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AN INTELLIGENT SYSTEM BASED ON ARDUINO FOR BLOOD LEAKAGE DETECTION

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ABSTRACT

Chronic kidney disease (CKD) is a global health issue, requiring renal replacement therapies like haemodialysis for patient survival. However, the procedure carries risks, particularly blood leakage, which can lead to severe complications. This study presents the design and implementation of an intelligent system that continuously monitors blood leakage during haemodialysis using an Arduino Nano-based platform. The main components include: a photoelectric sensor, HC-05 Bluetooth module, and piezoelectric buzzer, all integrated to detect blood loss and trigger alarms. The photoelectric sensor identifies blood leakage by sensing interruptions in an infrared beam, with data transmitted wirelessly to a mobile application. When leakage is detected, visual and auditory alerts are generated, allowing for immediate intervention. This system highlights the potential for IoT-enabled medical monitoring to improve the quality of life for haemodialysis patients through real-time data transmission and remote supervision.

KEYWORDS: blood leakage detection, Arduino, haemodialysis, chronic kidney disease, IoT

1. Introduction

Chronic kidney disease affects millions of people globally, and renal replacement therapy, as well as haemodialysis, is crucial for patient survival. In this context, effective monitoring of haemodialysis patients becomes essential to prevent complications and increase their quality of life [1-6]. The number of deaths caused by chronic kidney disease is globally prevalent [7], regardless of ethnicity, race, or gender. Chronic kidney disease is a serious and progressive condition that affects kidney function over the long term. It can result from a variety of factors, such as hypertension, diabetes, glomerulonephritis, or unidentified causes. (Figure 1) [8].

Haemodialysis is an essential medical procedure for patients with chronic or acute kidney failure who can no longer naturally eliminate toxins and excess fluids from the body. This technology has revolutionized kidney disease treatment, offering patients a new chance at life and an improved quality of life [9-12].

Haemodialysis involves extracting blood from the patient's body, filtering it through a dialysis machine to remove toxins and excess fluids, and then returning the purified blood to the body. Any interruptions, such as blood leakage, can lead to significant complications, including hypotension, anaemia, or infection [13-17]. Traditional methods of monitoring, which rely heavily on manual observation, are insufficient for ensuring rapid detection and response [18]. Here, Arduino-based systems provide a modern, automated solution. Arduino microcontrollers have become indispensable in developing intelligent systems for healthcare applications due to their versatility, affordability, and ease of use. In the context of haemodialysis, these microcontrollers offer a reliable platform for integrating multiple sensors, actuators, and communication modules, enabling real-time monitoring and efficient management of critical parameters [19-23].

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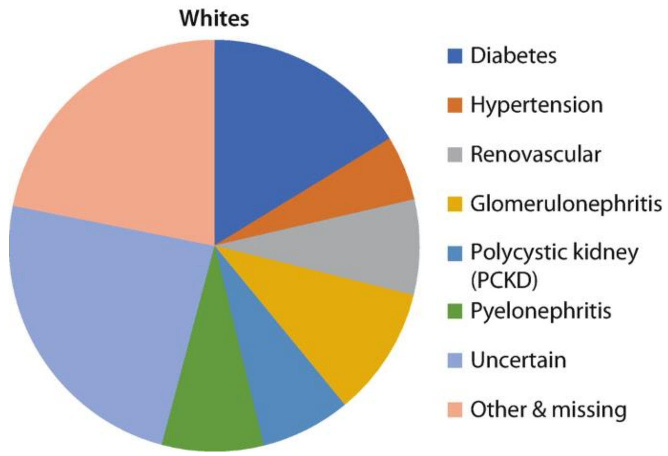

Fig. 1. *The causes of chronic kidney disease* [8]

2. Experimental procedure

The research consists of implementing an intelligent system for monitoring blood loss during haemodialysis therapy. The components used for this study, as shown in Figure 2, include the Arduino Nano board, Bluetooth module, photoelectric sensor, buzzer, and stop button. Once all elements are connected, the Arduino IDE platform and the code will be used to program the proposed system. There are two main components involved in the alarm system: the detection unit and the receiving unit. The sensing unit is responsible for detecting alarm conditions, while the receiving unit receives this information and can take appropriate action.

