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Article

A Raspberry Pi-based digital stethoscope: Advancing real-time heart and lung sound diagnostics with IoT and machine learning integration

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Abstract: Digital transformation is reshaping auscultation by moving the stethoscope from a purely acoustic instrument to an intelligent, data-driven diagnostic platform. This review critically examines Raspberry Pi 3-based digital stethoscope technologies for heart and lung sound monitoring, with an emphasis on system architecture, sensor integration, signal acquisition, real-time processing, storage, playback, and connectivity. The paper synthesizes current designs and implementation strategies, highlighting how low-cost embedded platforms can improve the repeatability, accessibility, and objectivity of cardiopulmonary assessment compared with conventional acoustic stethoscopes. Particular attention is given to technical performance factors, including filtering, signal-to-noise ratio, latency, audio distortion, noise suppression, and time-frequency analysis, which are essential for detecting clinically significant acoustic features such as heart murmurs, crackles, and wheezes. The review also identifies key limitations affecting clinical translation, including power consumption, device portability, casing size, environmental noise, hardware constraints, and the need for robust validation in real-world settings. Future directions include optimized embedded processing, wireless and IoT-enabled tele-auscultation, cloud-assisted data management, and machine learning models for automated classification and decision support. Overall, Raspberry Pi 3-based digital stethoscopes represent a promising pathway toward affordable, scalable, and clinically meaningful cardiopulmonary monitoring, particularly for point-of-care, remote, and resource-limited healthcare environments. By integrating acoustic sensing, edge computing, and intelligent analytics, these systems can strengthen diagnostic workflows and support the next generation of connected digital healthcare.

Keywords: digital stethoscope; Raspberry Pi 3; heart sound monitoring; lung sound recording; real-time signal processing; medical diagnostics; IoT in healthcare; acoustic signal detection

1. Introduction

The stethoscope has long been the cornerstone of bedside auscultation, functioning as an acoustic transducer that captures, transmits, and amplifies minute body-sound vibrations before they reach the clinician's ear. Foundational work on the spectral and temporal properties of heart and lung sounds established that chest-wall acoustics and phonocardiographic signals can be represented as a repertoire of frequency bands and time-frequency structures, which has guided later digital analyses and visualization methods [1]. More recent studies of chest-wall and neonatal breath sounds further confirm that breath and heart sounds possess characteristic spectral signatures that can be leveraged for diagnostic purposes, even when recorded with non-invasive transduction channels such as contact microphones or digital stethoscopes [2–4]. The historical trajectory from classical spectral phonocardiography toward modern digital phonographic analysis provides a strong rationale for embedding signal-processing and vibration-analysis concepts into contemporary auscultation tools [1].

The emergence of digital stethoscopes represents a natural extension of this body of work, enabling quantitative, repeatable, and storable aural data that can be interrogated with advanced signal-processing techniques. Digital stethoscope designs now replace or augment the acoustic pathway with electronic sensors and onboard analog-to-digital conversion, supporting real-time filtering, feature extraction, and data logging for subsequent evaluation [5, 6]. Notably, multimodal and wireless stethoscope concepts have been proposed to improve robustness and coverage of cardiopulmonary signals, including multi-channel stethograph implementations and wireless transmission architectures designed for clinical workflows [6, 7]. Reviews of pulmonary- and phonocardiogram-based diagnostics emphasize how signal-processing pipelines, spectral analysis, time-frequency representations, adaptive filtering, and fusion with ECG or imaging data can improve diagnostic objectivity beyond the limitations of subjective auscultation [7, 8].

Critical to this shift are findings that conventional auscultation remains vulnerable to human perceptual variability and ambient noise interference, which can compromise sensitivity and specificity for phenomena such as murmurs, crackles, and wheezes [3]. Systematic reviews and experimental studies have documented considerable inter- and intra-operator variability in heart- and breath-sound interpretation, motivating the development of objective acoustic metrics and automated classification methods that can complement clinician judgment [1, 3, 9]. In this context, digital implementations that combine robust sensing with real-time processing become particularly attractive for enhancing diagnostic reliability in busy clinical environments.

A practical realization of these ideas is the design and implementation of cost-effective digital stethoscopes that leverage readily available consumer electronics while delivering clinically relevant signal quality. Several works demonstrate the feasibility and value of low-cost hardware integration and software-driven analysis for auscultation signals. For example, multimodal smart stethoscope designs illustrate how digital microphones, compact processing units, and flexible software pipelines can capture heart and lung sounds with improved repeatability while preserving portability and ease of use [10]. Related efforts have focused on electronic stethoscopes and their software environments, using MATLAB and LabVIEW to perform real-time filtering, denoising, feature extraction, and visualization to support clinician interpretation [11, 12]. These studies collectively show that well-chosen digital sensing architectures, paired with accessible software ecosystems, can deliver clinically meaningful performance without prohibitive cost or complexity.

In the digital-stethoscope design space, several concrete capabilities are repeatedly demonstrated as essential to translating engineering concepts into clinical value. Real-time recording, processing, and playback of cardiopulmonary sounds are enabled by fast ADC paths and efficient digital filtering, with performance metrics such as SNR and latency quantified under realistic noise conditions [5,12,13]. The literature shows that real-time pipelines can maintain acceptable latency for interactive auscultation while applying noise-reduction strategies to reveal subtle murmur or crackle signatures [12, 13]. Quantitative, objective analysis of heart and lung sounds through time-frequency representations and automated classification is supported by software tools that implement spectral estimation, feature extraction (e.g., MFCC-like or domain-specific acoustic features), and machine-learning-based decision support [12,14,15]. These developments align with the broader push in biomedical acoustics to replace or augment subjective listening with reproducible, auditable analyses [1]. Integration with wearable or patch-based sensing approaches enables ambulatory monitoring and continuous assessment of cardio-respiratory status while maintaining user comfort and data integrity [4,10,16]. The literature emphasizes that wearable and skin-attachable sensors can extend auscultation beyond the clinic while presenting new challenges in motion tolerance and environmental noise [16,17].

