Al-Khwarizmi Engineering Journal
ISSN (printed): 1818 – 1171, ISSN (online): 2312 – 0789
Vol. 20, No. 2, June, (2024), P P. 65- 72

Al-Khwarizmi Engineering Journal

GSM-enabled Wireless Patient Monitoring System Integrating Microcontroller for Managing Vital Signs

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(Received 20 November 2023; Accepted 23 May 2024; Published 1 June 2024)
https://doi.org/10.22153/kej.2024.05.001

Abstract

The primary focus of this project is developing a cutting-edge remote monitoring of patients device for use in an intensive care unit (ICU). The gadget is designed to capture and transmit vital health data from the patient's body, including oxygen saturation levels, heart rate, and temperatures. It is also capable of monitoring a pacemaker. Information is then sent to a remote location after that. The suggested system receives the patient's vital signs and uses them as input on a computer in the nursing room. This transmission is made possible via a transmitter-receiver system consisting of two Arduino kits connected to Bluetooth devices. If any anomalous numbers are discovered as the data is processed, the computer notifies the doctor via the Global System for Mobile Communications (GSM) and the doctor's mobile device. The primary objective of this device is to enable remote monitoring of a patient's medical parameters and prompt alerting of doctors who are situated in remote places of any concerning circumstances. The doctor's mobile device receives the collected values from the workstation. The entire system's structure is implemented using the Visual Basic programming dialect.

Keywords: *Arduino kit; medical sensors; Bluetooth; visual basic; GSM mobile; ICU*

1. Introduction

The subject of health monitoring has significantly advanced as a result of breakthroughs in the biological sciences and healthcare field [1]. Many applications have been studied in-depth over the years, including emergencies, home care, hospitals, military, and sports training [2]. In the field of health monitoring, the use of telemedicine has been crucial [3]. The Intensive Care Unit (ICU) network serves as an example of how this technology facilitates remote monitoring and diagnosis by enabling the electronic communication of a patient's medical information [4].

ICU networking entails using communication protocols to connect ICU PCs (clients) to a nursing room PC (server) across Local Area Networks (LANs), Metropolitan Area Networks (MANs), or other networks. These protocols are essential for smooth communication between computers that have different operating characteristics. This enables nursing personnel who are not physically present in the ICU to recognize problematic circumstances right once. The doctor's mobile device can then get these alerts immediately Abdirahman et.al. 2023 [5].
The Arduino platform, an open hardware board that has transformed robotics and control projects, was made possible by the advancement of microcontrollers. The open hardware

programming language (Arduino C) developed by Arduino is well-known for being easy to use, and it can be integrated with engineering languages such as MATLAB and Java. It is a well-liked option among microcontroller kinds because of its ease of use and programming capabilities Brocker et. al., 2023 [6]. Although there has been a great deal of research in this area, more work has to be done to demonstrate the medical benefits and economic feasibility of these solutions. Experts like G. Virone et al. 2023 have created concepts for innovative healthcare based on mobile sensor networks (WSNs), highlighting the potential for low-cost deployment of integrative sensors to enhance quality of care [7].

BK Harsha et al., 2023 [8] state that this technique provides women with protection during moments of insecurity, enabling people to venture forth with trust. In a threatening circumstance, a woman may use the tool's warning button to defend itself by utilizing analgesic inject in addition to the poison. The device incorporates an automatic painkiller injector, an alarm, a stun gun, an Arduino UNO, and technologies like GPS and GSM. A handheld actual time global surveillance device that enables controlled manipulation of a patient's heart rate and oxygen level in the blood was developed in 2023 by Dr. Deepak et al. With an operational area of 10–15 square meters, the gadget was built utilizing ZigBee connectivity and may monitor medical in customer houses [2]. A patient monitoring device was used in this research to keep an eye on the patient's condition in real time. The main element of the design of the system was an Arduino framework computer kit, which was utilized to send critical medical data from the patient's body over a Bluetooth network. The Intensive Care Unit (ICU), a computer with special capabilities dedicated with gathering and evaluating this critical information, received the data from a remote location. By avoiding problems with connection and data transmission dependability, this method offers a substitute to the traditional usage of networks of computers for the observation and exchange of significant data.

