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AUTOMATED SYSTEM FOR BIOMETRIC HEART ANALYSIS: DEVELOPMENT, TECHNICAL ASPECTS, AND PROSPECTS

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Abstract. *This article presents the development and implementation of an automated system for biometric heart analysis designed as a portable electrocardiograph. The study highlights the device's functional principles, focusing on the processing of bioelectrical signals of the heart and their visualization. The system operates through collecting, filtering, and analyzing signals, enabling real-time diagnostics. The structural design ensures portability and ergonomic use, while the software supports reliable data transmission for further evaluation. The results confirm the system's effectiveness in cardiovascular diagnostics, with potential applications in mobile healthcare. Future improvements include integrating artificial intelligence and expanding diagnostic capabilities.*

Key words: *Automated system, biometric dynamic signal, electrocardiogram (ECG), biosignals, monitoring, portable electrocardiograph.*

Introduction.

Cardiovascular diseases account for over 17.9 million deaths annually worldwide, making early diagnosis critical for reducing mortality and severe complications [1]. Traditional diagnostic methods, such as in-clinic electrocardiograms (ECGs), often require the patient's physical presence, which can be challenging for individuals with limited mobility or those in remote areas [2]. Advances in technology now offer portable solutions capable of continuous heart activity monitoring in non-clinical environments. This study aims to develop an automated system for biometric heart analysis—a portable electrocardiograph designed to capture, process, and transmit biosignals with high diagnostic accuracy. The proposed system meets the growing demand for accessible, efficient, and user-friendly cardiac monitoring solutions.

1.The principle of operation of the automated system

To implement the development of an automated system for biometric heart examination, based on the principle of recording bioelectrical heart signals generated during each cardiac cycle (Fig. 1). Signals will be recorded using three main electrodes, each of which performs a specific function. The left electrode is located on the fingers of the left hand, the right one is in contact with the fingers of the right hand, and the ground electrode ensures stability and accuracy of measurements.