The detection unit is represented by the Arduino Nano board, together with the photoelectric sensor. The receiving unit is represented by the HC-05 Bluetooth module connected to the Arduino board and the mobile phone. This unit receives information from the sensing unit. The photoelectric sensor records the amount of blood loss, and the microcontroller analyse the received recording. The Arduino board to perform the calculations send the data to the buzzer and Bluetooth module. The mobile phone also being the receiving unit receive the transmitted data and the alarm will activate.

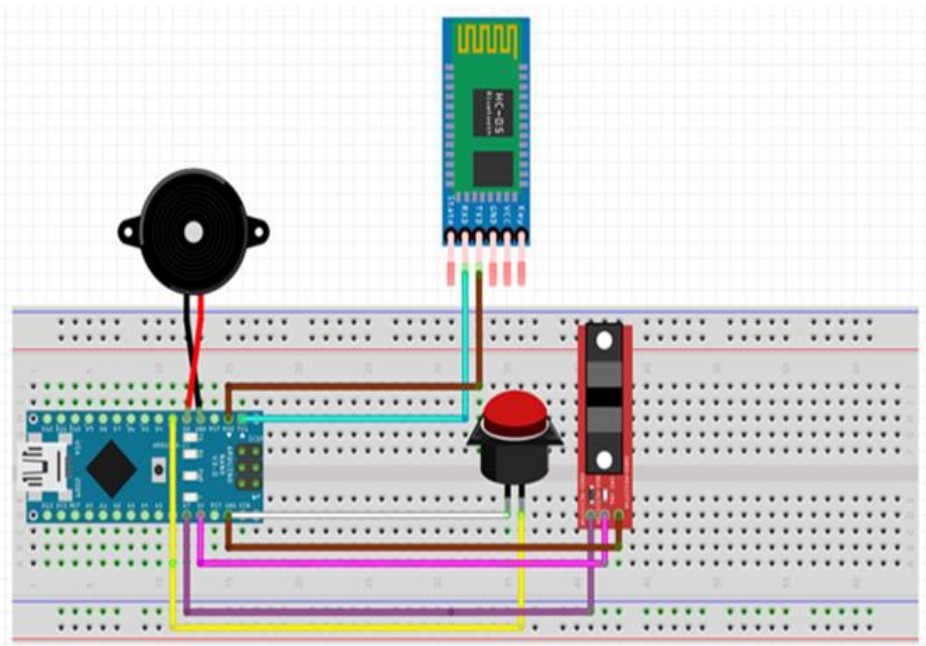

Fig. 2. *The system block diagram*

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The infrared photoelectric sensor has three pins: the supply pin (VCC), the ground pin (GND), and the output pin (OUT). The infrared photoelectric sensor is an optical coupling component, it is electrically isolated, divided into the emission part and the reception part. The principle is to convert input electrical signals into light, which causes the light emitting unit to emit infrared light. The receiving unit, the collector, receives the infrared light and will transform it into electrical signals, thus the receiving portion and the emitting portion of the photoelectric sensor become conductive.

The sensor model used is MOC7811 (Figure 3) for detecting blood leaks. When blood is present and interrupts the light beam, it is detected by the sensor, indicating the presence of blood. In cases of blood loss or a blockage in blood flow, the light beam will be obstructed, triggering warning signals.
The Arduino Nano (Figure 4) is a compact development board that is part of the diverse Arduino board range, which includes models such as Uno, Leonardo, Mega, and Micro. The microcontroller, composed of a central processing unit (CPU), memory, and various peripheral devices, performs the typical function of reading incoming data, performing calculations on this data, and controlling the environment based on the results.

