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International Journal for Modern Trends in Science and Technology
Volume 10, Issue 04, pages 445-448.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol10issue04.html
DOI: https://doi.org/10.46501/IJMTST1004070

Realistic 2D Image of the Human Lungs for Electrical Impedance Tomography

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To Cite this Article
K. Saranya, S. Abish, M. Mohamed kaif, K. Sanjay, Realistic 2D Image of the Human Lungs for Electrical Impedance Tomography, International Journal for Modern Trends in Science and Technology, 2024, 10(04), pages. 445-448. https://doi.org/10.46501/IJMTST1004070

Article Info
Received: 11 April 2024; Accepted: 27 April 2024; Published: 30 April 2024.

ABSTRACT

Electrical impedance tomography (EIT) stands as a cost-effective, non-invasive, and secure method, widely embraced for real-time thoracic impedance imaging. This technique involves recurrently measuring surface voltages derived from a rotating injection of high-frequency, low-intensity alternating current flowing across electrodes encircling the chest. The crux of lung monitoring via EIT hinges on accurately modelling the human thorax and lungs in a true-to-life geometry, particularly in solving the forward problem. To this end, an intricate 2D numerical model of the human thorax, complete with authentic electrical characteristics, is meticulously crafted based on a single section of Computed Tomography (CT) scan data from the EIDORS library, employing a thresholding technique. Subsequently, the forward calculation is executed utilizing the pyEIT library. The resultant potential distribution is scrutinized across two breathing states: exhale and inhale. Furthermore, diverse current injection patterns are juxtaposed to assess their impact on image reconstruction accuracy, employing the regularized Gauss-Newton (GN) algorithm. This comparative analysis sheds light on the influence of forward modelling on image resolution, thereby enhancing the understanding and efficacy of EIT in lung imaging applications.

KEYWORDS: EIT, Non-invasive, Human Lungs Image, pyEIT library, Image Reconstruction

1. INTRODUCTION

In recent years, significant advancements have been achieved in Electrical Impedance Tomography (EIT) research, prompting considerable interest among practitioners and researchers across various fields. These developments span disciplines such as mathematics, physics, electronic engineering, and clinical medicine, each seeking to leverage EIT's potential in unique ways. EIT operates by administering an electrical current through the body, capturing its response via electrodes placed on the skin to generate electrical impedance measurements. Widely regarded for its non-invasive nature, EIT holds promise in medical imaging for conditions like lung infections and breast cancer. During monitoring, cyclic electrical current injections are sequentially applied across adjacent electrodes, enabling the detection of variations in electrical conductivity within biological tissues, influenced by fluid and gas movement. Skin-level potential measurements are then utilized to derive the electrical impedance distribution, facilitating organ imaging. In the realm of medical diagnostics, EIT stands alongside conventional techniques such as chest X-rays, computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET), offering valuable insights for detecting, characterizing, and monitoring thoracic conditions. Numerous studies have explored the modelling of the human thorax in both 2D and 3D geometries, employing various software tools and libraries. While 2D models have been developed, often lacking detailed organ representations, efforts towards 3D modelling have yielded more intricate representations, incorporating CT or MRI scans to capture realistic anatomical features. This work aims to present a novel approach by constructing a 2D numerical model of the human thorax based on CT images. The paper is structured into sections elucidating the proposed methodology, including information extraction from CT scans, Finite Element Method (FEM) application, measurement patterns, and image reconstruction. Subsequent sections delve into the findings, examining the impact of current injection patterns and breathing states on image reconstruction, culminating in a conclusion. Overall, this endeavour contributes to advancing our understanding and application of EIT in medical imaging, offering insights into optimizing image reconstruction processes and enhancing diagnostic capabilities.

2. RECENT WORKS

Recent advancements in creating realistic 2D images of the human lungs for electrical impedance tomography have focused on enhancing the accuracy and detail of these representations. Researchers have been employing advanced computational techniques and imaging technologies to generate images that closely resemble the actual anatomy and physiological properties of the lungs. By incorporating factors such as tissue conductivity and lung geometry, these images provide valuable insights for improving the efficacy of electrical impedance tomography in diagnosing respiratory conditions and monitoring lung function.