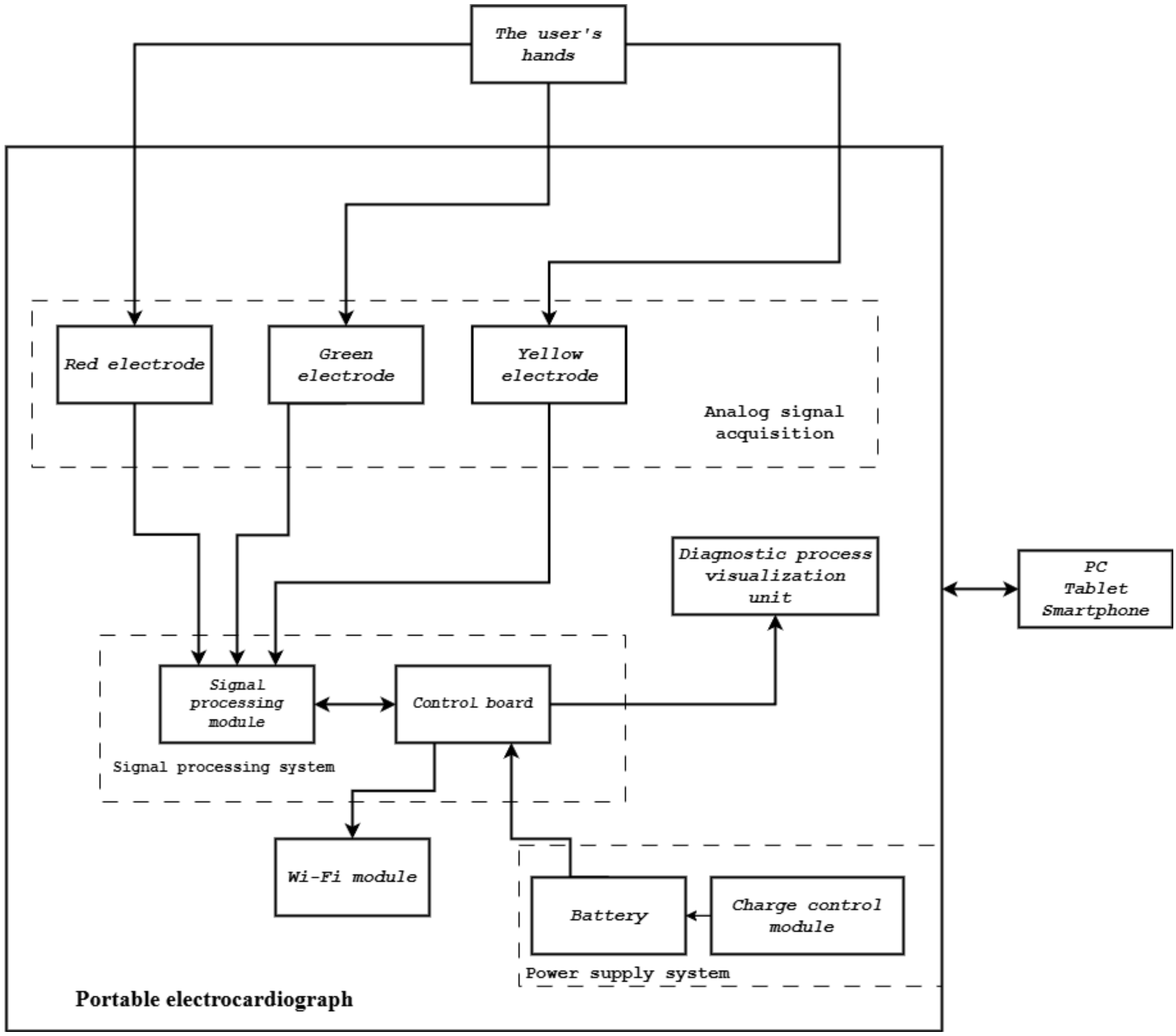

Fig. 1. Structural and functional diagram of the system for biometric heart analysis

Source: developed by the authors

The collected analog signals are transmitted to the AD8232 module, which performs initial noise filtering and signal amplification. Then the amplified signals are transmitted to the control unit based on the Arduino Uno + Wi-Fi R3 microcontroller for digital processing and data preparation. The processed data can be visualized on the built-in display and transmitted to external devices via Wi-Fi for further analysis.

The system consists of several interconnected functional blocks, each of which plays a specific role in signal acquisition, processing, and presentation:

Analog signal acquisition block: This block contains three electrodes responsible for detecting the heart's electrical activity. The red electrode records signals from the left side of the heart, the green electrode records signals from the right side, and the yellow electrode serves as a grounding mechanism to stabilize the measurement process.

Signal processing block: The AD8232 signal processing module filters and amplifies analog signals, minimizing noise and ensuring clarity. The processed signals are then digitized by a microcontroller for further use.

Visualization block: The system displays the processed data as an electrocardiogram (ECG) on a TFT screen. In addition, it supports wireless data transmission to external devices such as personal computers, tablets, or smartphones, which allows remote access to the data.

Wireless Data Transmission Unit: The built-in Wi-Fi module ensures the uninterrupted transmission of recorded signals to remote devices in real time, facilitating remote cardiac monitoring by healthcare professionals.

Power Supply: The system has a rechargeable battery, ensuring autonomous operation. The charge control module prevents overcharging or over-discharging, guaranteeing the reliable and long-lasting operation of the device.

The surgical procedure begins when the user touches the designated electrodes. Analog signals representing the heart's electrical activity are collected, filtered, and amplified by the signal processing module. The processed signals are then visualized as an ECG graph on the device display or transmitted to an external server or device for further diagnostic interpretation.

This portable electrocardiograph is designed to accurately monitor cardiac activity in real-time, offering significant benefits in clinical and non-clinical settings. Integrating advanced components and wireless capabilities into the system allows it to be used for the early detection of cardiac pathologies and continuous monitoring of patients with chronic diseases.