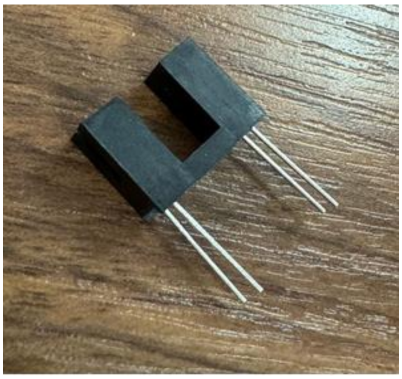
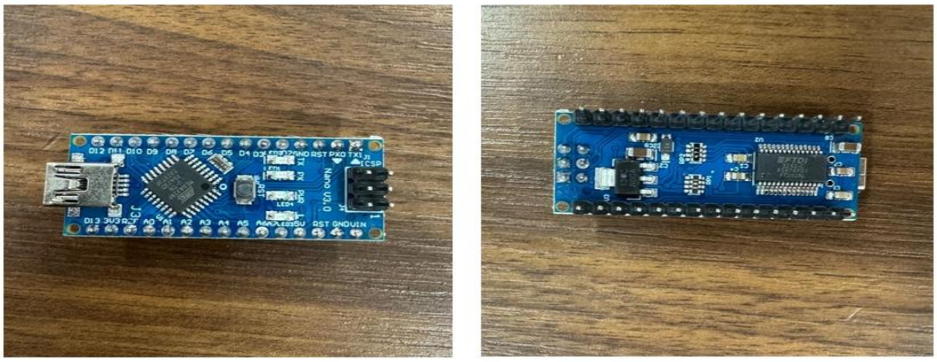


Fig. 3. *Connecting the sensor pins to the Microcontroller*



a b

Fig. 4. *Arduino Nano Microcontroller: a) front side; b) back side*

The HC-05 module (Figure 5) is designed for compatibility with Arduino microcontrollers, enabling wireless serial connections without the need for a direct line of sight between devices. Its cable-free operation, combined with low power consumption and minimal processing power requirements, makes it particularly suitable for healthcare devices. As a user-friendly Bluetooth SPP (Serial Port Protocol) module compliant with Bluetooth V2.0, the HC-05 offers a practical and efficient solution for a wide range of wireless applications.

a b

Fig. 5. *HC-05 Bluetooth Module: a) front side; b) back side*

Furthermore, Bluetooth is extremely relevant in the current context, where the large number of gadgets requires wireless solutions to avoid clutter and ensure efficient and convenient interfacing. The

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piezoelectric buzzer HND-2312 operates within a voltage range of 3-24V. The buzzer is used as an alarm that activates when the value read by the photoelectric sensor exceeds a certain threshold, indicating an issue. A warning sound is emitted until the alarm is manually deactivated.

Figure 6 illustrates the interface of the LEDS CONTROL APP, downloaded on a phone after the setup configurations are completed. The Bluetooth option is activated from the Android device settings, and in the LEDS CONTROL APP. The connection of the Arduino board with jumper wires is depicted in Figure 7. The connection of the photoelectric sensor on the breadboard is presented in Figure 8. The connection of the buzzer to the Arduino Nano system is presented in Figure 9. BT04-A is the Bluetooth module to which the connection is established, as shown in the Figure 10, managing serial communication to receive data from the Arduino. In Figure 11 is represented the connection of the stop button on the breadboard. In Figure 12 is illustrated the complete system configuration.