2. Proposed Work

The purpose of this study is to develop a wireless clinical monitoring device and can measure and track the vital indicators of a person, including body temperature, heart rate as indicated by blood pressure measurements, and the ability of cardiac pacemakers to regulate erratic heartbeats. This method is shown in Figure 1.

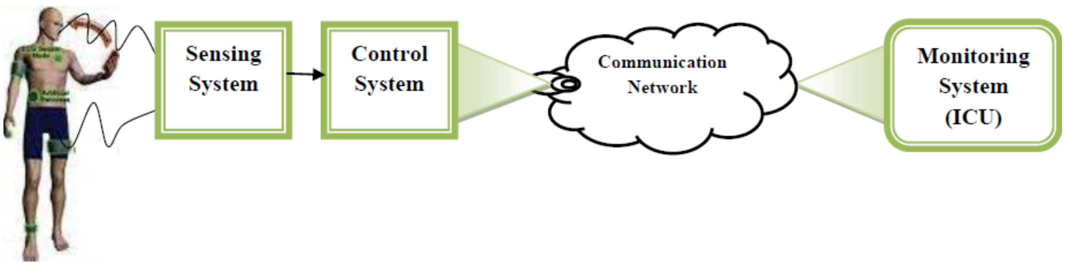

Fig. 1. General Block Diagram of The Monitoring System.

2.1 System Descriptions

The purpose of this research is to create a wireless medical monitoring system capable of tracking a person's health, involving their internal temperatures and heart rate, as determined by pressure measures, as well as pacemaker-assisted heart control. Figure 1 illustrates this strategy.

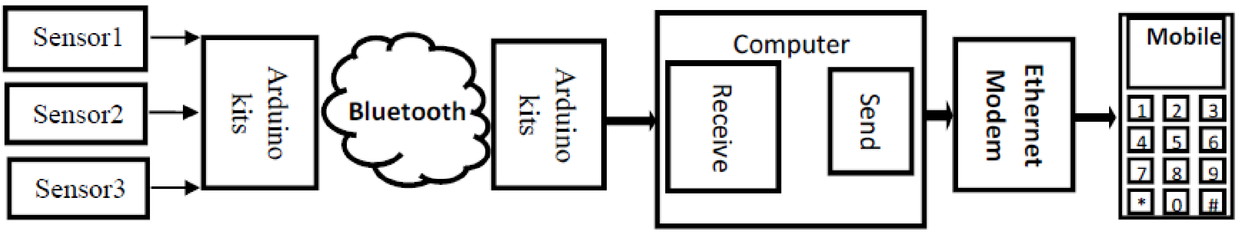

Fig. 2. Main Components of the Health Monitoring System.

2.1.1 Sensors

The ports on the Arduino were used to attach a variety of medical sensors to gather and track the patient's vital signs.

a) The temperature sensor is in charge of taking the patient's body temperature and determining how they are feeling right now.

b) The number of heartbeats per minute, or heart rate, is depicted in Figure 3, each heartbeat represents a representation of the heart's contraction and relaxation.

c) The pacemaker sensor is a tool for controlling irregular cardiac rhythms. The input/output leads, sensor circuit, and pulse generator are its three basic components. The electrodes known as the input/output leads are affixed to the heart chambers and serve to transfer signals from the heart to the pulse generator and the pacemaker's output back to the heart. The heart's input signal is processed by the sensor circuit, and the output—a square wave—is utilized by the pulse generator.