2. The principle of operation of the automated system

The developed system, based on the studied ECG, begins when the user places his fingers on the designated electrodes. This initiates the collection of biosignals, which represent the electrical activity of the heart. The obtained data is transmitted to the signal processing module, where noise filtering and signal amplification are performed. Then the processed signal is sent to the control board, which prepares the data for visualization and transmission. The final result is displayed on the device screen as an electrocardiogram (ECG) graph or transmitted to an external device for further analysis. The system is housed in a compact case made of lightweight material, which ensures ease of use and protection against mechanical damage. Designed for autonomous operation, the device provides uninterrupted data transmission to a remote server, which allows medical professionals to analyze the results and provide timely medical advice. Biometric signals represent a highly promising area of research with broad applications extending beyond traditional medical diagnostics [3-5]. While their use in monitoring and diagnosing physiological conditions, such as cardiac activity, has been extensively explored, these signals also hold significant potential for personal identification and authentication. The unique patterns of biometric signals, such as those generated by the heart, provide a reliable and secure basis for distinguishing individuals, offering innovative solutions in fields such as cybersecurity, access control, and personalized medicine. This dual-purpose functionality underscores the importance of further research and development in this domain, as it has the potential to revolutionize both healthcare and identity verification systems.

3. Algorithm of the automated system for biometric heart examination

The operation of the portable electrocardiograph begins with powering on the device, after which the automated system follows a sequential workflow (Fig.2). Initially, the device initializes all components, performing a functionality check of its modules.

An appropriate message is displayed on the screen if any malfunctions are detected. The system also verifies the correct placement of electrodes to ensure reliable contact with the user's skin. If the electrodes are improperly positioned, the device notifies the user to adjust them.

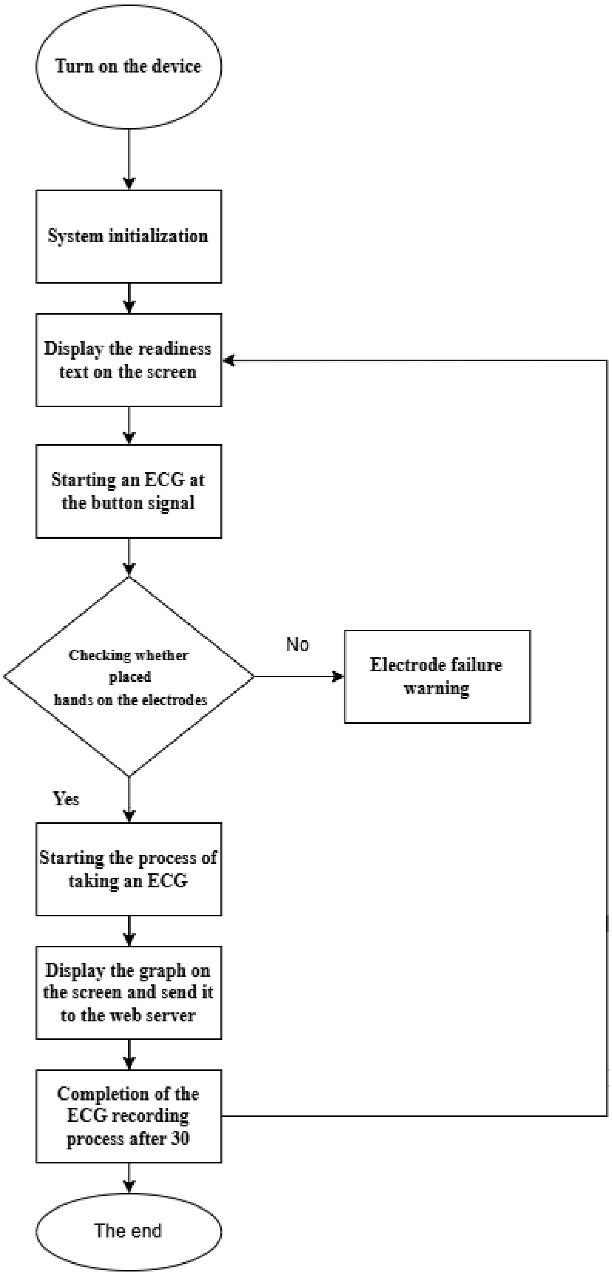

Fig. 2. Algorithm of the automated system for biometric heart examination

Source: developed by the authors

Once proper contact is confirmed, the system acquires the heart's bioelectric signals in real-time. These signals undergo filtering and processing to remove noise components. The AD8232 module plays a crucial role in this process by eliminating artifacts. Subsequently, the microcontroller analyzes the signals, which performs preliminary interpretation of the acquired data.