Fig. 6. *Interface of the LEDS CONTROL APP*

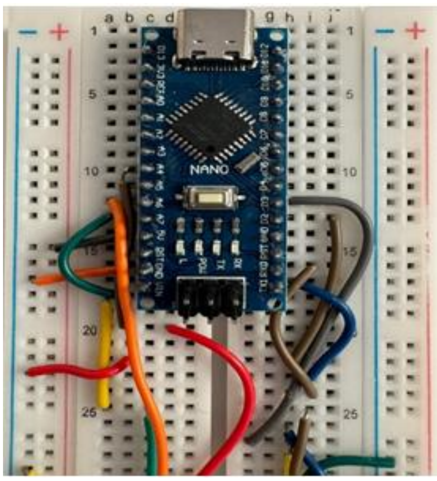

Fig. 7. *Connecting the Arduino board with jumper wires*

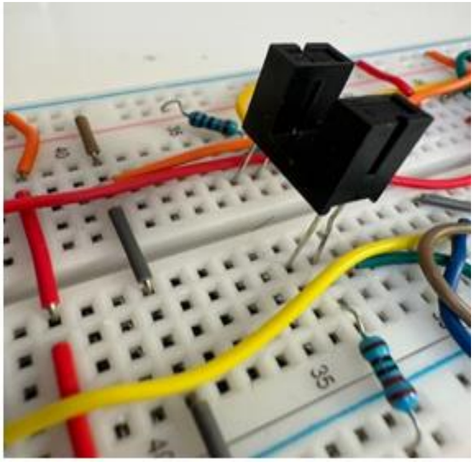

Fig. 8. *Connecting the photoelectric sensor on the breadboard*

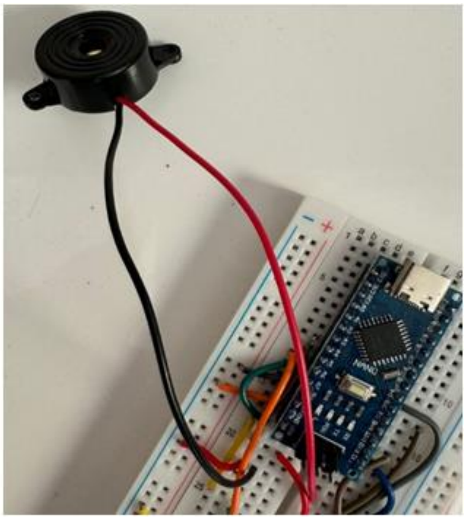

Fig. 9. *Connecting the buzzer*

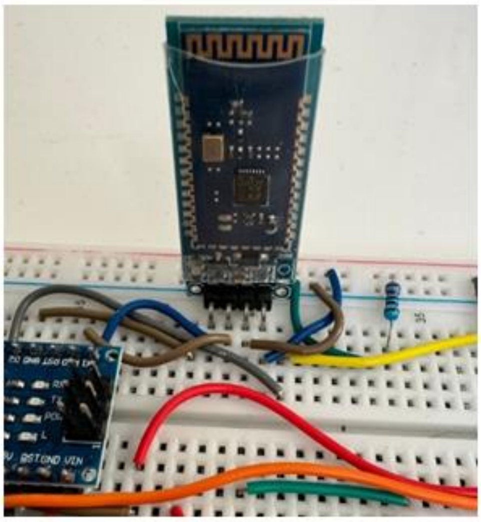

Fig. 10. *Connecting the Bluetooth module*

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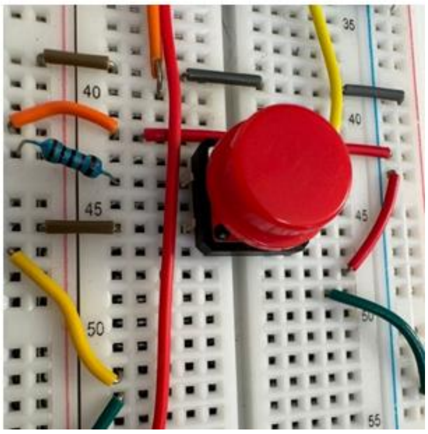