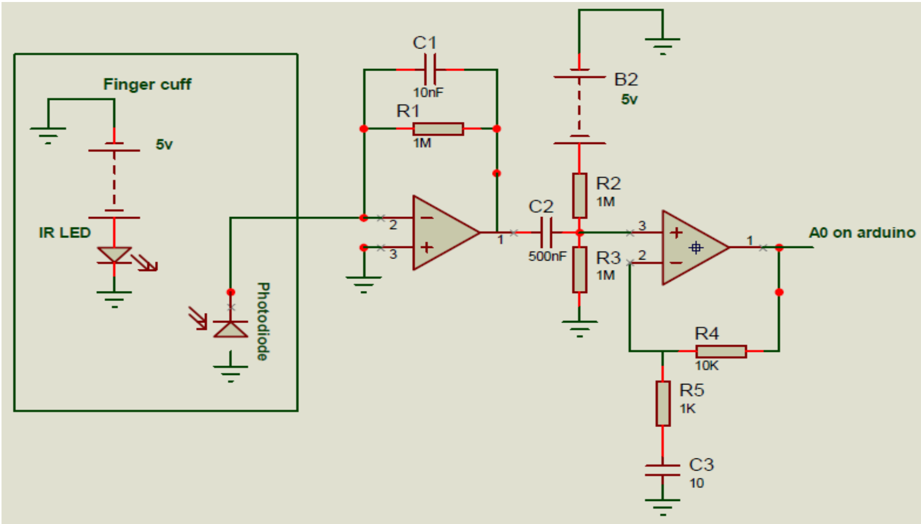

Fig. 3. Circuit diagram of Heart Rate [9].

The pulse generator, which functions as a preprogrammed microprocessor, is an essential part of the pacemaker. Through the sensing circuit, it receives input signals from the heart and responds by sending stimuli back to the heart. As shown in Figure 4, these stimuli are produced in line with the generator's pre-programmed schedule. It's important to remember that the pacemaker's pacing mode should only be used when required to avoid interfering with the heart's normal pacing process [10]. This guarantees that the pacemaker will only need to intervene when the heartbeat doesn't follow its typical pattern. When it comes to artificial pacing, the R wave represents the ventricular contraction that pumps blood into the main arteries. A single-chamber pacemaker works in the following order: RESET Timer, WAIT, and PACE. It is designed to regulate only one chamber of the heart. The pacemaker detects an R wave, counts down to 0.83 seconds—typically the gap between two R waves—and then goes into the RESET Timer state. During this waiting period, the gadget returns to the WAIT mode if another R wave is detected. If no more R waves are found during the wait, the pacemaker switches to the PACE mode and uses leads to stimulate the heart with electricity. By syncing with the heart's natural rhythm and only stimulating the pacemaker when a normal pulse is absent, this clever pacing mechanism makes sure that the pacemaker only acts when needed [8].

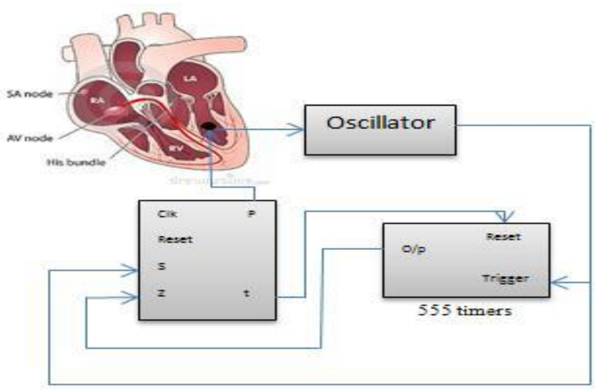

Fig. 4. Block diagram of Pacemaker.

Oximeter sensor: As seen in Figure 5, the oximeter sensor is a complex circuit made up of red and infrared LEDs that produce the corresponding wavelengths. These wavelengths are sent to a photodiode detector via the finger. A portion of these wavelengths are absorbed by blood vessels, especially arterioles, in the finger. The percentage of oxygen saturation, or the proportion of oxyhemoglobin and deoxyhemoglobin molecules to total hemoglobin molecules, determines the absorption ratio. One photodiode receives the wavelengths that are delivered by both LEDs. The received light then passes through some procedures. By producing pulses at the proper repetition rate, a timing circuit functions as a digital switch. Then, using an operational amplifier (op-amp) in a current-to-voltage converter circuit, these pulsed wavelengths—both red and infrared—are amplified and converted to voltage. A sample and hold circuit is used to separate the wavelengths separately because the pulsatile nature of arterial blood flow causes the wavelengths to be received in pulsed form. Control pulses for the sample and hold circuit are produced once again using the timing circuit. After that, a band-pass filter is used to filter out both high- and low-frequency noise from the output voltage. Ultimately, the voltage signal is cleaned and delivered to an Arduino, which uses Bluetooth to transform it into a digital signal that can be sent to a computer [11].

