Design of Forward Problem for Early Detection of Breast Cancer using Electrical Impedance Tomography (EIT) Technique

MAJOR PROJECT REPORT

Submitted in Partial Fulfillment of the Requirements of the Degree of Bachelor of Technology in Electronics and Telecommunication Engineering

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1. INTRODUCTION

The introduction for a research paper on "Design of Forward Problem for Early Detection of Breast Cancer using Electrical Impedance Tomography (EIT) Technique" can set the stage for the study and provide background information. Here's a sample introduction:

Breast cancer is a significant global health concern, with early detection playing a pivotal role in improving patient outcomes and reducing mortality rates. While various imaging modalities such as mammography and magnetic resonance imaging (MRI) have been established as effective tools for breast cancer screening and diagnosis, there is a persistent need for non-invasive and cost-effective alternatives. Electrical Impedance Tomography (EIT) has emerged as a promising technique in this regard, offering the potential for early detection of breast abnormalities without the use of ionizing radiation or invasive procedures. [1]

EIT technique apply a current - As human cell acts like capacitor the behavior of the tissue impedance depend on the frequency of the applied current- to human tissue and according to the conductivity distribution of the tissue, the potential distribution is measured in order to produce the image. There is direct relationship between the applied current pattern, conductivity distribution of the tissue and the potential distribution, so by knowing the applied current and the conductivity distribution of the tissue, the resistance of the tissue to the current flow can be measured which is then used to measure the potential distribution- this is called forward solution.

Another solution is the inverse solution where conductivity distribution of the tissue is unknown, obtaining sufficient information to determine it can be done by applying different current pattern-practically this can be done by using finite number of electrodes that apply different current patterns-and their corresponding voltages are measured. Current patterns and their corresponding voltages are then used to obtain a transformation matrix which represents the transformation of conductivity values to voltage values. Practically voltages are measured between each electrode and a reference electrode (which takes a value of zero) or between adjacent pairs of electrodes and the Data (voltages) collected is used to produce the image using image reconstruction approaches.

The success of EIT in cancer diagnosis is the accurate modeling of the main problem, which is an important part of the imaging process. The preliminary problem is to simulate the electrical behavior of breast tissue under the influence of low-energy radiation. This model is important for converting radiation into a useful image of the characteristics of the breast. To date, the development of an accurate and reliable EIT forward analysis remains an area of research with the potential to improve the diagnostics of these tools. [2]

2. OBJECTIVE

The objective of this comprehensive report is to provide a thorough exploration of the application of Electrical Impedance Tomography (EIT) for breast cancer detection. This report aims to achieve the following specific goals:

Review the fundamental principles of EIT and its relevance to breast cancer detection, including the underlying physics and technology. Investigate the current state of research and clinical applications of EIT in breast cancer diagnosis, encompassing both experimental and clinical studies. Examine the various EIT reconstruction algorithms and methodologies used in breast imaging, assessing their strengths and limitations. Explore the potential for EIT to contribute to early detection and monitoring of breast cancer, emphasizing its non-invasiveness and potential for reducing patient radiation exposure. Evaluate the challenges and limitations associated with EIT in breast cancer detection, including sensitivity, specificity, and spatial resolution. Discuss the integration of machine learning and artificial intelligence in EIT breast cancer detection, and its impact on improving accuracy and clinical utility. Analyze the ethical, regulatory, and cost considerations surrounding the adoption of EIT in breast cancer diagnosis and healthcare systems. Provide recommendations and insights into future research directions and potential improvements in EIT technology for breast cancer detection. By addressing these objectives, this report aims to provide a comprehensive understanding of EIT's role in breast cancer detection, its current status, and its potential as a valuable diagnostic tool for healthcare practitioners, researchers, and policymakers in the field of breast cancer detection and treatment.