An electrocardiogram (ECG) graph is displayed on the device's screen, allowing the user to assess the heart's activity. Simultaneously, the results are transmitted via

Wi-Fi to a server, where they can be accessed for further analysis by a healthcare professional. After 30 seconds of recording, the system automatically transitions into standby mode to minimize energy consumption and ensure the device's operational efficiency. The algorithm's logic is structured and implemented in the microcontroller's software code. This ensures the stability and high accuracy of the portable electrocardiograph, which is a critical factor in its effectiveness for clinical use.

The software, developed in Arduino IDE, supports the following functions: initialization of modules and self-diagnostics, real-time data acquisition from the AD8232 module, noise filtering and digital signal processing, ECG visualization on the TFT display, wireless data transmission to a server via Wi-Fi.

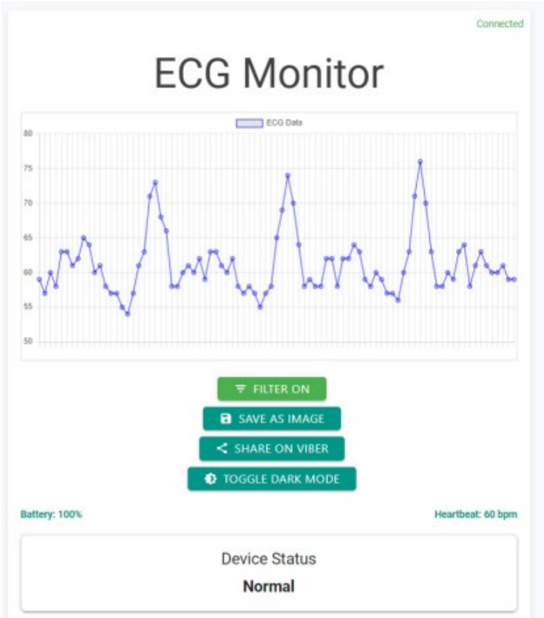

Fig. 3. Software interest of the automated heart examination system

Source: developed by the authors

The intuitive user interface displays clear messages and graphical data to minimize user errors. Algorithms ensure proper electrode placement and notify users of malfunctions, enhancing the device's reliability and accessibility.

4. Development and Technical Aspects of the System

The device's component base includes an AD8232 module, which enables the recording of biosignals with minimal noise levels, featuring a frequency bandwidth of 0.5–40 Hz and a signal gain of up to 100x. The Arduino Uno with Wi-Fi R3 is the control board, equipped with an ATmega328P microcontroller operating at 16 MHz and providing sufficient computational capacity for signal processing and real-time data transmission (Fig.4). The Wi-Fi module supports IEEE 802.11 b/g/n standards, enabling reliable wireless connectivity.