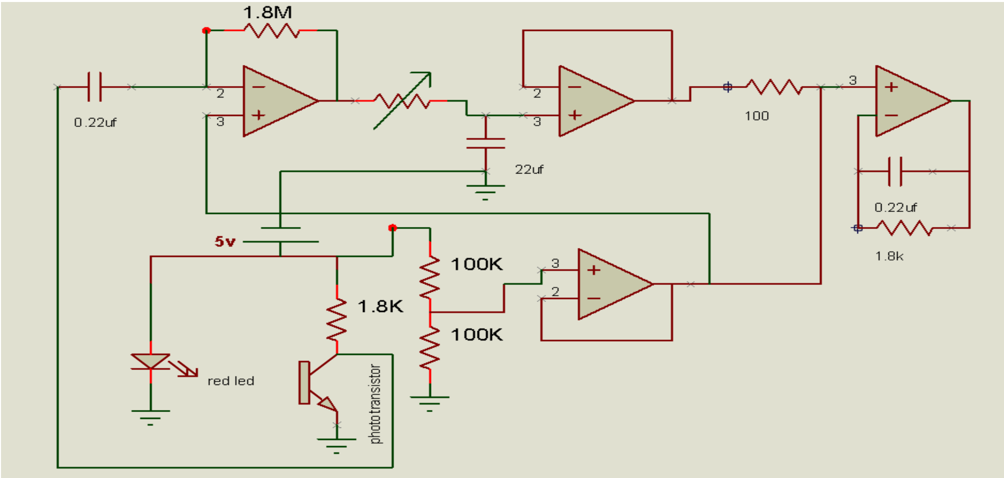

Fig. 5. Block diagram of Oximetry Sensor [11].

2.1.2 Connecting the Bluetooth with microcontroller kit (Arduino)

Using a particular communication protocol, Bluetooth is a wireless communication technology that allows data to be sent between devices across short distances. Bluetooth is employed in this work to enable the transfer of data from medical sensors to a computer. As shown in Figure 6, this is achieved by connecting the Bluetooth module—more precisely, the HC-05 Bluetooth module—to an Arduino Uno microcontroller kit on both ends. The Arduino kit and the Bluetooth module communicate wirelessly over the serial. To do this, mark two pins on the Arduino board to act as the serial port connection points between the Arduino and the Bluetooth shield. The Arduino's Tx pin is linked to the Bluetooth module's Tx (Transmit) pin, and the Arduino's Rx (Receive) pin is linked to the Bluetooth module's Tx pin. It is possible to enable data transfer using suitable Arduino software. As seen in Figure 7, the system's overall function is designed to monitor the patient's condition by effortlessly sending critical data from the sensors to the computer via this Bluetooth-enabled configuration.

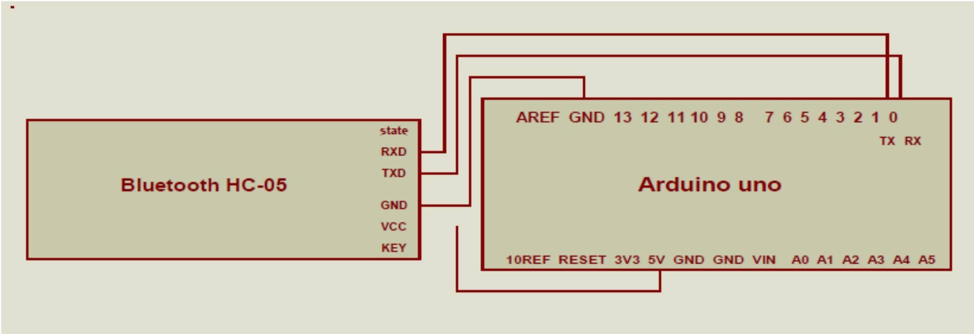

Fig. 6. Shows the block diagram of Bluetooth connection with microcontroller kit (Arduino).