Against this backdrop, a Raspberry Pi 3-based digital stethoscope fits naturally within the existing design space: the Pi's computational capabilities and flexible I/O enable real-time sampling, filtering, and playback of acoustic data while leveraging low-cost peripherals to keep the device accessible and scalable in clinic or point-of-care settings. The feasibility and utility of similar low-cost, software-centric approaches are well supported by prior work on digital stethoscopes and signal processing pipelines. For instance, platforms that replace conventional transducers with digital microphones and feed signals into analog-to-digital stages or embedded processors have demonstrated robust heart- and breath-sound acquisition, with real-time processing enabling denoising, SNR enhancement, and visualization of phonocardiograms and lung-sound spectrograms [10, 13]. Moreover, several studies report successful real-time audio processing, waveform and spectral analysis, and even machine-learning-based classification for cardiopulmonary signals using consumer-grade hardware or general-purpose embedded platforms, underscoring the practical viability of such approaches for broad clinical adoption [12,15,18].

In terms of specific performance benchmarks relevant to a Raspberry Pi–based solution, the literature consistently shows that effective noise suppression and SNR improvement can reveal clinically meaningful acoustic features, such as murmurs or crackles, that may be obscured by ambient noise during auscultation, particularly when recordings are performed in non-ideal environments. Digital filtering, adaptive denoising, and spectral analysis are central components of successful pipelines [1,8]. These capabilities are integral to any low-cost digital stethoscope intended for real-time interpretation or tele-auscultation [6,10]. Real-time data processing, including streaming capture, filtering, latency assessment, and immediate playback, has been demonstrated in several digital stethoscope and stethograph implementations, providing a validated blueprint for Raspberry Pi-level computing resources to meet performance requirements in practice [19]. The successful deployment of such systems in research and clinical pilot studies reinforces their feasibility for scalable, low-cost solutions [10]. Beyond purely acoustic considerations, recent work on multimodal and wearable sensing emphasizes how combining acoustic data with other physiological signals, such as ECG and respiratory effort, can improve diagnostic discriminability and robustness to noise. For example, patch-like cardiovascular monitoring devices collect multiple streams, including heart sounds, lung sounds, and ECG, to form a richer picture of cardiopulmonary status, illustrating a practical pathway toward integrated bedside or remote health monitoring using affordable hardware and open software pipelines [10,17]. These multimodal capabilities can be readily integrated with a Raspberry Pi–based digital stethoscope to enable synchronized, multi-sensor data collection, processing, and storage for offline or cloud-assisted analysis.

In summary, the proposed Raspberry Pi 3-based digital stethoscope aligns with a substantial body of evidence showing that the stethoscope remains a transduction-based sensing modality whose clinical value is enhanced when acoustic signals are digitized and subjected to quantitative analysis [1,4,20]. Digital stethoscopes support real-time recording, filtering, and playback, facilitating objective quantification of cardiac and pulmonary sounds and enabling downstream machine-learning analyses [12–14,18]. Low-cost hardware platforms, including single-board computers and commodity sensors, can deliver clinically useful performance when paired with robust signal-processing pipelines, enabling scalable deployment and broad accessibility in clinical environments [10,18,19].

2. Literature review

The Raspberry Pi is a credit card-sized, low-cost computer that has attracted significant attention due to its versatility and broad applicability. Originally developed to promote computer science education in schools, it has since evolved into a powerful and adaptable platform used across diverse fields such as education, hobbyist electronics, automation, and Internet of Things (IoT) development. Its compact design, affordability, and compatibility with multiple sensors and programming environments have made it a preferred choice for embedded systems and digital prototyping. Numerous studies have highlighted its use in various domains, from robotics and home automation to environmental monitoring and medical instrumentation, demonstrating its potential as an accessible gateway to advanced computational applications. A summary of previous studies exploring the Raspberry Pi's functions, strengths, and limitations is presented in **Table 1**, which outlines the key findings from related review papers on Raspberry Pi-based systems.

A Comprehensive Review of the Raspberry Pi and Its Uses paper provides a thorough introduction to the Raspberry Pi, including information on its background, features, and numerous uses in diverse industries. It highlights how affordable and versatile the gadget is, which makes it a popular option for hobbyists and educational applications. The paper presents interesting projects that make use of the Raspberry Pi, highlighting its potential applications in robotics, IoT, and home automation. It also highlights areas for future development and solves the Raspberry Pi's limitations [21].

Table 1. Summary of prior Raspberry Pi-based systems and their relevance to acoustic or IoT applications.