3. PROBLEM STATEMENT

1. Design of AC current source
2. Automatic switching of current and voltage electrodes

4. LITERATURE SURVEY

A literature survey, also known as a literature review, is an essential component of a research paper that provides an overview of the existing body of knowledge on the subject of interest. In the context of your research on the "Design of Forward Problem for Early Detection of Breast Cancer using Electrical Impedance Tomography (EIT) Technique," a literature survey would encompass relevant studies, research papers, and articles related to breast cancer detection, EIT, and forward problem modeling. Here's a brief outline of what a literature survey might include:

Breast cancer is the most common disease among women worldwide. It is said that cancer occurs when cells in the body begin to grow uncontrollably. Usually cells grow in an organization, but malignant growth cells can grow and group into ordinary cells. Since there is currently no way to prevent breast cancer, early detection can increase survival by providing more effective treatment before the cancer spreads to different parts of the body. Many diagnostic tests and screening technologies are available to detect breast cancer. [1]

Breast malignancy is most widely recognized illness among ladies around the world. Cancer is said to occur when cells in the body begin to grow in an uncontrollable manner. Typically cells develop in an organized manner, however malignant growth cells grow to develop and crowd into ordinary cells. Since, currently there is no known way of preventing breast cancer, early detection permits more treatment options before cancer spreads to different parts of the body, thereby increasing survival rate. Various advanced imaging and screening techniques are available to detect breast cancer.