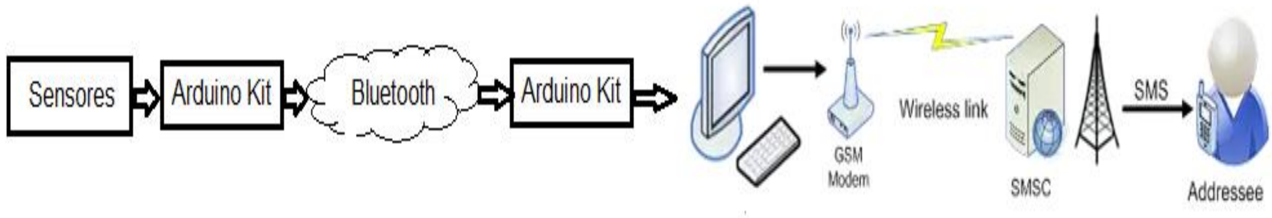

Fig. 7. The interface between personal computer and mobile phone through GSM modem.

2.1.3 Connecting Mobile Phone with Personal Computer

Advancements in mobile phone technology in recent times have made it possible to send Short Message Service (SMS) messages from a computer to a mobile phone using various programs. Within the framework of the monitoring system that is being described, this technology is activated either upon detection of a medical condition that is dangerous or high-risk or upon the achievement of a predetermined threshold. In these situations, the monitoring system instantly notifies the doctor of the emergency by sending SMS notifications via the Global System for Mobile Communication (GSM) to their cell phone. The SMS gateway is responsible for handling SMS transmission. The contact number of the attending physician is kept up to date in a database maintained by the Patient Information Management System. Consequently, the system sends an SMS after starting a database query. Using the patient's ID guarantees that the SMS message with precise information about the patient's health reaches the appropriate doctor. The responsible healthcare professional and medical monitoring system may communicate promptly thanks to this integrated system.

3. Working of the System

The clarity of the health monitoring system's operational procedures and decision-making processes is enhanced through the visual representation provided in Figure 8, which depicts the system's flowchart. This graphical representation offers an accessible means of understanding how the system functions and the sequential steps it undertakes to monitor and respond to a patient's health state. The comprehensive flowchart serves as a valuable tool, summarizing the intricate reasoning and procedures utilized across the entirety of the health monitoring system, contributing to a more insightful comprehension of its functionality.