Title	Key findings	Limitations
A Review Paper on Raspberry Pi and its Applications [21]	The paper provides a comprehensive review of the Raspberry Pi, detailing its historical development aimed at increasing interest in computer science, with the first model launched in 2012 and over 19 million units sold. It highlights the technical specifications of the latest Raspberry Pi 4 Model B, including its powerful processor and connectivity options, and outlines the multi-stage boot process. The Raspberry Pi's versatility is showcased through various applications, such as home automation, security systems, and robotics, while also addressing limitations such as the lack of integrated heat sinks, challenges in running the Windows OS, and the absence of a real-time clock. The paper suggests improvements, including enhanced internal storage and better user guides, emphasizing the Raspberry Pi's potential as an educational tool and its ongoing evolution in computing and embedded systems.	The paper outlines several limitations of the Raspberry Pi that impact its usability and performance. One significant issue is overheating; the board lacks integrated heat sinks or a cooling fan, which can lead to overheating during extended use. Additionally, the Raspberry Pi faces challenges in running a full version of Windows, limiting its applicability for software that requires this operating system. Another limitation is the absence of a real-time clock (RTC) with a backup battery, which can hinder applications that depend on accurate timekeeping. Furthermore, the paper highlights the need for improvements in internal storage availability and the integration of heat sinks to enhance the device's efficiency. Lastly, while the Raspberry Pi can function as an individual computer, it cannot fully replace traditional computers due to these specific limitations, making it more suitable for certain applications rather than as a complete substitute for conventional computing devices.
A Review Paper on Raspberry Pi [22]	The key findings of the paper emphasize the Raspberry Pi as a powerful and affordable computer that has significantly influenced the learning and application of technology. It serves as a catalyst for experimentation and innovation, making it accessible to a wide range of users, including students and hobbyists. The paper also highlights several interesting projects developed using the Raspberry Pi, showcasing its versatility and potential for creative applications. Overall, the Raspberry Pi has transformed the landscape of technology education and project development, encouraging users to explore and innovate in ways that were previously less accessible.	The paper does not explicitly outline specific limitations of the Raspberry Pi. However, it implies that while the Raspberry Pi is a powerful and affordable tool for learning and experimentation, it is not intended to replace traditional computers or laptops. Instead, it serves as a supplementary device, which may suggest limitations in processing power, software compatibility, or functionality compared to more advanced computing systems. The focus remains on its role in education and innovation rather than a comprehensive analysis of its limitations.
A Review on Raspberry Pi and its Robotic Applications [23]	Highlight the versatility and effectiveness of the Raspberry Pi in various robotic applications. The review identifies several innovative uses of the Raspberry Pi, including multi-utility robots, surveillance systems, line-following robots, and fire extinguishing robots, among others. It emphasizes that Raspberry Pi's affordability, reliability, and strong anti-interference capabilities make it an ideal platform for developing low-cost robots that can perform complex tasks. The paper also notes the significant potential for the Raspberry Pi in enhancing functionalities across different domains, such as agriculture, military, and industrial applications. Overall, the findings suggest that the Raspberry Pi not only facilitates the creation of diverse robotic solutions but also encourages further exploration and development within open-source communities, paving the way for future advancements in robotics.	The paper identifies several limitations of the Raspberry Pi in robotic applications, including its performance constraints compared to more powerful computing platforms, which can hinder complex algorithm execution and real-time processing. While versatile, the Raspberry Pi may not be suitable for applications requiring high computational power or specialized hardware. Additionally, reliance on open-source software can result in inconsistent performance and support, posing challenges for developers. Overall, these factors indicate that the Raspberry Pi, while valuable, may not be ideal for all robotic scenarios.
A Comparative Study of Arduino, Raspberry Pi and ESP8266 as IoT Development Board [24]	The key findings of the paper highlight the comparative strengths and weaknesses of Arduino, Raspberry Pi, and ESP8266 as development boards for Internet of Things (IoT) applications. The analysis reveals that while the Raspberry Pi offers superior performance in terms of storage and computing speed, making it suitable for complex IoT systems, it comes at a higher cost. In contrast, Arduino excels in sensing capabilities due to its built-in analog-to-digital conversion, making it ideal for applications requiring continuous analog signal monitoring. The ESP8266 stands out for its compact size and wireless connectivity, making it effective for device-level sensor networking. Overall, the paper emphasizes that the choice of development board should be based on the specific requirements of the IoT application, balancing performance, cost, and functionality to achieve optimal results.	The paper acknowledges a limitation in the overall functional knowledge and capabilities of the available development boards, which may hinder engineers from fully exploring the potential of Internet of Things (IoT) approaches. This lack of comprehensive understanding can restrict the effective implementation of IoT systems, as developers may not be aware of the specific strengths and weaknesses of each platform. Additionally, the paper suggests that while it provides a comparative analysis, the rapidly evolving nature of technology means that new boards and features may emerge, potentially altering the relevance of the findings over time. Thus, continuous research and updates are necessary to keep pace with advancements in IoT development platforms.

Table 1. *Cont.*

Title	Key findings	Limitations
Arduino, Raspberry Pi, and Smartphone Usage Comparison for Voice-based Virtual Assistant [25]	The key findings of the paper indicate that smartphones are the most effective platform for implementing voice recognition and text-to-speech features in virtual assistants aimed at supporting individuals with borderline personality disorder (BPD). The research highlights that smartphones offer a faster, cheaper, and more user-friendly solution compared to Arduino and Raspberry Pi devices. While Arduino requires additional modules for voice recognition and IoT connectivity, and Raspberry Pi necessitates a more complex setup with multiple components, smartphones can leverage built-in capabilities and accessible development tools like MIT App Inventor to facilitate voice interactions seamlessly. The study underscores the potential of virtual assistants to provide continuous companionship and support, thereby helping to alleviate feelings of loneliness and hopelessness in individuals with BPD. Overall, the findings advocate for the integration of voice-based technology in mental health support systems, emphasizing the importance of accessibility and ease of use in enhancing the user experience.	The paper acknowledges several limitations in its research regarding the implementation of voice-based virtual assistants for individuals with borderline personality disorder (BPD). One significant limitation is the focus on only three specific platforms—Arduino, Raspberry Pi, and smartphones—without considering other potential devices or technologies that could also support voice recognition and chatbot functionalities. Additionally, the study primarily emphasizes the technical aspects and cost comparisons, which may overlook other critical factors such as user experience, accessibility, and the psychological impact of using these technologies on individuals with BPD. Furthermore, the research does not delve deeply into the effectiveness of virtual assistants in real-world scenarios or their long-term impact on users' mental health. This lack of empirical data on user interactions and outcomes suggests that further research is needed to comprehensively evaluate the effectiveness and practicality of these voice-based systems in providing support for individuals with BPD.
Comparative study of Arduino Types and Raspberry Pi with Programming Languages [26]	The key findings of the paper reveal significant differences between Arduino and Raspberry Pi, which influence their suitability for various applications. Arduino is identified as a microcontroller that excels in simplicity and ease of use, making it ideal for straightforward electronic projects that do not require complex processing or an operating system. It operates at a clock speed of 16 MHz and is designed for single-task operations, which allows for low-cost implementations. In contrast, Raspberry Pi is characterized as a more powerful microprocessor capable of multitasking, with a clock speed of up to 1.2 GHz, enabling it to handle more demanding applications such as data processing and graphics. The paper also highlights the programming languages used for each platform, with Arduino primarily utilizing C/C++ and Raspberry Pi supporting a broader range of languages, including Python and Ruby. Ultimately, the findings suggest that while Raspberry Pi is better suited for projects requiring advanced processing capabilities, Arduino remains a valuable tool for simpler, standalone applications, guiding developers in their choice of platform based on project requirements.	The paper acknowledges certain limitations in its research, primarily related to the scope of the comparative analysis between Arduino and Raspberry Pi. One limitation is that the study does not delve deeply into the extensive range of applications and specific use cases for each platform, which could provide a more comprehensive understanding of their practical implementations. Additionally, the paper may not cover the latest advancements and updates in both technologies, as the field of microcontrollers is rapidly evolving. This could lead to a gap in the relevance of the findings over time. Furthermore, the authors suggest that while they provide a general overview of the strengths and weaknesses of each platform, individual project requirements may vary significantly, and thus, the choice of platform should be tailored to specific needs rather than relying solely on the comparative analysis presented.
A Comparison of Arduino, Raspberry Pi and ESP8266 Boards [27]	The key findings of the paper reveal distinct characteristics and advantages of each development board—Arduino, Raspberry Pi, and ESP8266 Node MCU—tailored for different IoT applications. Arduino is identified as a versatile 8-bit microcontroller ideal for simple projects requiring direct hardware interaction, while Raspberry Pi is characterized as a more powerful mini-computer capable of running a full Linux operating system, making it suitable for complex computing tasks and applications that require a graphical interface. The ESP8266 NodeMCU stands out for its integrated Wi-Fi capabilities, making it particularly effective for wireless IoT applications where connectivity is essential. The comparison also highlights differences in processing power, memory, and connectivity options, guiding users in selecting the appropriate board based on their project requirements, whether they prioritize ease of use, computational power, or wireless functionality.	The paper acknowledges certain limitations in its research, primarily related to the scope of the comparison and the evolving nature of technology. One limitation is that the analysis is based on specific models of the development boards, which may not encompass all variations and updates available in the market. As technology rapidly advances, new models with enhanced features may emerge, potentially altering the relevance of the findings. Additionally, the paper does not delve deeply into practical applications or case studies that demonstrate the real-world performance of these boards in IoT projects. This lack of empirical data may limit the applicability of the findings for users seeking insights into practical implementation. Overall, while the paper provides a foundational comparison, it suggests that further research and real-world testing are necessary to fully understand the capabilities and limitations of each platform in diverse IoT scenarios.

