

Electrical Impedance Tomography

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Abstract: Electrical impedance tomography (EIT) is the technique that applies time varying currents to the surface of a human body and stores the resulting voltages in order to reconstruct and display the electrical conductivity and permittivity in the interior of the body. This technique exhibits the electrical properties of tissues such as resistance and capacitance. It exploits the differences in the electrical properties of tissues in order to generate a tomographic image. When electric current is fed through different available electrode pairs and by measuring the corresponding voltages at remaining pair of electrodes, it is possible to create an image of the impedance of different regions by using certain reconstruction algorithms. This method is called impedance imaging.

Keywords: Electrical Impedance Tomography (EIT); Data Acquisition; current Injection; Electrodes.

I. INTRODUCTION

The cancer disease continues to increase largely because of the aging and growth of the world population with an increase in adoption of cancer-causing behaviours, particularly smoking, in economically developing countries. Worldwide, cancer is the most common among the various diseases. The number of cancer affected patients is increasing day by day. The number of cases worldwide has significantly increased since the 1970s, a phenomenon partly attributed to the modern lifestyles. The incidence of cancer varies greatly around the world. It is low in less-developed countries and high in the more-developed countries. The rise is being documented mainly in the metros, but it can be safely said that many cases in rural areas go unnoticed. There are many techniques to detect cancer like MRI, Mammography, Sonography and Thermal Imaging. However these techniques have their flaws like harmful radiation caused by MRI or inadequacy of thermal imaging to detect cancer in its early stages. Also these techniques are costly and unaffordable to the common man. Electrical impedance tomography is an alternative method which is cheap, safe and non-invasive to detect cancer.

II. LITERATURE SURVEY

Electrical Impedance Reconstruction and Diffuse Optical Reconstruction Software can be used for reconstructing electrical or optical properties using boundary measurements. Non-linear problems such as electrical impedance and optical tomography are approached using a finite element model for the forward calculations and a non-linear solver for obtaining a unique and stable inverse solution. Many commercially available finite element programs are not suitable for solving these problems because of the conventional inefficient way of calculating the Jacobian, and their lack of accurate electrode modeling. According to the survey carried out, we found that Matlab was the software used for EIT implementation.

For improving the speed and accuracy we are implementing EIT on Labview using MyDAQ for interfacing between the hardware components and software.

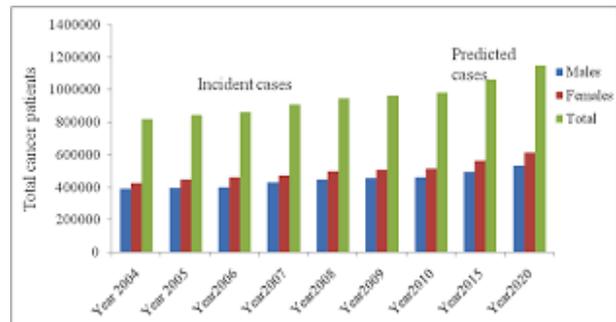


Fig 1: Statistics of cancer affected patients

A. EIT Basics

Electrical impedance tomography (EIT) is the technology used to reconstruct an impedance distribution in an object under consideration from electrical measurement on the boundary of the object. Because of its non-invasiveness, portability, EIT is being studied from 1970s and has led to many useful and inspiring results.

Electrical impedance tomography (EIT) is the medical imaging technique in which an image is reconstructed to exploit the conductivity or permittivity of the body part from surface electrical measurements. The conducting electrodes are attached to the skin of the object under consideration and small alternating currents are applied to some or all of the electrodes. The resulting electrical voltages are acquired, and the process is repeated for numerous different configurations of applied current. The measurement may be made across all the pairs of electrodes keeping the current source in one position. The process may be repeated for different positions of the current sources.

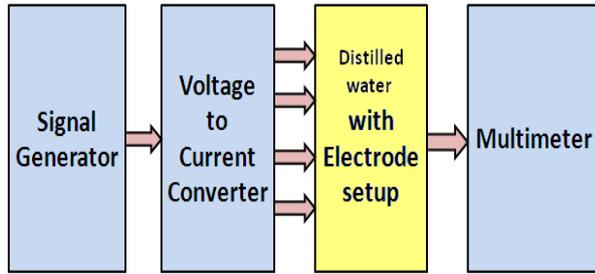


Fig 2: EIT generic Block Diagram

In this project the emphasis is on developing an EIT system consisting of 8 electrodes with suitable hardware setup which can meet the requirements. With the help of this system the aim is to construct an image of the conductivity distribution of a tissue.