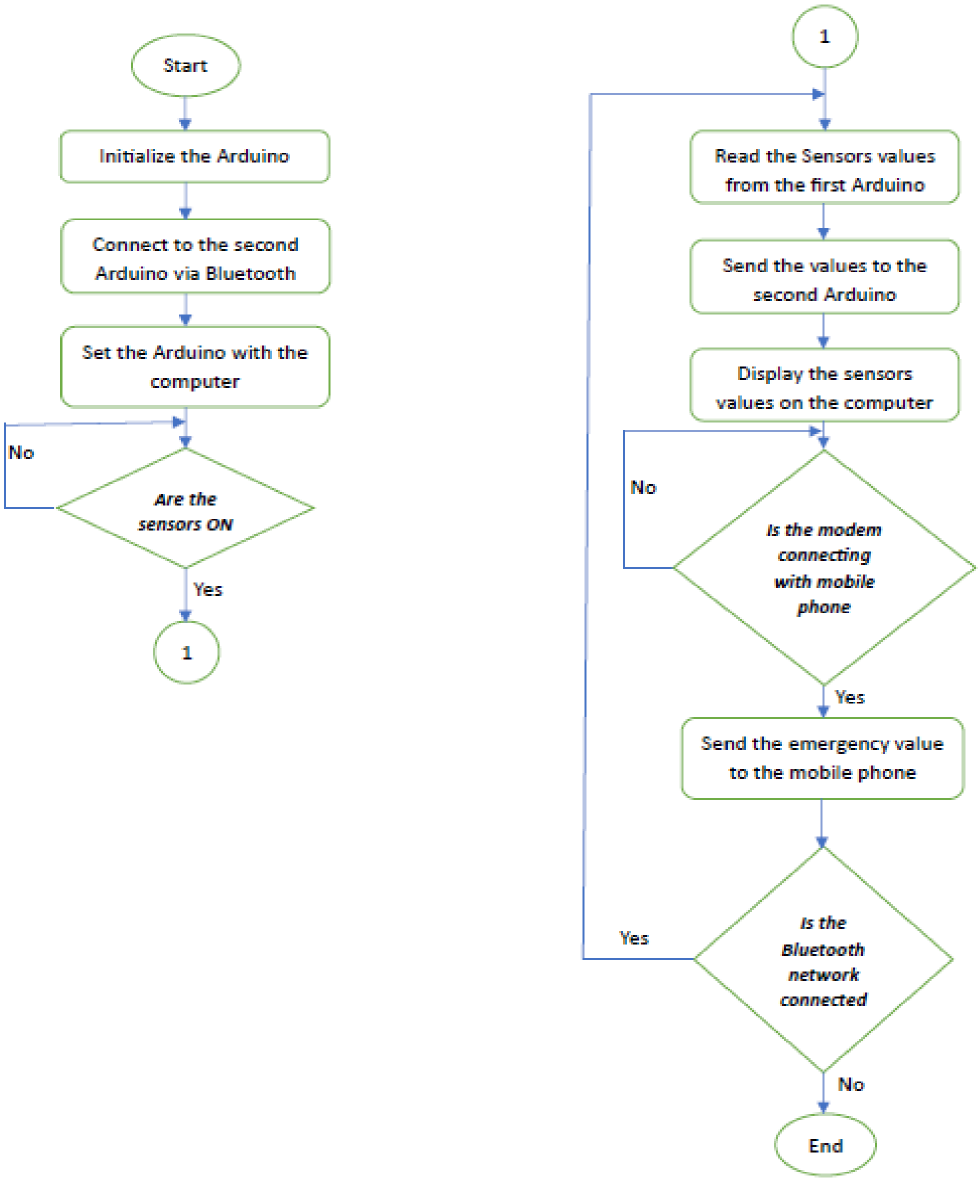

Fig. 8. Flowchart illustrates the overall system mechanism.

4. Implementing the Proposed System

Our surveillance method's installation is the result of careful preparation, creative engineering, and a resolute dedication to the highest standards of medical technology. Every element of our execution, from the deliberate design of the software's structure to the meticulous selection of equipment, has been created with intention and accuracy. We go into great detail in the parts that proceed, emphasizing the user-centric designs, strong security measures, future-ready capacity, and the smooth integration of hardware and software as the main components that make the system, we are using rich yet efficient.

1. **Equipment Collaboration**: We start the process by carefully choosing and integrating components that are made to specifically address health care tracking requirements. This consists of networking devices for smooth data transfer and detectors that record vital indicators including blood sugar, humidity, and pulse. Every component of the hardware is put through a thorough certification and validation process to guarantee peak functionality and dependability in actual medical settings.

2. **Visual Basic Programming Expertise**: We create a program architecture which will function as the nerve center for the control structure by utilizing the powerful features of Visual Basic version 6. Each element of the program, from the layout of the interface to computing algorithms, is painstakingly designed to satisfy the highest requirements for accuracy and reliability.

3. **Integration Architecture**: A complex integrative design is responsible for coordinating the smooth operation of hardware and software components under each other. This covers the protocols used for sending data safely across several networks, as well as middleware layers for data translation and protocol transformation. As a consequence, a coherent system is created in which many components cooperate to give doctors useful information.
4. **User-Centric Design:** the needs and tastes of users as well as healthcare providers are carefully considered throughout the creation of the interface for patients seen in Figure 11. The user engagement is streamlined by the interface's obvious visual signals and functionalities, which are arranged naturally. Users may customize their monitoring experience and be updated regarding their physical condition with features like real-time notifications and customizable displays.
5. **Compliance and Security Measures**: Tight legal and safety procedures are followed during the setting up phase to guarantee the protection of private medical information. This entails access control methods for user authentication, encryption techniques for data transfer, and routine security checks to find and fix any weaknesses.
6. **Scalability and Future-Proofing**: As medical technology advances, our solution can easily expand and include novel functions since it is built with these two factors in mind. Usability with current healthcare systems is ensured by flexible designs and open standards, while long-term viability and performance optimization are guaranteed by continuous upkeep and assistance initiatives.

