2a-b which were placed closest to the iron rod showed a drop in the current recorded. This happens because iron conducts electricity and there is a voltage drop across the iron rod and hence the current reaching electrode pairs 8a-b and 2a-b are of a reduced value. However the current obtained at the other electrode pairs did not show much of a change because there was no obstruction to the path of current reaching the other electrodes.

When the iron rod was placed away from the source, near the electrode pair 5a-b, a drop in current was observed because the iron rod takes up some of the current as it is a conducting material. The current obtained from electrode pairs placed away from the iron rod remains somewhat the same when compared to the reference. This happens because the path taken by the current does not face any obstruction. Figure 6 shows the two scenarios.

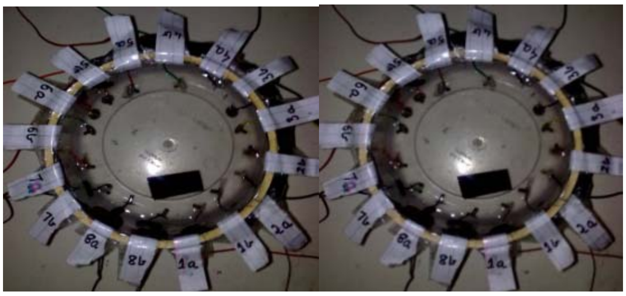
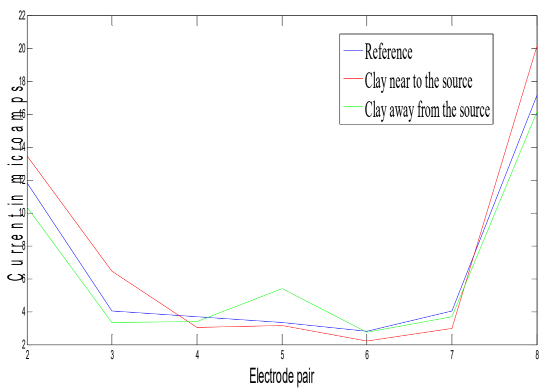


Figure 6: Iron rod placed near and away from source

Figure 7 shows the comparison of current distribution in electrode pairs when iron rod and clay were placed near and away from the source. Left graph shows the comparison of current distribution when clay was placed and the right one show the variations in current inside the phantom when iron rod was placed.



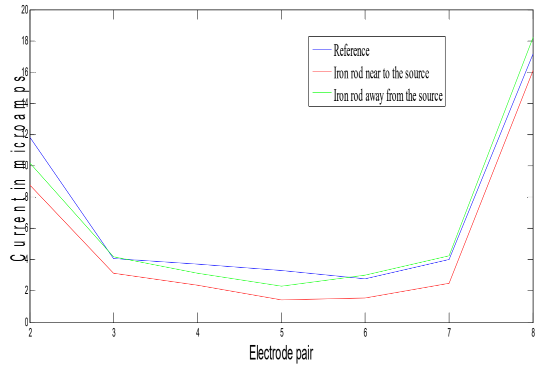


Figure 7: Comparison of Current distribution in electrode pairs when clay and iron rod were placed near and away from the source

Figure 8 shows the actual image of the water container. Figure 9 and 10 show the reconstructed images using EIDORS with 2410 and 576 elements respectively.

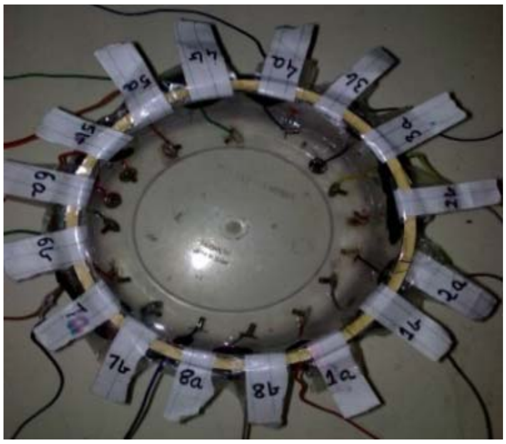


Figure 8: Actual image of the water container

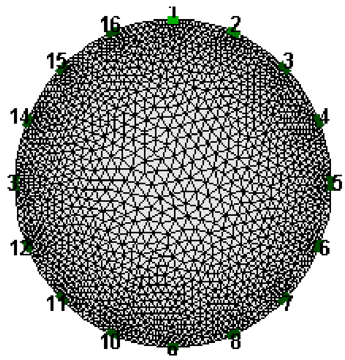


Figure 9: Reconstructed image using EIDORS and with 2410 elements

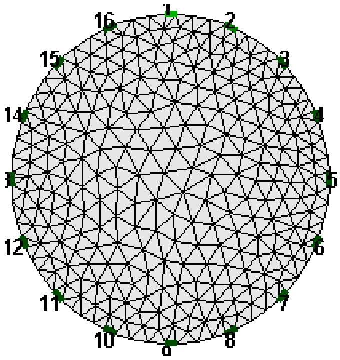


Figure 10: Reconstructed image using EIDORS and with 576 elements

Figure 11 shows the presence of foreign object like clay. Figure 12 shows the reconstructed image which clearly identifies the presence of foreign object (by means of change of color).

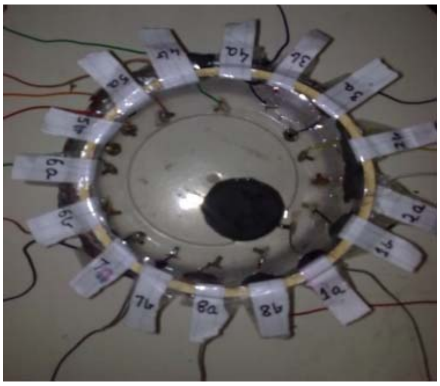


Figure 11: Actual image of water container with a foreign object like clay

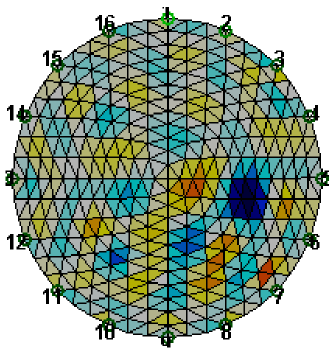


Figure 12: Reconstructed image clearly showing the presence of foreign object

However, certain factors limit the resolution of EIT images; the principal ones being noise, number of measurements and mesh size. There were various difficulties encountered. The entire set of reading had to be taken in one session only as the phantom that was used becomes soggy and starts decaying. Hence phantom cannot be used for long time. Attempts were made to image smaller objects like pin, screw drivers, and small plastic objects; however it turned out to be unsuccessful. This is due to the resolution of EIDORS software and shortcomings of hardware [1].

Conclusion

An EIT system for 16 electrodes was developed and various tests were conducted using two different techniques. Radial method on phantoms (watermelon and papaya) yielded better results and it is observed that whenever there is any abnormality present in tissue there is a change in the impedance. EIT procedure was repeated for the pair wise method on the plastic box and position of the abnormality is detected. Various results were obtained when foreign objects (both conducting as well non-conducting) were placed near and away from the source. The simulations and tests carried out prove that the circular container can be used for 2D imaging. Using EIDORS as a reconstruction software and MATLAB as a programming language, images were reconstructed and various stimulation patterns were shown both for adjacent as well as opposite techniques. The results also reveal that plastic bottle is capable of detecting objects of poor conductivity as well as the one with higher conductivity.

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