Table 1. *Cont.*

Title	Key findings	Limitations
Exploring Sensor with Raspberry Pi and Arduino: A Comparative Analysis [28]	The key findings of the paper indicate that both the Raspberry Pi and Arduino have unique advantages that make them suitable for different types of applications involving the MAX30102 sensor. The study reveals that Arduino boards are generally more cost-effective and excel in low-power, real-time applications due to their quick response times and lower power consumption. In contrast, Raspberry Pi boards provide superior processing capabilities, supporting a full operating system and a wider range of programming languages, which makes them more suitable for complex data analysis tasks. Additionally, the research highlights that while the Raspberry Pi offers higher precision and faster clock speeds, Arduino's simplicity and ease of use make it a preferred choice for straightforward sensor applications. Ultimately, the findings suggest that the choice between these platforms should be guided by the specific requirements of the project, balancing factors such as cost, power consumption, and processing needs.	The paper acknowledges certain limitations in its research, primarily related to the scope of the comparative analysis. One key limitation is that the study focuses specifically on the integration of the MAX30102 sensor with Raspberry Pi and Arduino, which may not encompass the full range of capabilities and applications of these platforms in other contexts. Additionally, the performance evaluation is based on specific configurations and setups, which may vary in different environments or with different sensor applications. The authors also note that while they provide insights into the strengths and weaknesses of each platform, the findings may not be universally applicable to all sensor projects, as the optimal choice of platform can depend heavily on the unique requirements and constraints of individual applications. This suggests that further research could expand on these findings by exploring additional sensors and use cases to provide a more comprehensive understanding of the platforms' capabilities.
Design And Implementation Of Raspberry Pi 3 Based Embedded System For Analysis Of Soil Parameters [29]	The key findings of the paper highlight the effectiveness and feasibility of using a Raspberry Pi 3-based embedded system for monitoring and optimizing irrigation in agriculture. The research demonstrates that by integrating low-cost sensors, such as the DHT 22 for temperature and humidity and the YL 69 Soil Moisture Sensor, the system can accurately collect and analyze data related to soil conditions. This data-driven approach allows for precise control of irrigation, ensuring that water is supplied according to the actual needs of the crops, thereby conserving water resources. Additionally, the study suggests potential future enhancements, such as incorporating pH and soil nutrient sensors, which could further improve the system's capability to monitor soil health. Overall, the findings indicate that this smart irrigation system not only addresses the challenges of water scarcity but also provides a sustainable and low-maintenance solution for farmers, promoting better agricultural practices.	The paper acknowledges several limitations regarding the proposed smart irrigation system. One significant limitation is the reliance on low-cost sensors, which, while economically beneficial, may not always provide the highest accuracy or reliability in data collection. This could potentially affect the precision of the irrigation control system. Additionally, the current setup primarily focuses on monitoring temperature, humidity, and soil moisture, leaving out other critical factors such as soil pH and nutrient levels, which are essential for comprehensive soil health assessment. The authors suggest that future enhancements could address these limitations by incorporating additional sensors to measure pH and soil nutrients, as well as air flow sensors to assess soil air permeability. Overall, while the system shows promise, these limitations highlight the need for further research and development to enhance its effectiveness and reliability in agricultural applications.
A comparative analysis of Raspberry pi Hardware with Adruino, Phidgets, Beaglebone black and Udoo [30]	The key findings of the paper indicate that the Raspberry Pi stands out as a highly affordable and versatile platform for IoT applications when compared to other hardware options like Arduino, Phidgets, Beaglebone Black, and Udoo. The analysis reveals that while Udoo offers superior performance, its high cost makes it less accessible to many users. In contrast, the Raspberry Pi, being a compact and inexpensive device, allows for easy programming and supports a wide range of peripherals, making it suitable for various applications. The paper also notes that when paired with a Linux operating system, the Raspberry Pi can deliver impressive performance, further enhancing its appeal for end users. Despite some limitations, such as the need for additional components like an SD card and keyboard, the Raspberry Pi's overall benefits make it a preferred choice for many in the IoT space.	The paper acknowledges several limitations regarding the research conducted on the comparative analysis of IoT platforms. One significant limitation is that, although the Raspberry Pi is presented as an affordable option, it incurs additional costs for essential components such as an SD card and keyboard, which may not be immediately apparent to potential users. Furthermore, the paper notes that while the Raspberry Pi excels in versatility and cost-effectiveness, it may not match the performance capabilities of more expensive platforms like Udoo in certain applications. Additionally, the analysis may not encompass all possible IoT platforms available in the market, potentially limiting the comprehensiveness of the comparison. These factors suggest that while the findings provide valuable insights, they should be interpreted with an understanding of these constraints.