Our solution exceeds the constraints of conventional surveillance equipment and ushers in a new era of proactive healthcare management by fusing various disparate pieces into a coherent whole. Our surveillance system, with its advanced software architecture, user-centric design theory, and strong hardware facilities is ready to transform the way medical data is collected, analyzed, and used to enhance treatment of patients. Lastly, we graphically represent the result of our work in Figures 9 and 10, which illustrate how all of the hardware and software components work together to produce a cohesive whole. The illustrations show how the software platform and the physical framework operate together seamlessly, giving a clear picture of the complex unification process. The creative combining technique at the heart of our monitoring system allows vital medical data to be seamlessly collected, processed, and transmitted. As seen in Figure 11, this strategy not only guarantees a successful flow of information but also establishes the framework for an interface that is easy to use. This interface acts as the starting point for interactions between medical personnel and patients, promoting effective dialogue and ensuring thorough surveillance of health.

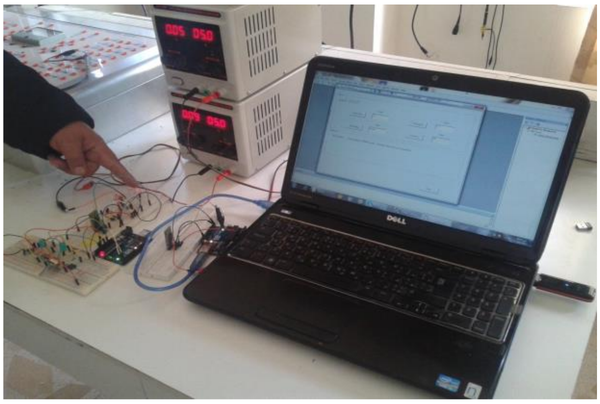

Fig. 9. Hardware implementation of monitoring systems

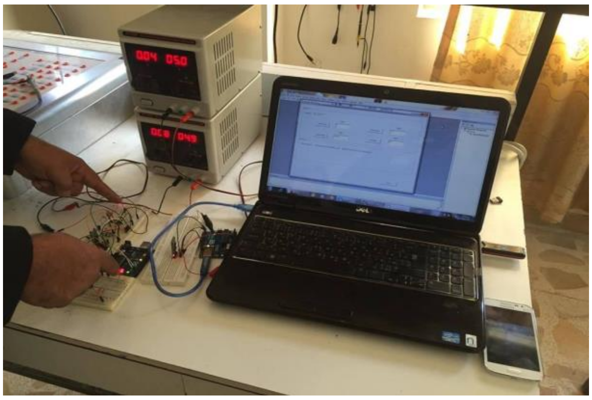

Fig. 10. Hardware implementation of monitoring systems with GSM and mobile phone.

Fig. 11. Monitoring systems GUI.

5. Conclusions

By using a Bluetooth connection between the first and second Arduino, the system gains more versatility. With this configuration, the server's PC may receive real-time vital signs and parameter data transmissions. Alarm messages can also be sent to a mobile phone to notify the person in charge of the patient's status. Utilizing the HC-05 Bluetooth module is essential as its range of about 10 meters is enough to cover a sizable structure and ensure smooth data transfer. The HC-05 module, interestingly, uses different pins for Tx (Transmit) and Rx (Receive) connections instead of using the pins on the microcontroller kit (Arduino) port. Because these distinct pins are devoted to the Bluetooth module, this design decision helps to decrease reaction times for data transmission and reception. The effective transfer of data from all the sensors to the mobile phone is made possible by the use of the GSM network, which has a faster baud rate. This improves the system's responsiveness and data transmission capabilities even more.

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