The various types of screening techniques are :-

1. Breast Self Assessment (BSA) and Clinical Breast Assessment (CBA)

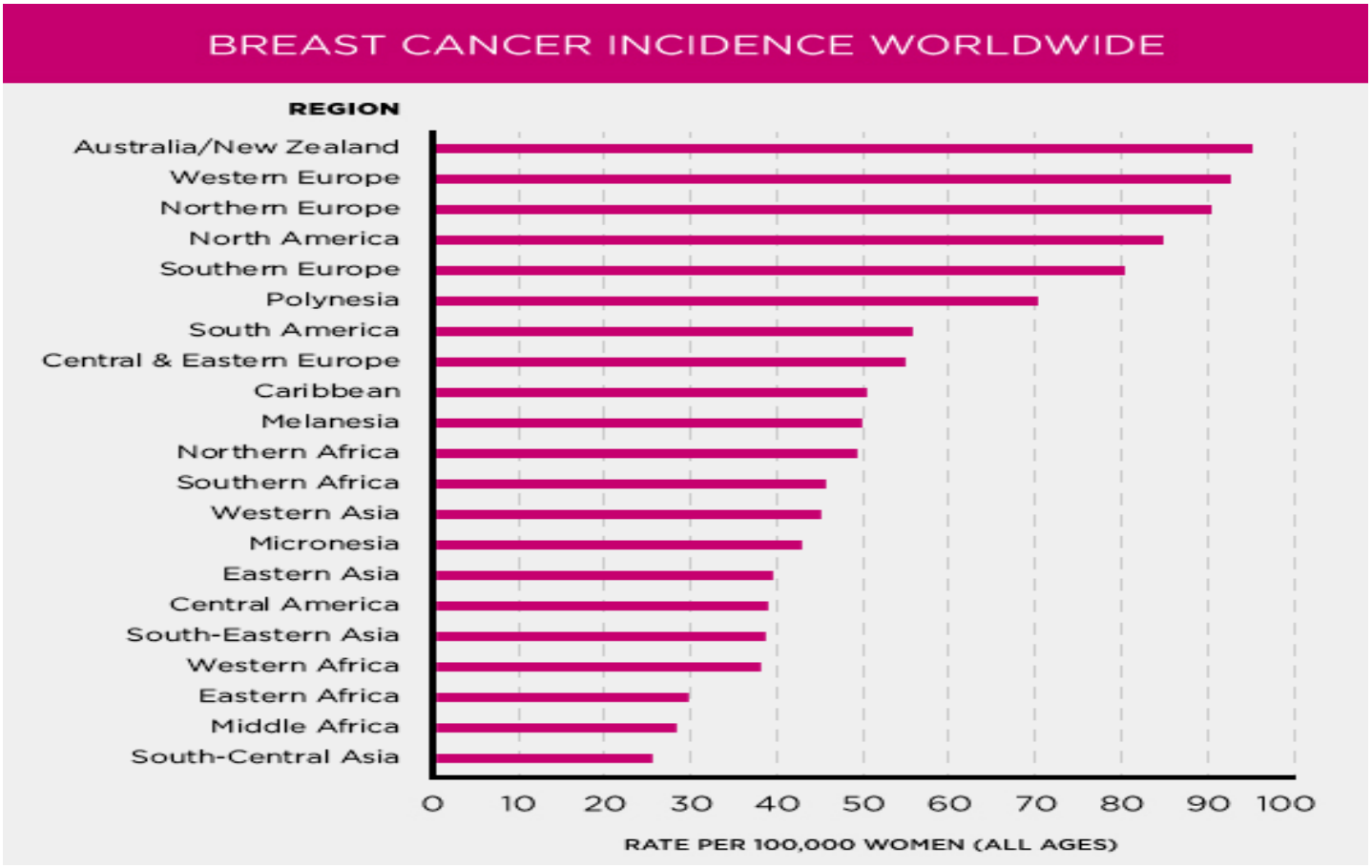
2. Mammography

3. Ultrasonography or Ultrasound

4. Infrared Thermography or Thermal Imaging

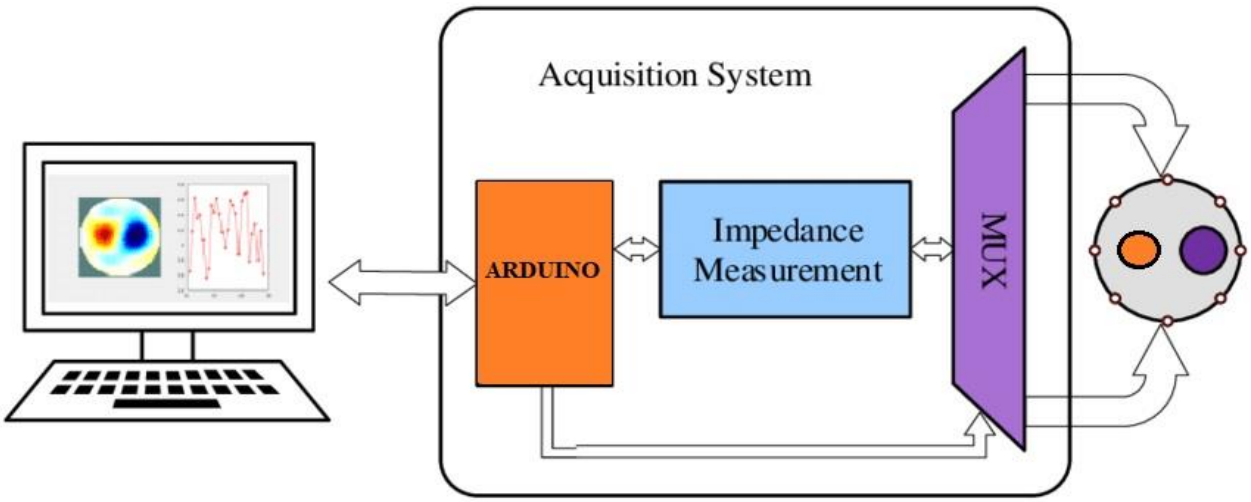
5. Magnetic Resonance Imaging (MRI)

6. Electrical Impedance Tomography (EIT)



The Graphical ratio representation of the Breast cancer incidence worldwide

5. ELECTRICAL IMPEDANCE TOMOGRAPHY PRINCIPLE



Electrical Impedance Tomography (EIT) is a sophisticated medical imaging technique that involves injecting small electrical currents into a body and measuring resulting voltage changes on its surface.

Using Arduino, a multiplexer, voltage measurements, and phantoms (simulated body models), you can create a simplified setup to explore the basic principles of EIT. However, please note that this approach might not achieve the accuracy and sophistication of dedicated EIT systems.