A Raspberry Pi Review article: The importance of the Raspberry Pi for technology education and project development is the main topic of this article. It draws attention to the qualities of the gadget, how it affects engineering tasks, and how it encourages experimentation and creativity. The writers highlight the Raspberry Pi's accessibility for amateurs and students as they go over its many uses. Additionally, the Raspberry Pi is compared to conventional computer platforms in the report, with its benefits in terms of cost and usability highlighted [22].

An Overview of Raspberry Pi and Its Uses in Robotics: The integration of Raspberry Pi in robotic applications is examined in this research. It talks about various robotics systems and approaches that take advantage of the Raspberry Pi's versatility and computational capability. The authors demonstrate the usefulness of the Raspberry Pi in augmenting robotic functionalities by highlighting particular projects that use it for activities like automation, control, and data processing in robotic systems [23].

Examining Arduino, Raspberry Pi, and ESP8266 in Comparison as IoT Development Boards Three well-known development boards—the Arduino, Raspberry Pi, and ESP8266—are compared in this study, with a focus on Internet of Things (IoT) applications. It lists each platform's advantages and disadvantages, pointing out that the Raspberry Pi is better at performance and storage, Arduino is better at sensing, and ESP8266 is well-known for having wireless communication [27]. The purpose of the study is to help developers choose the right board for their Internet of Things projects [24].

Comparing the Use of Arduino, Raspberry Pi, and Smartphones for Voice-Activated Virtual Assistants: This study compares the development of voice-activated virtual assistants using Arduino, Raspberry Pi, and smartphones. It discusses how well each platform can handle tasks like voice recognition and processing. The writers analyse the benefits and disadvantages of each technology for developing virtual assistants, offering suggestions about which platform might work best for particular voice interaction application scenarios [25].

Comparative Analysis of Programming Languages for Raspberry Pi and Arduino Types: In this study, the various Arduino board models are examined, and their programming languages and development environments are compared with those of the Raspberry Pi. It highlights the languages that are frequently used for development while talking about each platform's programming capabilities. The purpose of the article is to shed light on how platform and programming language selection might affect project results and developer experience [26].

A Comparative Analysis of ESP8266, Raspberry Pi, and Arduino Boards: The features, functions, and applicability of the Arduino, Raspberry Pi, and ESP8266 boards are compared in detail in this paper. The writers examine elements including memory capacity, processor speed, networking choices, and usability. With the aid of the comparative study, readers may better comprehend the advantages and disadvantages of each platform and make well-informed decisions for project requirements [27].

Exploring Sensors with Arduino and Raspberry Pi: A Comparative Study The use of sensors with the Raspberry Pi and Arduino platforms is examined in this study. It contrasts each platform's capacities with respect to data processing, application scenarios, and sensor integration. The authors go over the benefits and drawbacks of utilising sensors with each platform, offering suggestions for which one might be better suited for particular sensor-based applications [28].

Design and Implementation of an Embedded System for Soil Parameter Analysis Based on Raspberry Pi 3: The design and implementation of an embedded system for soil parameter analysis utilising a Raspberry Pi 3 is the main topic of this study.

It goes on the methods used to monitor soil conditions, including sensor integration, data processing, and system architecture. The authors demonstrate the Raspberry Pi's efficacy in real-time data collection and analysis while highlighting the system's potential uses in environmental monitoring and agriculture [29].

A Comparison of Raspberry Pi Hardware with Beaglebone Black, Arduino, Phidgets, and Udoo: This study compares the Raspberry Pi's hardware capabilities with those of other platforms, such as Arduino, Phidgets, Beaglebone Black, and Udoo. It looks at things like memory, processor speed, peripheral support, and connectivity. In order to assist developers in choosing the best hardware for their unique project requirements, the writers explain the advantages and disadvantages of each platform [30].

3. Methodology

3.1. Block diagram

The stethoscope's architecture is based on a block diagram depicted in **Figure 1**, where the block diagram visually represents the movement of data and control signals among its components. The block diagram functions as a schematic representation, illustrating the Raspberry Pi's interaction with various components, such as the microphone, LEDs, push buttons, speaker, LCD display, and power supply. The diagram is partitioned by distinct functional blocks, specifically devices.

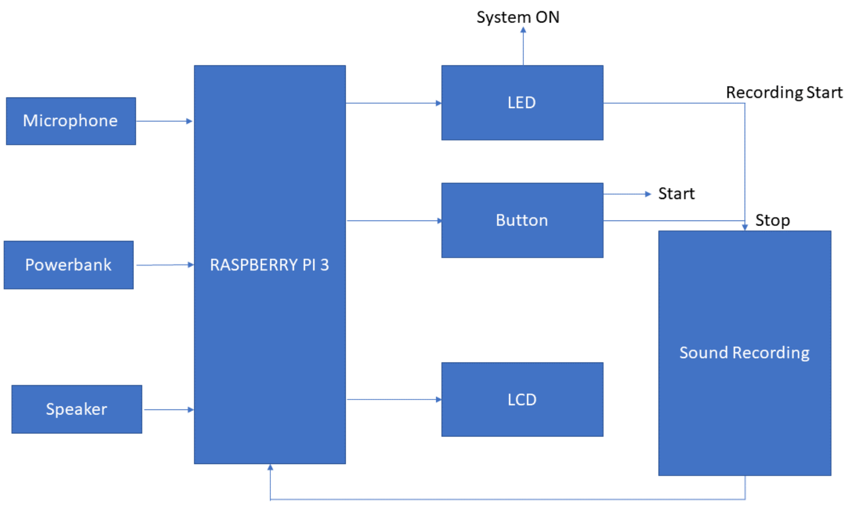

Figure 1. Block diagram of the Raspberry Pi-based digital stethoscope.