Fig. 11. *Connecting the stop button on the breadboard*

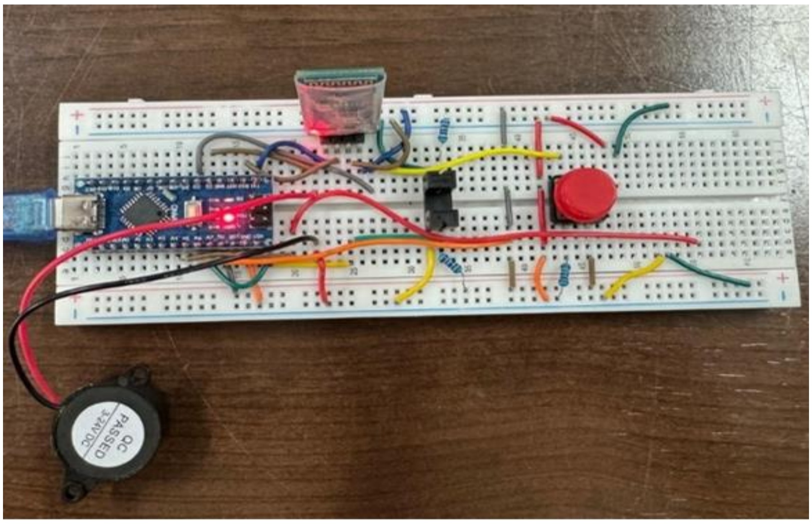

Fig. 12. *Complete system configuration*

3. Results and discussions

The primary components of the system as infrared photoelectric sensor, Arduino Nano microcontroller, HC-05 Bluetooth module, and buzzer work in tandem to monitor, detect, and alert in the event of blood leakage. The results indicate that the sensor achieved consistent readings in controlled environments, successfully detecting blood or blockage in the tubing. This is critical in haemodialysis, where even minor leaks can lead to significant health risks. The sensor's sensitivity threshold, set at a value of 1000, was adjusted for optimal balance between sensitivity and false positives, ensuring the system only triggered alarms in genuine cases of leakage.

When the value detected by the sensor exceeds a certain threshold (in this case, 1000), with the tube being red and at least 10 seconds having passed since the last alarm deactivation, the system will activate the alarm to notify the user (Figure 13), where the value displayed in the app is increased, and the alarm is triggered. On the mobile phone, the message displayed is "WARNING: LEAKAGE DETECTED!"

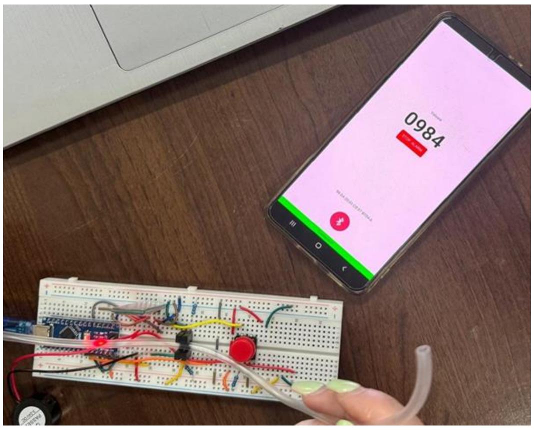

Fig. 12. *Initial value recorded by the sensor and tube placement*

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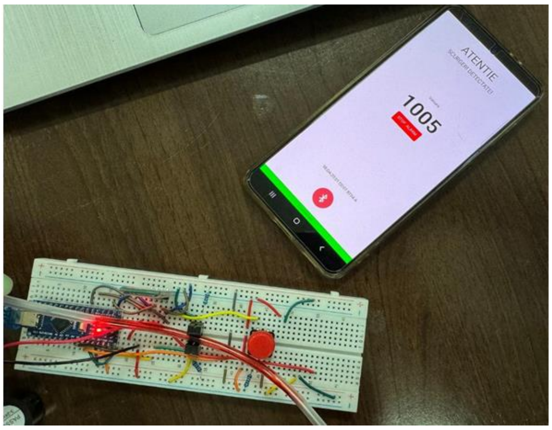

Fig. 13. *The red colour of the tube and the increased value activate the alarm*

4. Conclusions

The developed system demonstrated its ability to detect blood leakage through the use of an infrared photoelectric sensor connected to an Arduino Nano platform. Experimental tests showed that the sensor can accurately detect fluctuations in blood levels, triggering auditory and visual alarms in emergency situations.

During testing, the system demonstrated a prompt reaction time, with the buzzer activating within milliseconds of a detected leak, and a notification promptly sent to the mobile app. The 10-second delay before reactivation, designed to prevent continuous triggering, provided a balance between effective monitoring and alarm fatigue. When the threshold was reached, the tube's red colour was detected, visually and audibly signalling leakage to the user and mobile device.

Integrating the Bluetooth module into the system enabled real-time data transmission to the mobile application, LEDS CONTROL APP. This feature facilitates continuous remote monitoring of vital parameters, providing valuable information for quick intervention to both medical personnel and patients.

While the system performed well in simulated environments, further testing in clinical settings would provide additional insights into its real-world efficacy. Variability in tubing material or blood consistency could influence detection sensitivity, suggesting potential for further refinement in sensor calibration. Future enhancements may include the integration of advanced data analytics to predict leakage trends or the addition of Wi-Fi capability for broader connectivity. Additionally, including a battery backup and waterproofing measures could enhance its practicality in diverse clinical contexts.

The system's results, as well as the ease of use and reliability, highlight its potential for enhancing patient safety during haemodialysis.

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