Before taking readings on human tissue, the EIT procedure is carried on distilled water because the tissue impedance of the distilled water is similar to the tissue impedance of the human tissue. The relationship between electromagnetic fields and tissue is important. The results will depend on the type and size of electrodes, particularly at lower frequencies, and exactly where the electrodes are placed. However, the result is mainly a function of the tissue properties. The impedance always drops with increasing frequency.

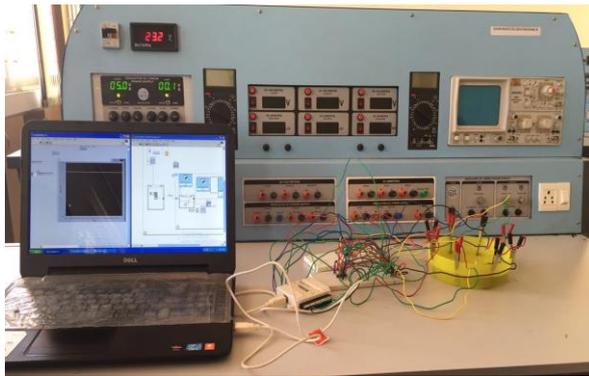


Fig 3: Circuit Setup

The first step in solving the conductivity distribution was to create a finite element model of the container and electrodes. With this finite elements and a set of current, the forward problem was solved assuming a system of homogeneous conductivity for the voltage data. The setup of the forward model is extremely important, as it will determine the accuracy of the result.

Basically the forward problem is solved by predicting the conductivity distribution equal to one and calculating the voltage distribution V . This voltage distribution can be used to create a predicted measurement set containing boundary measurements. The next step was to load the real data set and solve the inverse problem. Actual measurements are compared to the predicted measurement set calculated from the forward problem. Inverse model uses the difference between the two to recalculate a more

accurate conductivity distribution. An image based on this conductivity distribution will be reconstructed.

III. METHODOLOGY AND MEASUREMENT TECHNIQUES

A. Voltage to Current Converter

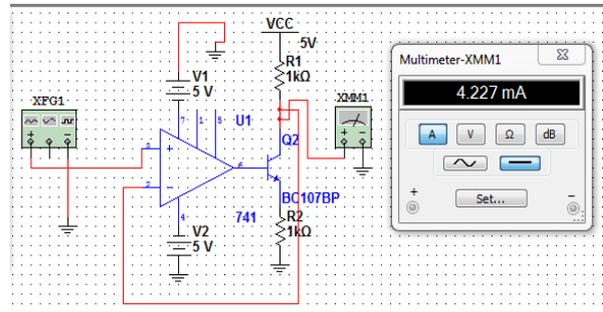


Fig 4: Voltage to Current converter circuit

Voltage to current converter is used to supply constant current to the setup. For the voltage to current converter circuit, we use operational amplifier (IC 741) and a transistor (BC 107). The circuit has a grounded load. The Op-amp has negative feedback. Due to negative feedback the voltage at both the input terminals of the Op-amp remains same. The transistor is used to further amplify the current from the output of the Op-amp. The input to the Op-amp is 5V signal and the output current ranges between 1mA–5mA depending on the load resistor. Further amplified output signal ranges between 10mA–15mA

B. Current Injection Method

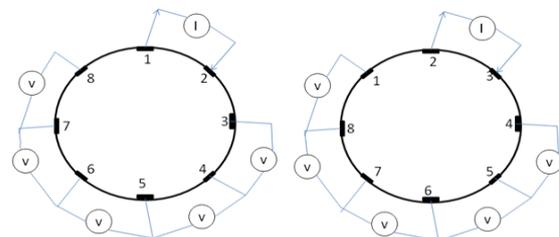


Fig 5: Adjacent current projection method

The constant current injection method is used for the selection of pair of electrodes used for current injection and voltage measurement. Fig.4.4 shows a measurement technique for adjacent current injection protocol. In this method initially constant current source is applied between the pair of adjacent electrode and then resulting boundary potential is measured between other pair of adjacent electrode which are non-current electrode. For projection 1 current source is applied between the electrode 1 and 2 and boundary potentials are measured between the electrode pair 3-4, 4-5 till 6-7. In this way total 5 readings are acquired in each projection. Then current source is switched between next adjacent pair of electrodes i.e. electrode 2 & 3. In this way total $5 \times 4 = 40$ voltage readings

are taken which forms voltage database for a single measurement. The time required for obtaining the voltages manually is large. Below fig.4.5 shows a flow chart for measurement.