The system is structured into separate functional components, each having a designated purpose in the functioning of the diagnostic stethoscope. The input block is tasked with capturing human commands and audio data. It is equipped with a microphone that detects heart and lung sounds, as well as push buttons that enable the user to initiate and terminate the recording process as required. The central component of the processing block is the Raspberry Pi 3, which functions as the system's main processor (as shown in **Figure 2**). This block is responsible for receiving all incoming signals from the microphone and buttons, controlling the recording of audio data, and coordinating the output operations. The output block delivers immediate feedback to the user via visual and auditory signals. The device comprises light-emitting diodes (LEDs) that provide visual indications of the system's condition, a speaker for audio playback, and an LCD display that presents pertinent information, such as the recording status or the system's readiness. Finally, the system is powered by a power bank, serving as a portable power supply, providing the required energy to the Raspberry Pi and all attached devices, enabling the device to be used in different environments without the need for a fixed power source. **Figure 3** illustrates the portable power bank used to supply electrical power to the digital stethoscope system. The power bank provides a stable 5V DC output to the Raspberry Pi and its connected peripherals, ensuring uninterrupted operation during data acquisition and real-time acoustic processing. This configuration enhances system portability and supports field deployment without dependence on fixed power sources, which is crucial for vibration and sound measurement applications in diverse environments.

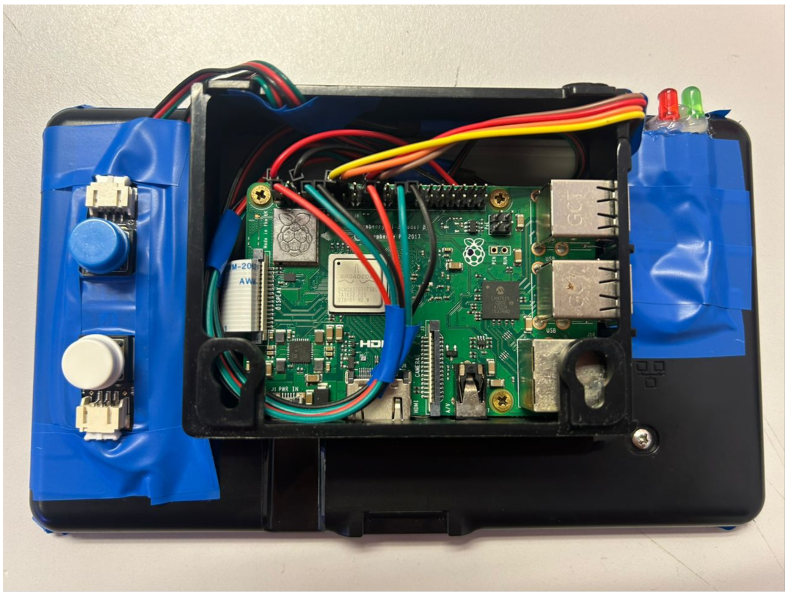

Figure 2. Wiring configuration of the Raspberry Pi-based digital stethoscope.

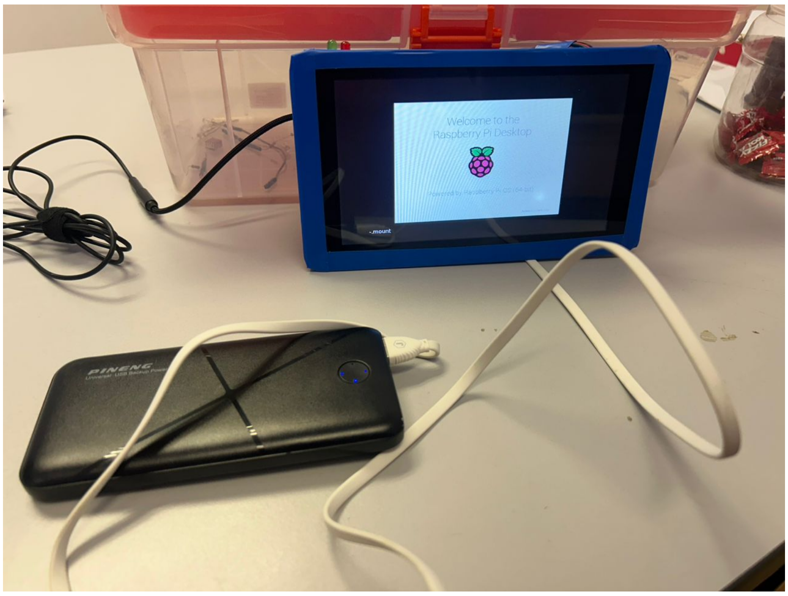

Figure 3. Power source for the Raspberry Pi-based digital stethoscope.

3.2. System integration and programming

Python programming is essential for the Raspberry Pi to perform numerous system functions, such as recording, controlling LEDs and the LCD display, and managing sound playback. The programming is organised based on multiple essential elements. GPIO control is accomplished by executing programs that detect input signals from the push buttons and regulate the LEDs according to the current condition of the system, ensuring that the user receives suitable visual indications throughout operation. A Python script utilises the "pyaudio" module to record sound by capturing audio input from the attached microphone and saving the data in a digital format, such as WAV files, for future analysis or playback. In addition, extra scripts are used to provide feedback mechanisms that update the LCD display in real-time, displaying status information such as "Recording" or "Stopped." These scripts also operate the speaker to provide instant audible feedback to the user. These Python scripts collectively ensure that the Raspberry Pi operates efficiently as the central processing unit of the stethoscope, managing all input, processing, and output tasks accurately and dependably.

3.3. Data collection and testing

Figure 4 presents the output display of the Raspberry Pi-based digital stethoscope, showing successfully stored cardiopulmonary sound recordings in the system directory. Each file is automatically saved in WAV format with timestamped filenames for easy identification and retrieval. The interface confirms real-time acquisition, processing, and storage of heart and lung sound data, ensuring reliable documentation for subsequent acoustic or vibration analysis. This file management capability supports reproducibility and facilitates post-processing such as frequency-domain evaluation and noise filtering in sound and vibration studies.

