ECG And Sound Based Angiography System

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Abstract - ***Objective:*** **The objective of this study is to develop a non-invasive diagnostic tool that integrates ECG signals with arterial sound data for the detection and analysis of blockages.** ***Methods:*** **The proposed system utilizes ECG and arterial sound signals, processed using complex signal processing techniques. Feature extraction methodologies are employed to drive meaningful data, which is then analyzed using machine learning algorithms to detect blockages.** ***Results:*** **The Detected blockages will be viewed in Dashboard in the form of signals or waveforms. Comparative studies with standard angiographic methods show promising results, validating the system's effectiveness in a non-invasive manner.** ***Discussion:*** **This innovative method will minimize patient risk with traditional invasive angiographic procedures. The integration of ECG and arterial sound data enhances diagnostic capabilities, offering a cost-effective and reliable alternative for cardiovascular diagnostics.**

Index Terms - Electrocardiogram (ECG), Angiography, Arterial sound data, Signal processing, Machine Learning algorithms, Support Vector Machine (SVM), Extreme Gradient Boosting (XGBoost), Feature Extraction, Non-invasive Diagnostics, Cardiovascular Health.

I. INTRODUCTION

By measuring the heart's electrical activity using non-invasive and inexpensive ECG tools detect and classify the blockages [1]. This project leverages advanced capabilities to create an integrated system for analyzing ECG signals, heart rate and sounds. Powerful signal processing tools are used for filtering, noise reduction, and feature extraction, ensuring accurate and reliable data for processing to obtain hybrid features to improve the diagnostic accuracy [3].Microvascular angina (MVA) is a condition characterized by chest pain resulting from abnormalities in the small coronary vessels, rather than blockages in the major coronary arteries. A variety of diagnostic techniques, both invasive and non-invasive, are available to detect MVA in clinical settings. Managing primary MVA can be complex, but both medication-based and lifestyle approaches are available to help alleviate symptoms effectively in most individuals [5]. Coronary computed tomographic angiography (CTA) allows earlier detection of blockages of low-risk patients, which results in cost effective. Modeled clinical and economic results of diagnostic strategies in patients will reduce the chest pain at low risk of CAD [6].In this paper they have discussed how the Electrocardiographic imaging (ECGI), useful in humans of a new imaging modality and which uses noninvasive method to display the electrical activity of the heart [7]. Deep learning models used to detect the cardiovascular blockages through ECG tracing and implemented in embedded system such as Raspberry Pi, facilitate real-time monitoring using smart watches. It is cost-effective and efficient cardiac health monitoring using deep learning models [8]. A Computerized repolarization measurement tools are used to identify electrocardiographic signatures of CMD by T wave analysis tool which is a invasive testing during angiography [9]. A real-time monitoring of ECG-SCG for cardiac CTA to develop a clinical application and Computed tomography is a high quality imaging method for diagnosing heart blockages and Synchronizing Seismocardiography and Electrocardiogram is accuracy over real-time [10]. To increase the clinical value, CCTA method is reconstructed the ECG-SCG fusion to improve the diagnosing process. Compared to ECG, SCG is significantly improves the accuracy of diagnostic method [11].

II. METHODS

The block diagram illustrates the automated processing of ECG (electrocardiogram) data for cardiac detection. The process begins with the collection of electrical impulse from ECG sensor by fixing the electrodes in the human body and monitoring devices. This data is sent to the ESP32 microcontroller and signals from the ultrasound sensor sent to the microcontroller which is amplified by instrumentation amplifier. Similarly, Microphone sensor will collect the impulses from human body and store it in the microcontroller. All the above mentioned sensors signals are amplified by the AD8232 instrumentation amplifier which is used to amplify the weak signals into stable ECG signal by removing the low-frequency noise from external sources. The amplified signals are stored in a cloud –based storage, allowing data collected from the microphone sensor, ultrasound sensor and ECG sensor to be transmitted and visualized remotely. The collected data from the ESP32 microcontroller are displayed in the LCD 16x2 display providing a interface for displaying important information processed by the ESP32.The connection between LCD and ESP32 is established a parallel communication.