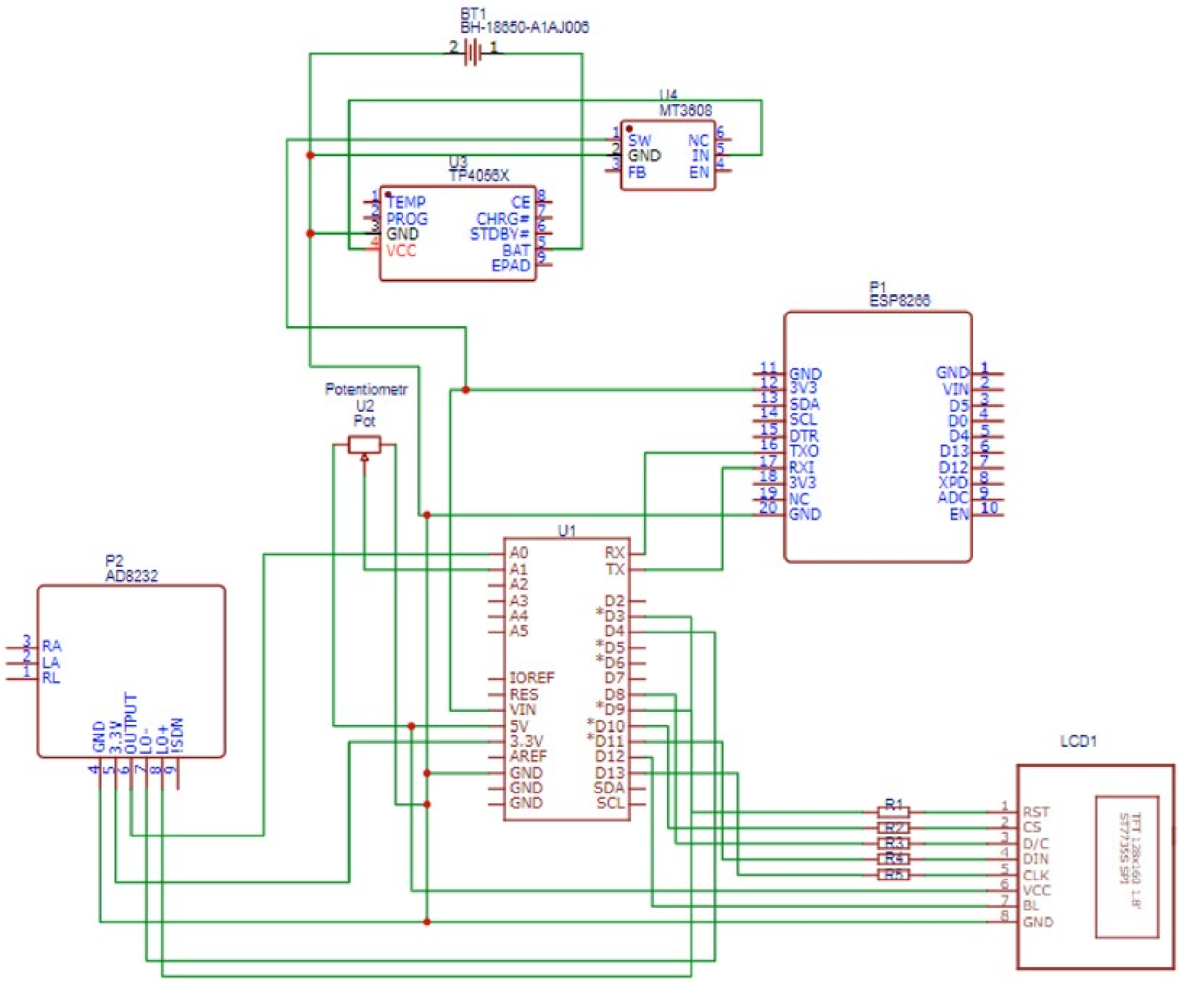

Fig. 4. Connecting the automated system elements

Source: developed by the authors

A TFT display MSP1804, a compact 1.8-inch color screen with a resolution of 128x160 px and an SPI interface, ensures clear visualization of the ECG graph. Power is supplied by a 3.7V lithium-ion rechargeable battery with a capacity of 1200 mAh, providing up to 8 hours of continuous operation. Charging is performed via a micro-USB interface, and the integrated charge controller protects the battery against overvoltage and overheating. The electrical circuit is optimized for low power consumption, with the overall system drawing an average of 80 mA during operation. The compact design minimizes the use of components, reducing costs and physical dimensions without compromising functionality. The device's housing is constructed from ABS plastic, which is lightweight, durable, and resistant to mechanical stress. Its ergonomic design features dimensions of 120x60x20 mm and a weight of approximately 150 grams, allowing users to hold the device during measurements comfortably. This integration of high-quality components with carefully selected technical parameters ensures that the portable electrocardiograph delivers reliable performance, user-friendliness, and durability, making it suitable for clinical and personal health monitoring applications.