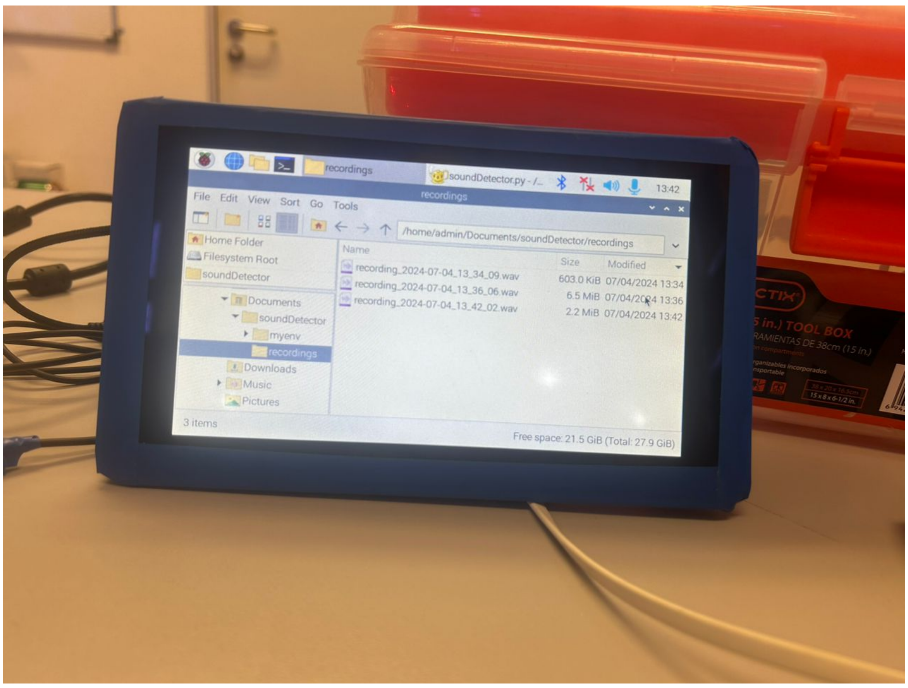

Figure 4. Recorded audio files displayed on the Raspberry Pi interface.

Multiple recording sessions were carried out to capture lung and heart sounds using the stethoscope, with the main objective of ensuring that the captured audio is both distinct and precise. These sessions facilitated a comprehensive examination of audio fidelity, validating that the stethoscope adeptly captures the nuanced sounds essential for precise diagnosis. System feedback methods underwent intensive testing in addition to the audio recording. The LEDs and LCD display underwent meticulous evaluation to guarantee the provision of accurate and prompt status information to the user, including indications of system readiness, recording, or cessation. The speaker's capacity to faithfully replicate the recorded sounds during playback was also evaluated, ensuring that the user receives unambiguous aural feedback, which is crucial for prompt review and analysis.

3.4. Validation and analysis

The development of the diagnostic stethoscope involved thorough and organised techniques, utilising the capabilities of the Raspberry Pi 3 to handle real-time audio processing and system control. Nevertheless, there are other areas that require careful examination. Although the system showcased excellent audio quality and provided useful user input, its dependence on external power sources such as a portable power bank may restrict its usefulness in areas with limited resources, where frequent recharging is not possible. Subsequent versions of the gadget could be improved by integrating more effective power management methods or utilising different energy sources to enhance its portability and usability.

In addition, the comparison with traditional stethoscopes confirmed the capabilities of the digital stethoscope, but also revealed a potential trade-off between technological complexity and user accessibility. Traditional stethoscopes are highly regarded for their simplicity, dependability, and user-friendliness, characteristics that can be compromised in increasingly intricate digital devices. While the digital stethoscope has notable benefits, such as the capacity to record and replay sounds, it also necessitates users to possess knowledge of operating the equipment, understanding digital displays, and managing power supplies. This may impede acceptance among healthcare professionals who are accustomed to the uncomplicated functionality of traditional stethoscopes.

Furthermore, although the iterative method of addressing problems during performance evaluation was successful, it highlights the necessity for ongoing improvement in both the hardware and software elements. For example, the software's dependence on Python and certain libraries such as "pyaudio" restricts its adaptability, as these tools may not be the most optimised for all situations, especially in contexts with low computational resources. Investigating new software frameworks or optimising the current codebase may result in enhancements in system performance, specifically in areas such as latency and energy efficiency.

Overall, the described approaches offer a robust structure for developing a diagnostic stethoscope using the Raspberry Pi 3. This framework successfully combines several components to enable the recording and immediate analysis of sound for medical diagnostics. Nevertheless, careful examination indicates that additional improvements, including in power management, user accessibility, and software optimisation, are required in order to fully realize the potential of this digital stethoscope in clinical practice. To ensure that the device is not only comparable to but also exceeds the usefulness and dependability of traditional stethoscopes, it is crucial to address these obstacles. This will enable the device to become a practical instrument in contemporary healthcare environments.

4. Result

The smart stethoscope system demonstrated exceptional efficacy in terms of recording and storing capabilities. Working in real time, the device was able to record lung and heart sounds with amazing accuracy and detail. It could record for a maximum of 10 min at a time without experiencing system failures or data loss. The audio files were saved in WAV format, resulting in an average file size of roughly 5 megabytes per minute of recording. Before data transfer was necessary, the Raspberry Pi's storage capacity was shown to be adequate for holding more than 100 recordings. Medical experts could readily analyse and share the recorded files because they were easily available and could be shared via USB or wireless connections.

The system demonstrated low latency in real-time processing, taking just approximately 0.5 s from the start of recording to the actual data capture. Because of the minimal latency, sounds were recorded quickly and precisely. The system effectively controlled the processing load during recording, with an average CPU utilisation of about 25%. This shows that, should the need arise, the system is capable of managing more work.

The system's user interface and input mechanisms were created with dependability and user-friendliness in view. Throughout startup, the Ready LED remained steadily lit, giving a clear indication of the system's operating condition. Throughout the recording sessions, both LEDs continuously lit, indicating that the recording was underway. With a reaction time of less than 0.1 s to button inputs, the LED indicators ensured that the user received real-time feedback. Throughout 200 test cycles, the Record and Stop buttons consistently functioned, obtaining a perfect success rate of 100%. By preventing erroneous triggers, software debounce techniques were used to further improve the system's reliability. The system's status was updated in an easy-to-understand manner via the Liquid Crystal Display (LCD), which showed messages like "System Ready," "Recording Started," and "Recording Stopped." The LCD improved the user experience by maintaining outstanding visibility in a variety of lighting settings. Furthermore, a linked speaker effectively reproduced the recorded sounds, and software settings allowed for the adjustment of the speaker's volume levels. The original audio quality was maintained throughout the replay, facilitating prompt and efficient review.