A) DATA COLLECTION

The power supply unit is essential for provide the necessary voltage and current to ESP32 and the associated sensors and amplifiers, which ensures stable and reliable operation. The ESP32 microcontroller handles multiple sensor input, process data and transmits the information using smart system. An ECG (Electrocardiogram) sensor used to measure the electrical activity of the heart and signals are captured through electrodes placed in skin and signals collected by the electrodes to filter out the noise sent to the ESP32 microcontroller. The transmitter converts electrical signals into ultrasonic waves, while the receiver captures the reflected waves. Ultrasound sensor signals are transmitted to the microcontroller and stored in the cloud. Microcontroller receives the sensor's output and processes the audio data to extract relevant information depend upon the requirements. The overall data is collected and stored in a cloud.

B) PRE-PROCESSING

Once the data is collected, it undergoes a pre-processing of the data and this step plays an important role because instrumentation amplifier amplifies the ECG signals are affected by noise from external sources, electrical interferences. Integrating SCG with ECG aims to improve accuracy [12]. AD8232 instrumentation amplifier which will improve the integrity of signals and reduce the unwanted noise extracted from the ECG, Ultrasound and Microphone sensor. This technique provides a accurate detection of blockage area which will be viewed in a LCD display. While detecting the blockages there will be variations in the electrical activity of the heart for that purpose amplifier will amplifies the signals and correct location of the blockage will be identified using the instrumentation amplifier because it is optimized for processing a weak signals.

C) CLASSIFICATION

The output of this stage is preprocessed ECG signal, are classified into wave forms like T waves, QRS waves, P waves which records the electrical activity of

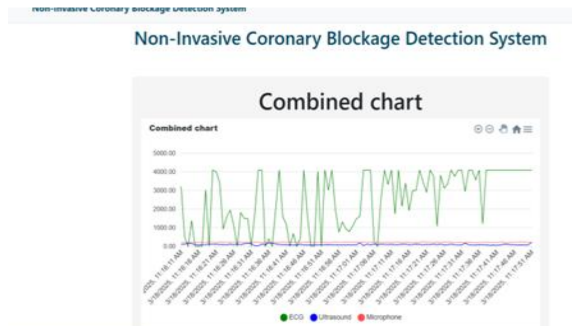

FIGURE: 2 Combinations of ECG, Microphone and Ultrasound Waves.

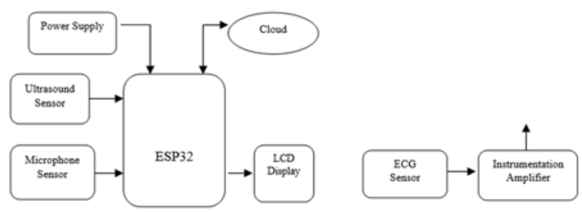

FIGURE: 1 BLOCK DIAGRAM

the heart, P waves which is the electrical activity that triggers the arterial contraction (0.08-0.10 sec) and T waves are the ventricular repolarization before the next contraction. QRS waves which represent, a small downward deflection is Q waves and a large upward deflection is R waves, downward deflection follows R wave (0.06-0.12 sec).

D) POST-PROCESSING

In the final stage, the classified ECG data is post-processed and displayed on a 16x2 LCD display as a value for the ECG, Ultrasound and Microphone sensor which indicates the blockage is detected or no blockage is detected. From ECG data, it aims to bridge gap between signal processing and medical imaging.

TABLE - 1 WAVES

WAVE COMPONENTS	DESCRIPTION	NORMAL RANGE
P wave	Atrial depolarization	0.08 – 0.12 sec
QRS wave	Ventricular depolarization	0.06 – 0.10 sec
T waves	Ventricular Repolarization	0.10 – 0.25 sec

E) COMPONENTS

POWER SUPPLY

The power supply provides the necessary voltage and current to the ESP32. The 12V power supply needs to be converted into 5V output and various sensors like microphone sensor; ultrasound sensor and ECG sensor require a 5V input for stable and efficient operation. Voltage converter is used to step down the 12V to 5V power supply.

ESP32

ESP32 is an open- source development board and firmware that provides an easy to use platform for IoT (Internet of Things) applications. ESP32 supports both Wi-Fi and Bluetooth allows wireless connectivity in diverse environment. It is a low power consumption but ideal for energy – efficient applications.