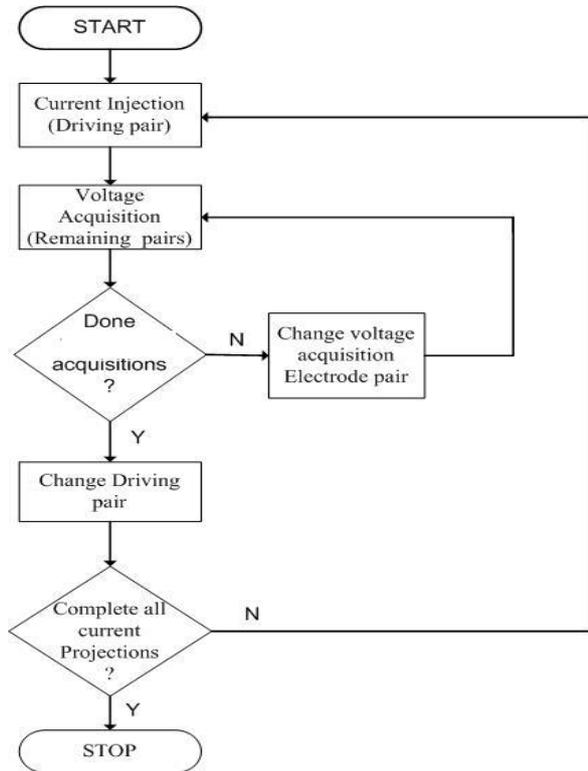


Fig 6: Flowchart

1. Circuit Description

The circuit consists of power supply, signal generator, electrodes and a phantom. The circuit setup is as shown in the figure 4.2. First a plastic box is taken assuming it to a closed phantom. Distilled water is poured in it and electrodes are attached as shown in figure 4.2. , care is taken to ensure all electrodes are immersed properly in the water. The power supply is switched on to 5v and necessary voltage is supplied to voltage to current converter circuit. The supply from voltage to current converter circuit is given to the multiplexer, which in turn is connected to the electrodes. The electrodes are numbered as 0, 1, 2, 3, 4, 5, 6, & 7 constituting total 8 electrodes. Depending upon the simulation pattern at a time one adjacent electrode pair is given the current supply. NI LABVIEW software is used to control the select lines of the multiplexers. The electrode pair to which current is supplied is considered as the source. Voltages across all other adjacent electrode pairs are acquired. Multiplexers are used to switch between the pair of electrodes through which the voltages are to be acquired. Again, controlling of the select lines of the multiplexers used to acquire voltage is done using LABVIEW Software. This process is repeated by switching the source till all the voltages are measured. This data is used to reconstruct the image. The same setup can be used for testing other scenarios.

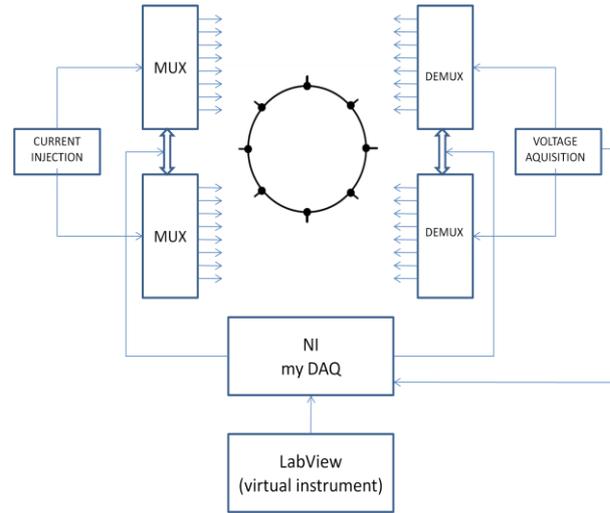


Fig 7: Block diagram of EIT setup

NI My DAQ is used as an interface between the labview software and the electrode setup. The digital output pins of My DAQ are used to control the select lines of the current injection and voltage acquisition multiplexers. The voltage acquired from the electrode pairs which passes through the multiplexers is an input to the Analog input pins of My DAQ. The voltage acquired by the My DAQ is provided to the labview software where the readings are directly saved in a Microsoft excel sheet. These readings are used to plot the reconstruction image.

IV. RESULTS

A. Box Readings

EIT is carried out on a closed object and hence the experiment was performed on circular plastic box. Here adjacent electrode pair method is used for taking the readings. The box is of 15cm diameter. The electrodes are placed around the circumference of box equidistant from each other at an angle of 45°. Different cases were tried on this box by applying input current to the electrode pair 0 and 1; this is acting as a source, while the voltage readings are obtained from other electrode pairs.