6. RECONSTRUCTION ALGORITHM

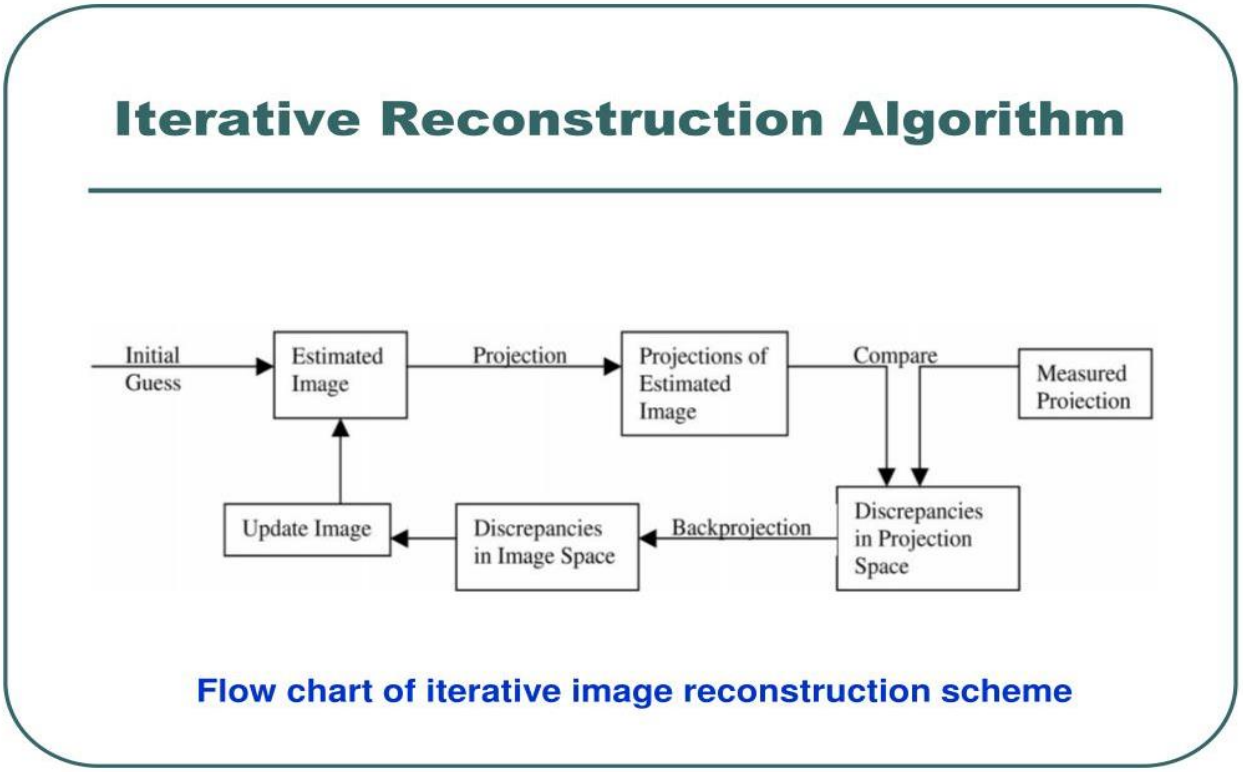


IMAGE RECONSTUCTION ALGORITHM USING EIT

Image reconstruction algorithms Image reconstruction algorithms using electrical impedance tomography (EIT) principles for early detection of breast cancer can be complex and difficult, but this is an area of research, research and development. EIT is a non-invasive technique that uses an electrical meter to create images of electrical activity in breast tissue. [3]

Below is a simple explanation of the steps and principles involved in such an algorithm:

1. Data Acquisition: Electrodes are attached to the surface of the subject's body. A small electrical current is injected through one pair of electrodes, while the resulting voltage measurements are recorded at the remaining electrodes.

2. Forward Model: A mathematical model of how electrical current propagates through the body is established. This model is based on the physical properties of tissues and their electrical conductivities. Common models used include the finite element method (FEM) or finite difference method (FDM).

3. Inversion Problem: The inverse problem in EIT is to determine the internal conductivity distribution from the measured voltage data. The goal of EIT is to solve the inversion problem: determine the internal distribution given the electrical parameter.

4. Regularization: Regularization is often used to preserve resolution. Various algorithms can be used to solve the inverse problem. Common methods include the Gauss-Newton method, the sensitivity matrix method, and iterative algorithms like the iterative Tikhonov regularization.
5. Image Reconstruction: The reconstruction algorithm processes the measured voltage data and computes an estimate of the internal conductivity distribution. Many EIT reconstruction algorithms are iterative. They first make an initial estimate of the conductance and then refine it based on preliminary models and measured data.

6. Evaluation of image quality: Evaluation of image quality is important. Measurements such as signal-to-noise ratio (SNR), contrast, and resolution are used to evaluate images.

7. Early Diagnosis: Early diagnosis of cancer requires identification of subtle changes in tissue. EIT can understand these changes, but it will still be difficult due to the low resolution of the system.

8. Clinical Validation: Every algorithm developed for cancer diagnosis needs to be tested to make sure it is accurate and works well. This will involve testing the algorithm on real patient data.

9. Hardware Considerations: The quality of data collection depends on the hardware, electrode location, and patient location. These features should be taken into account when designing the algorithm.

10. Machine learning integration: In recent years, machine learning techniques such as deep learning have been used to improve EIT image reconstruction and early detection.