ECG SENSOR

An ECG sensor is a crucial device used to measure the electrical activity of the heart. The sensor includes three leads: positive, negative and ground. The ECG (Electrocardiogram) sensor is responsible for monitoring the heart electrical activity. It detects the electrical impulses from the human and transmitted to ESP32 for pre-processing.

ULTRASOUND SENSOR

An ultrasound sensor (JSN- SR04T) is an electronic device that uses ultrasonic waves to measure distance and perform sensing tasks or monitoring specific health parameters works by sending high frequency sound waves and analyzing their reflections. This is used to locate the blockages.

MICROPHONIC SENSOR

Microphonic sensor (KY-038) is an essential component responsible for detecting sound and converts it into electrical signals that can be processed by ESP32 microcontroller. It captures a wide range of sound frequencies and used in applications like speech recognition.

INSTRUMENTATION AMPLIFIER

Specialized AD8232 instrumentation amplifier designed to amplify the weak signal from ECG sensor. It includes high-pass filter to eliminate baseline wander, caused by slow-changing signals such as respiration. Additionally, AD8232 uses low-pass filter that reduces high-frequency noise.

LCD DISPLAY

The 16X2 LCD display is used to display the readings of the sensors which is temporarily stored in the ESP32 and helps to point out the blocked area in the normal electrical activity of heart.

CLOUD STORAGE

The cloud connectivity used here is Thingspeak and helps to connect the data with cloud to monitor the patient's condition enabling real-time monitoring.

THINGSPEAK

Thingspeak is an Internet of Things (IoT) platform that provides a cloud-based service for collecting, analyzing and visualizing data from the connected devices. The collected data is sent via HTTP, MQTT to Thingspeak making wide range of devices like ESP32 and other microcontroller used in IoT applications.

12V 2A ADAPTER

A 12V 2A adapter is used power supply that provides a stable 12V output with a maximum current of 2A.

F) CIRCUIT DIAGRAM

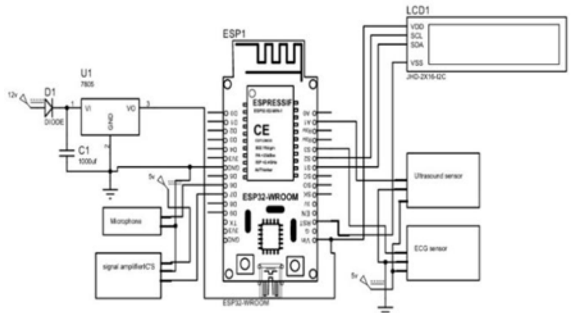

FIGURE: 3 CIRCUIT DIAGRAM

The circuit diagram demonstrates the connection of an ESP32 microcontroller with multiple components, includes an LCD display, an ultrasound sensor, an ECG sensor, a microphone, instrumentation amplifier and power supply. The ESP32 microcontroller is the central processing unit and managing data from the connected sensors and modules. The power supply section consists of a 12V input that passes through a diode for protection against reverse polarity. The voltage regulator 7805 that converts the 12V input to a stable 5V output. A Capacitor with 1000 microfarad is used for smoothing the voltage to eliminate any ripples and provide a stable power supply to ESP32 and components. The regulated 5V output from the 7805 voltage regulator is supplied to the ESP32 microcontroller and sensors. The ESP32 microcontroller is directly interfaced with LCD display (LM016L) which is connected through I2C communication protocol. The LCD display has four pins: VDD for power, SCL for clock line, SDA for data line and VSS for ground. The SCL and SDA pins are connected to its corresponding I2C pins of the ESP32, allowing efficient communication for displaying data. The Ultrasound sensor is connected to the microcontroller ESP32 for measurement. It requires trigger and echo pins to send ultrasonic pulses and measure the time taken for the echo to return. The ESP32 processes the data from the ultrasound sensor to calculate the distance between the sensor and an object. The ECG sensor that captures electrical activity from the heart that connected to ESP32 for health monitoring. The ECG sensor's output is fed to the instrumentation amplifier
to boost the weak signals from the human body. The amplified signals are then send to the ESP32's analog input pins for further processing and analysis. The microphone sensor captures sound signals from human body and then boosts the audio signals before processing to ESP32. The ground connections of all the sensors are tied to the ESP32 microcontroller's ground for better circuit operations. The ESP32 processes data from all the three sensors and display it in the LCD screen. ESP32's Wi-Fi capability allows data to be sent to the cloud for analyzing and monitoring the signals.