5. Modeling automated systems

A 3D visualization of the automated system for biometric heart research was presented in Fig. 5. The development was carried out using the SolidWorks 2020 computer-aided design (CAD) software with the SolidWorks Visualize 2020 module for enhanced rendering and visualization. Figure left illustrates the structural components of the system's blocks.

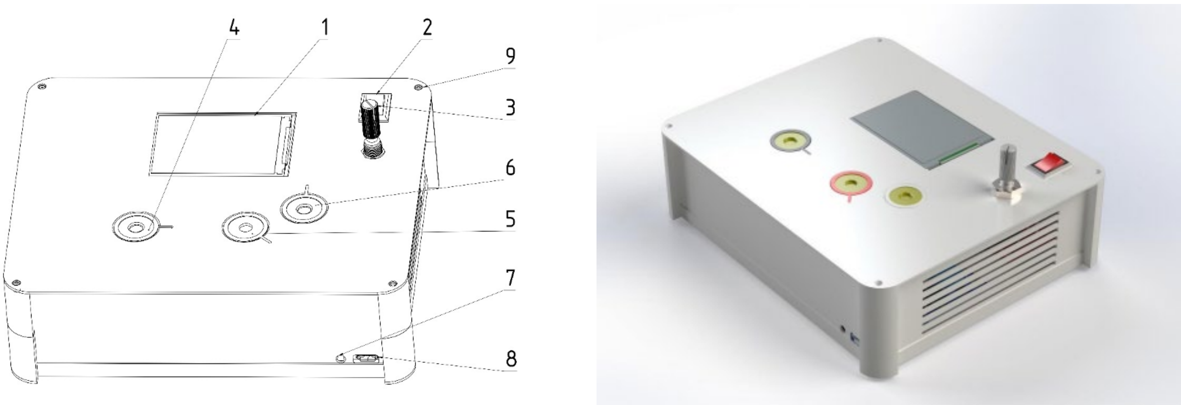

Fig. 5. General view of the system:

1 - Display, 2 - Power button, 3 - Potentiometer, 4 - Left electrode, 5 - Right electrode, 6 - Grounding electrode, 7 - LED indicator, 8 - Type-C power connector, 9 - Hole for M3x0.5 screw

Source: developed by the authors

A 3D model of the device housing was created to optimize the design. The modeling process in SolidWorks enabled achieving maximum compactness and functionality. The housing is compact, making the device convenient for transportation. The placement of electrodes and buttons was designed to ensure ergonomic use. Additionally, the housing is made of durable, scratch- and impact-resistant plastic. The construction is designed to allow for quick replacement of components, simplifying device maintenance. The housing is lightweight and has a pleasant tactile feel thanks to modern materials. This thoughtful design and development process ensures the system's reliability, usability, and suitability for practical biomedical applications.

Summary and conclusion

The proposed automated system for biometric heart analysis successfully combines compact hardware, reliable software, and user-friendly design to address the growing need for accessible cardiac diagnostics. By ensuring portability, accuracy, and remote monitoring capabilities, the system represents a valuable contribution to modern healthcare technologies. Further advancements, including AI integration and expanded diagnostic functions, will enhance its applicability in diverse medical settings.

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Анотація. *У статті представлено розробку та впровадження автоматизованої системи біометричного аналізу серця у вигляді портативного електрокардіографа. Дослідження висвітлює принципи роботи пристрою, зосереджуючись на обробці біоелектричних сигналів серця та їх візуалізації. Система працює шляхом збору, фільтрації та аналізу сигналів, що дозволяє проводити діагностику в реальному часі. Конструкція забезпечує портативність і ергономічне використання, а програмне забезпечення підтримує надійну передачу даних для подальшої оцінки. Результати підтверджують ефективність системи в діагностиці серцево-судинної системи з можливим застосуванням у мобільній медицині. Майбутні вдосконалення включають інтеграцію штучного інтелекту та розширення діагностичних можливостей.*

Ключові слова: *автоматизована система, біометричний динамічний сигнал, електрокардіограма (ЕКГ), біосигнали, моніторинг, портативний електрокардіограф.*

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