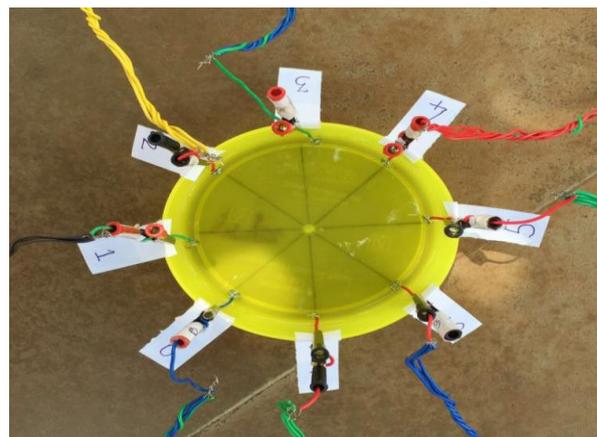


Fig 8: Electrode setup with current supply at electrode pair 0-1

B. Box Readings with Stone

Stone was placed near and away from the source.



Fig 9: Electrode setup with stone placed near the source between electrode pair 2-3



Fig 10: Electrode setup with stone placed away from the source between electrode pair 4-5

Stone which is a non conducting material is placed near the source (electrode pair 2-3). Stone acts like an obstruction and does not allow any voltage to pass through it. No voltage is taken up by the stone and this causes a rise in the voltage measured from the electrode pairs (2-3) which are closest to where the stone is placed. However the voltage measured from electrode pairs (3-4, 4-5, 5-6, 6-7) which are further away from the stone do not show much of a deviation when compared to the reference because the path taken by the voltage is free from any obstruction.

When stone is kept away from the source, which is near electrode pair 4-5, the voltage measured from the electrode pairs close to the source do not show much of a deviation when compared to the reference. This happens because there is no obstruction to the path of voltage reaching these electrodes. However the voltage measured from electrode pair 4-5, where the stone is placed, is seen to rise. This happens because the stone does not absorb any of the voltage and thus the voltage reaching electrode pair 4-5 is more.

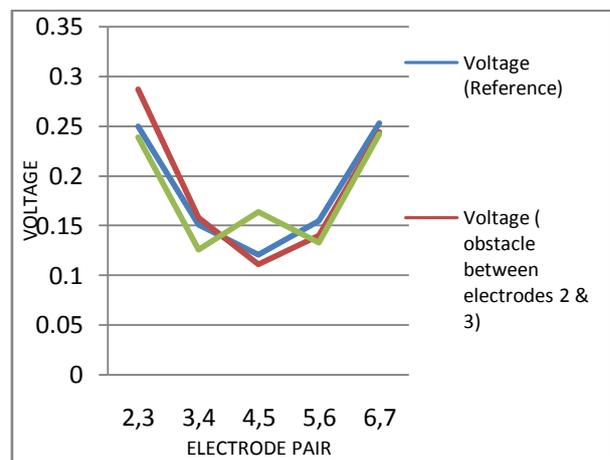


Fig 11: Comparison of voltage distribution when stone is kept near and away from the source.

C. Advantages

- EIT is not harmful and is a radiation free medical process.
- It is inexpensive, portable and can be easily applied at the bedside.
- It offers a low diagnosis cost and is suitable for ambulatory monitoring.
- It is highly flexible in nature.
- Is suitable for critically ill patients, as well as children and infants.

D. Disadvantages

- EIT has lower maximum spatial resolution.
- Adjacent drive method is sensitive to error and noise.

E. Applications

- EIT is an imaging method which can be used to complement X-ray tomography (computer tomography, CT), ultrasound imaging.
- Detecting objects like non-hardening clay, plastic bottle and metal object in the distilled water bath.
- Doctors can use the system to image tumors including cancer.
- EIT system is used for non-destructive evaluation of biological and non-biological objects in fields such as biotechnology, microbiology, polymer science, civil engineering and material engineering.
- EIT is used Fetal imaging, detection of thyroid cancer, Pulmonary monitoring, Brain imaging.

V. CONCLUSION

An EIT system for 8 electrodes was developed and tests were conducted using distilled water as a replacement for human tissue for the demo. It was observed that whenever there was any abnormality present in the water there was a change in the impedance demonstrating irregularity in human tissue. EIT procedure is repeated for the pair wise method on the plastic box and position of the abnormality is detected. Various results were obtained when the foreign object was placed near and away from the source.

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