G) MACHINE LEARNING ALGORITHMS

- XGBOOST – The XGBoost is a powerful and efficient machine learning algorithm used for the classification, regression of signals from the sensors.
- SVM – Support Vector Machine is a supervised machine learning algorithm used to classify the signals and for regression tasks.

III. RESULTS

The implemented system efficiently integrates multiple sensors like ECG, microphone and ultrasound, an LCD display, a cloud platform and a power supply ensuring seamless data acquisition, processing and transmission. The power supply of 12V is converted to 5V allowing the ESP32 and other components to function properly without voltage fluctuations. These sensors provide the real time data, which is processed by the ESP32 and then displayed on the LCD. The instrumentation amplifier provides the ECG sensor signal to ensure accurate physiological data measurement. The ESP32 manages data flow between the sensors, LCD display and cloud platform that utilizing Wi-Fi connectivity to transmit processed information to Thingspeak for continuous monitoring. This system ensures reliable communication and data storage for real time analysis of signals. The combination of real-time display and cloud-based storage provides accessibility. The results confirm that the system provides stable and efficient data processing and transmission mechanism for monitoring analysis.

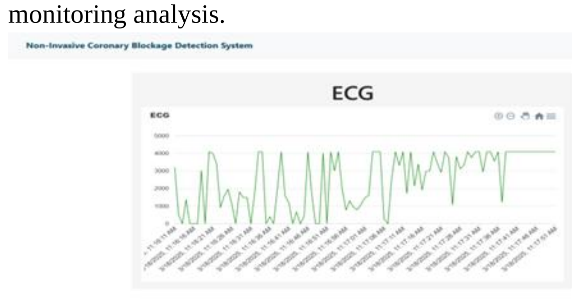

FIGURE: 4 ECG Waveform

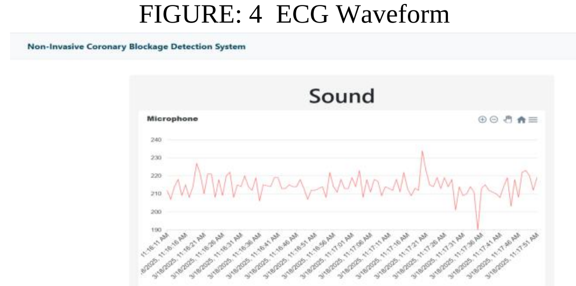

FIGURE: 5 Sound Waveform

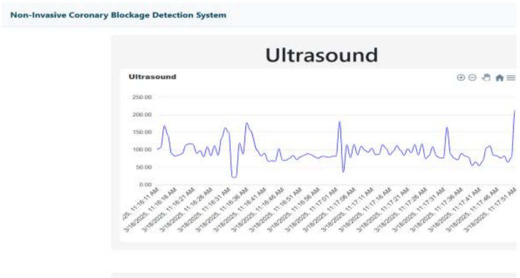

FIGURE: 6 Ultrasound Waveform

IV. DISCUSSION

The system is based on integrating various sensors for real-time analysis of data collection. It has efficient power supply for stable connection to all components. The ECG sensor captures the electrical activity of the heart and then sent to the instrumentation amplifier for boosting the weak signal. Other sensors like microphone and ultrasound collect the data and sent to the ESP32. The ESP32 with its Wi-Fi and Bluetooth connectivity is used for continuous monitoring of real-time data. The collected data from the sensors are displayed on the LCD display for monitoring. The ESP32 provides the system's efficient by enabling wireless data transmission and for IOT functionality.

V. FUTURE SCOPE

The future scope of this system is wide with several possibilities for enhancing advancements in hardware, software and connectivity. The integration of AI and ML can improve data processing that provides pattern detection. Advanced power management such as solar charging or low power modes can improve efficiency and sustainability. Expanding cloud integration from Thingspeak to other platforms like AWS, Google Cloud or Microsoft Azure can provide scalability for more data storage. Enhanced wireless communications such as the use of 5G or LoRa can provides better connectivity. The development of energy – efficient and cloud integration will improve scalability and reliability of the system.

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