3. PROPOSED WORK EXPLANATION

In contemporary healthcare practices, lung monitoring has become increasingly prevalent, offering valuable insights into a patient's respiratory status. The proposed system employs a three-lead electrode configuration to facilitate lung monitoring. This system is designed to amplify subtle bio signals originating from the lungs and transmit them to a controller for further analysis. Central to lung monitoring is the continuous measurement of surface voltages generated by applying a low-intensity, high-frequency alternating current across electrodes strategically positioned across the chest. These electrodes capture the electrical activity of the lungs during the breathing cycle. The three-electrode module is a key component of the system. It functions by fixing one electrode to the chest (electrode 1) while the other two electrodes receive signals transmitted from electrode 1. By analysing the voltage discrepancies between these signals, the system generates output representations using a serial plot. The process involves the Atmega microcontroller collecting data from the electrodes and transmitting it to MATLAB for visualization. MATLAB plays a crucial role in displaying the output on a monitor, providing a comprehensive representation of the patient's current respiratory health. By analysing these voltage values, healthcare providers can conduct in-depth breathing analysis, allowing for timely interventions or adjustments in treatment plans based on the patient's respiratory status. Overall, this system offers a non-invasive and efficient method for continuous lung monitoring, enhancing patient care and management.

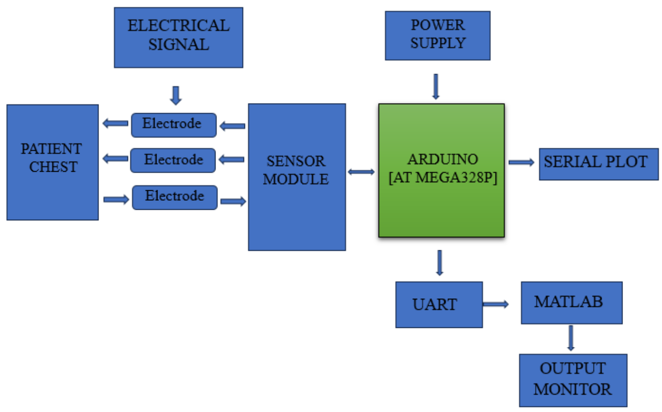

Figure 1: Proposed Block diagram

3.1 HARDWARE EXPLAINATION

3.1.1 ATMEGA328P

The ATmega328P is a microcontroller commonly used in Arduino boards. It features 32KB of flash memory for program storage, 2KB of RAM for data storage, and 1KB of EEPROM for non-volatile storage. It has 23 general-purpose I/O pins for interfacing with external devices, analog-to-digital converters for reading analog sensors, and serial communication interfaces like UART for data exchange. Additionally, it includes timers and interrupts for time-sensitive tasks and supports low-power modes for energy-efficient operation. Overall, the ATmega328P provides a versatile platform for embedded system development.

3.1.2 CHEST ELECTRODES

Chest electrodes are used to measure the impedance of lung tissues. These measurements help in creating images of lung ventilation and detecting abnormalities such as lung edema or pneumothorax. The chest electrodes provide information about the distribution of air and blood in the lungs, aiding in clinical diagnosis and monitoring of lung function.

3.1.3 SENSOR MODULE

The sensor module plays a crucial role in capturing electrical impedance data from the body. It typically consists of multiple electrodes placed on the body's surface, which emit small electrical currents and measure the resulting voltages. These measurements enable the reconstruction of internal conductivity distributions, allowing for the creation of diagnostic images. Essentially, the sensor module serves to gather the impedance data needed for imaging algorithms to generate meaningful visualizations of physiological processes within the body, such as lung ventilation or blood flow.

3.1.4 UNIVERSAL ASYNCHRONOUS RECEVIER TRANSMITTER (UART):

UART stands for Universal Asynchronous Receiver-Transmitter. It's a hardware communication protocol used for serial communication between two devices. UART communication involves the transmission of data one bit at a time over a single wire (usually two wires, one for transmission and one for reception). This makes UART suitable for communication over long distances and between devices that may not share a common clock source.

4. RESULT AND DISCUSSION

The two-pole sensing method uses different injection patterns to improve image resolution in Electrical Impedance Tomography (EIT). Opposite injection pattern is found to be the best for reconstructing conductivity distribution in the lungs, especially when objects are far from the injecting electrodes. This pattern shows better current flow through the thorax and lungs, highlighting differences in dielectric properties. In contrast, adjacent injection pattern is less accurate for detecting objects in the centre of the test medium. Regardless of breathing state, opposite injection pattern is most suitable for lung conductivity reconstruction, as it considers changes in potential distribution caused by lung and body fluid characteristics.

5. CONCLUSION

This study uses a detailed 2D model of the human thorax created with the Finite Element Method (FEM) in pyEIT. It explores various injection patterns and breathing states to simulate real conditions, incorporating lung variations from a CT scan. Results show that the opposite injection pattern is most effective in capturing lung shapes and conductivity. The model's realism opens possibilities for simulating lung diseases like COVID-19, with future research aiming to improve image reconstruction using advanced algorithms and evaluation metrics.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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