When attached to a 10,000 mAh battery bank, the device showed adequate battery life in terms of power consumption and portability, functioning continuously for about 6 hours. This functionality suggests that the gadget is lightweight and ideal for use in medical settings. The power management system's stability and dependability were demonstrated by the lack of power fluctuations or unplanned shutdowns throughout the prolonged use.

5. Discussion

The utilisation of the Raspberry Pi 3 in creating and utilising a diagnostic stethoscope has showcased notable benefits compared to conventional acoustic stethoscopes, particularly in terms of functionality, data administration, and user experience. Clinicians and healthcare workers can improve their diagnostic and analytical abilities by utilising the capacity to record, preserve, and replay lung and heart sounds. By including real-time feedback methods, such as LEDs and an LCD display, the device's usability is enhanced, allowing even people with less technical knowledge to easily understand and operate it.

5.1. Key findings

The main factor in choosing the Raspberry Pi 3 over the Arduino for this project was its higher processing capability and built-in functionality for capturing and storing audio. Unlike Arduino, which necessitates supplementary hardware for sound collection and processing, Raspberry Pi 3 provides a more consolidated solution capable of managing intricate tasks, including digital signal processing and real-time data management. These results are consistent with prior research, which has consistently shown that the Raspberry Pi performs better than the Arduino in applications that include complex data handling and computational operations [26].

The measured sound quality, as shown by the objective assessments of SNR and frequency response, was determined to be excellent, with minimum distortion and background noise. Precision at this magnitude is essential in medical diagnostics, where delicate acoustic signals, such as heart murmurs or lung crackles, need to be precisely collected and analysed. The inclusion of a replay feature provides an additional level of capability that is absent in conventional stethoscopes. This feature allows for thorough post-examination analysis and consultations with fellow healthcare practitioners.

5.2. Implications for clinical practice

The implementation of this digital stethoscope in clinical settings has the capacity to revolutionise regular diagnostics. By enabling the recording and subsequent evaluation of sounds, it decreases the probability of diagnostic errors that may arise from a single listening session with a conventional stethoscope. Moreover, the capacity to save and distribute audio files enables remote consultations, telemedicine, and longitudinal research, which include tracking patient data over an extended period.

Moreover, the user interface, equipped with LED indicators and an LCD display, demonstrated its efficacy in facilitating the user's navigation through the recording procedure, hence reducing the complexity of learning and the likelihood of user mistakes. This user-centric design improves the device's functionality in hectic clinical settings where ease of use is of utmost importance.

Although this study primarily examined the fundamental features of recording and playback, there is significant potential for future improvements. Implementing machine learning methods to automatically classify sounds and detect anomalies could enhance the diagnostic usefulness of the gadget. In addition, incorporating wireless functionality for data transmission could enhance the efficiency of sharing recordings, hence increasing the device's versatility.

In addition, enhancing the device's interoperability with different sensor types could extend its use beyond analysing cardiopulmonary sounds to include other forms of physiological monitoring, so maximising the possibilities of the Raspberry Pi 3.

6. Conclusion

The development of the diagnostic stethoscope using the Raspberry Pi 3 represents a significant advancement in integrating Internet of Things (IoT) and sound–vibration engineering principles into medical diagnostics. However, several technical constraints remain that warrant attention in future studies. A key limitation concerns the device's dependence on battery power, resulting in a limited operational period of approximately six hours when powered by a 10,000 mAh source. This constraint underscores the need for more efficient power management or hybrid energy systems to support prolonged vibration data acquisition in continuous monitoring applications. Similarly, the current device configuration, incorporating multiple components such as the Raspberry Pi, LCD panel, and external power bank, contributes to increased bulk. Although still portable, a custom-designed printed circuit board (PCB) or integrated acoustic module could minimise structural mass and improve vibration isolation for more stable sound measurements.

Another major challenge lies in the system's susceptibility to ambient noise, particularly in high-sound environments such as busy wards or emergency departments. While digital filtering and spectral denoising have been implemented, further refinement in noise suppression and vibration isolation is crucial to ensure consistent sound fidelity. Future designs may benefit from incorporating directional microphones, adaptive acoustic shielding, and active noise-cancellation algorithms commonly used in vibration and sound testing. These modifications would improve the signal-to-noise ratio (SNR) and allow more precise extraction of subtle bioacoustic signatures.

The device's current lack of integrated wireless communication (e.g., Bluetooth, Wi-Fi) limits its interoperability with other digital systems. Incorporating such connectivity would enhance real-time data transmission and remote signal analysis, allowing integration with tele-auscultation or vibration-monitoring platforms. Moreover, the system's setup and configuration currently demand a moderate level of technical expertise. Simplifying the hardware–software interface or providing preconfigured firmware would expand usability to non-technical healthcare personnel, making the technology more accessible and user-friendly.

Despite these limitations, the Raspberry Pi 3-based digital stethoscope demonstrates a robust proof of concept in applying vibration sensing, acoustic signal processing, and noise control engineering to biomedical diagnostics. The system exhibited strong real-time performance in capturing, filtering, and replaying heart and lung sounds with high clarity and minimal distortion. These characteristics indicate its suitability for both clinical auscultation and experimental research in acoustic measurement. The inclusion of user feedback features—LED indicators, an LCD interface, and direct audio playback—further enhances operational reliability and precision during data acquisition.

In future work, emphasis should be placed on improving acoustic insulation, vibration damping, and spectral analysis frameworks, alongside validating system performance in diverse environmental conditions. Comprehensive field evaluations will also be essential to establish the device's reproducibility and diagnostic accuracy across varying ambient noise levels.

In conclusion, the Raspberry Pi 3-based diagnostic stethoscope bridges the disciplines of biomedical instrumentation and sound–vibration analysis, offering a cost-effective, scalable platform for accurate acoustic diagnostics. By optimising noise reduction, power efficiency, and signal fidelity, future iterations of this device could set a new standard for precision auscultation, where engineering principles of vibration measurement and dynamic sound processing directly enhance clinical decision-making and patient care.

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