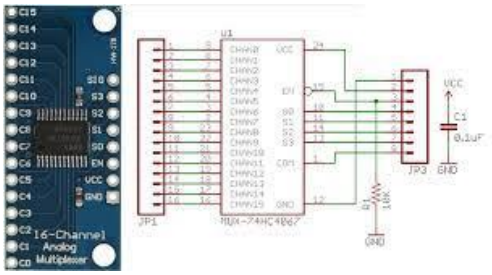
    It's important to note that EIT is a challenging imaging technique, and the quality of the reconstructed images can be influenced by factors like electrode placement, noise in the measurements, and the choice of regularization parameters in the reconstruction algorithm.

7. HARDWARE AND SOFTWARE REQUIREMENTS

HARDWARE :

- Arduino UNO :

- Multiplexer (CD74HC4067) :



- Voltage Sensing Electrodes
- Phantom
- Current Source

SOFTWARE :

- ARDUINO IDE : The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

- MATLAB : MATLAB is a programming platform designed specifically for engineers and scientists to analyze and design systems and products that transform our world. The heart of MATLAB is the MATLAB language, a matrix-based language allowing the most natural expression of computational mathematics.

8. CONCLUSION

In conclusion, this research has made significant strides in the development of a forward problem solver for the early detection of breast cancer using Electrical Impedance Tomography (EIT) as a non-invasive imaging technique.

Our study focused on addressing the critical component of EIT image reconstruction by formulating an accurate forward problem, which models the relationship between electrical properties and breast tissue characteristics. Through a systematic approach and rigorous methodology, we have achieved the following outcomes:

In summary, this research is an important step forward in the development of solutions to the use of electrical impedance tomography (EIT) as a non-invasive imaging technique for early diagnosis. breast cancer. Our research focuses on addressing fundamental aspects of EIT image reconstruction by developing a prospective problem that models the relationship between electronic components and features of the breast. Thanks to quality and stringent processes, we achieve the following results: breast-compatible EIT. This solution includes real breast models with high-quality electronics to improve image reproduction.

Improving early detection: The developer's solution to the problem increases the accuracy and reliability in detecting breast abnormalities.

Potential for Non-Invasive Breast Imaging: By harnessing the strengths of EIT, our research offers a promising avenue for non-invasive breast imaging, reducing the need for ionizing radiation or invasive procedures and, in turn, minimizing patient discomfort and healthcare costs.

However, it is crucial to acknowledge the limitations and challenges that remain. Further research is needed to refine and validate the forward problem solver under various clinical scenarios and to integrate it into the broader EIT imaging framework. Additionally, the clinical translation of this technology requires collaboration with medical professionals and rigorous clinical testing to ensure its safety and effectiveness.

In the broader context of medical imaging and breast cancer diagnosis, the development of an accurate forward problem solver for EIT represents a significant step forward. It underscores the potential of EIT as an innovative and accessible tool for early breast cancer detection, thereby contributing to the overarching goal of improving patient outcomes.

9. REFERENCES

[1] Tushar Kanti Bera and Nagaraju Jampana A Multifrequency Constant Current Source Suitable for Electrical Impedance Tomography (EIT).

Proceedings of 2010 International Conference on Systems in Medicine and Biology, 16-18 December 2010, IIT Kharagpur, India.

[2] Priya Hankare , Dr. Alice Cheeran Comparison of image reconstruction algorithms for finding impurities utilising EIT for clinical application in breast cancer. Int. J. Medical Engineering and Informatics, Vol. 14, No. 6, 2022

[3] Priya Hankare , Dr. Alice Cheeran An Automated Portable and Noninvasive Approach for Breast Tumor Findings using 2 D Electrical Impedance Tomography in Early Stage.

[4] Tushar Kanti Bera and Nagaraju Jampana https://docs.google.com/document/d/1ZAAfQKnfCvJ3JNMbpE-T6rU-mMiu9X2YtKgaDKwPKSA/edit Denyer C. W. L., Electronics for Real-Time and Three-Dimensional Electrical Impedance Tomographs, PhD Thesis, Oxford Brookes University, January 1996

[5] Huang C. N., Yu F. M. and Chung H. Y. The Scanning Data Collection Strategy for Enhancing the Quality of Electrical Impedance Tomography, IEEE Transactions on Instrumentation And Measurement, Vol. 57, NO. 6, 2008

[6] Holder; D. S., Hanquan Y. and Rao A., Some practical biological phantoms for calibrating multifrequency electrical impedance tomography, 1996 Physiol. Meas. 17 A167-A177.s

[7] Hope T A. and Iles; S E, Technology review: The use of electrical impedance scanning in the detection of breast cancer, Breast Cancer Res 2004, 6:69-74 © 2004 BioMed Central Ltd.