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Smart Medical Monitoring System Based on Arduino and Medical Sensors

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Annotation: With the advent of the communications and information revolution, the integration of the Internet of Things (IoT) and Artificial Intelligence (AI) has become crucial across various aspects of life. The adoption of these technologies is now a vital requirement to keep pace with the significant advancements in communication, thereby enhancing modern human existence. IoT represents a rapidly evolving technology that finds applications in numerous fields, including agriculture, industry, and healthcare. Medical facilities can leverage this technology to monitor and analyze the activities of individuals and patients via mobile devices such as smartphones and wearable wireless technologies connected to the Internet, thereby facilitating the development of intelligent systems that offer a more precise understanding of human activity throughout the day.

In the current study, a Smart Monitoring Health (SMH) system was designed and built based on IoT using ESP8266 for wireless communication, which can measure the patient's heart rate/pulse (BPM) and blood oxygen level (SpO2) using the MAX30100 pulse oximeter sensor, as well as measure body temperature using the MLX90614 temperature sensor. The system is controlled through Arduino.

Keywords: IOT, AI, SMH, BPM, SpO2.

1. Introduction

After the success of the internet in connecting people around the world, it is now the turn of the things around us to become part of the state information network "Internet" [1]. The Internet of Things (IoT) is a collection of devices or objects that are capable of connecting to the internet and interacting with each other (machine- to-machine) or with humans (machine-to-human) to achieve various tasks [2] It started as a concept that involved connecting some devices around us such as household appliances to a network that allows us to know their status and precise information without needing to be near them. The term first appeared in 1999, precisely on the British scientist Kevin Ashton's idea of connecting some devices around us, such as household appliances, to a network that allows us to know their status and precise information without needing to be near them [3].

The healthcare sector has benefited from digital transformation and modern communication technologies, and it is likely to increasingly rely on smart Internet of Things (IoT) technologies in the coming years, thanks to the continuous development of communication systems and artificial intelligence tools that have contributed to innovative ways of delivering healthcare services as shown in figure (1.1) [4]. With the widespread use of mobile phones and wearable devices, it has become easier to connect to the internet and exchange information in almost real-time. In case of a heart attack where the person's heartbeat stops, the person may die within a few minutes, unless someone intervenes to help. The chances of survival increase threefold if someone performs CPR on the person suffering from a heart attack [5].

Due to the advancement of technology speed, accuracy, intelligence and enhancement of interconnection of the physical devices, and other items embedded with electronics, software and sensors, it makes possible to share information quicker and accurately.

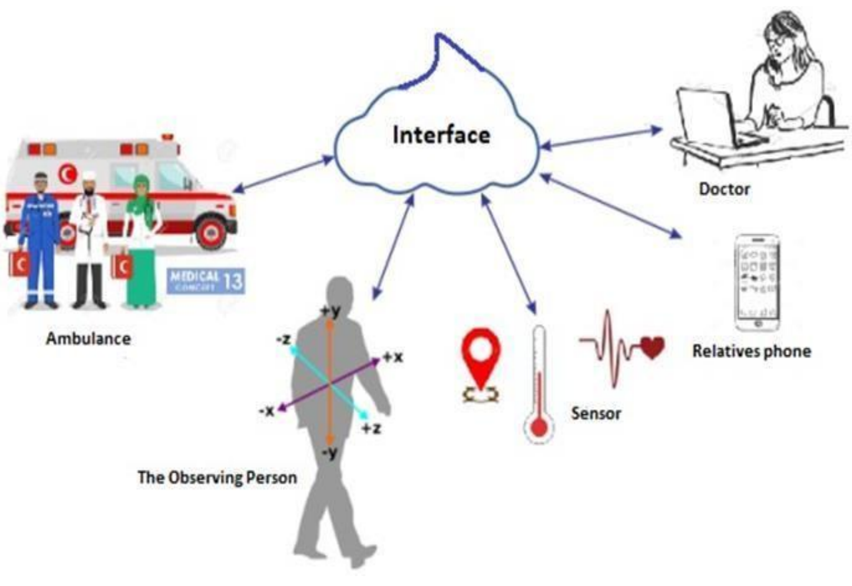

Fig (1.1) Health Monitoring System (IOT)

Health experts are increasingly taking advantage of the benefits these technologies bring, So, nurses and caretakers are using sensors devices to keep with their patient by using IoT.[6],[7] Conventional patient monitoring systems in healthcare facilities facilitate the ongoing observation of vital signs, necessitating that sensor be physically connected to adjacent bedside monitors or computers, thereby restricting the patient's mobility to the hospital bed. Furthermore, even after establishing a connection to the patient, a paramedical assistant is compelled to manually track and document all relevant information. This approach is prone to errors and could lead to catastrophic outcomes in the event of human mistakes.[8].

Smart healthcare is a health service system that uses technology such as wearable devices, IOT, and mobile internet to dynamically access information, connect people, materials and institutions related to healthcare, and then actively manages and effectively respond to medical ecosystem needs.

It provides easier measurement of patient's conditions as well as communication between hospitals and patients, Also, it facilitates various operations like report sharing to multiple individuals and locations, record-keeping [8],[9],[10]. Remote patient monitoring (RPM) helps us to monitor patient even when the patient is not in the clinic or hospital.

This approach could enhance access to healthcare services and facilities while reducing expenses. Frequent visits to hospitals and medical centers can be financially burdensome, particularly for low-income individuals who require regular check-ups. Affordable healthcare options in private hospitals are often limited, making hospital visits not only time-consuming but also a significant challenge for economically disadvantaged individuals in rural and remote regions. Consequently, there is a growing interest in developing an alternative system that allows for convenient and cost-effective monitoring of the health conditions of these individuals.[11],[12].

1.2 Aim of the study

In this research, a smart health monitoring system (HMS) based on Arduino- controlled temperature, blood oxygen, and heart rate sensors is proposed and put into practice for remote patient monitoring.

2. Material

The Internet of Things (IoT) powered smart health monitoring system allows for continuous patient observation around the clock. In today's world, IoT is transforming technological infrastructure. By promoting seamless communication between different components, IoT has made it possible to develop a range of intricate systems, including smart home devices, intelligent traffic management systems, automated office environments, eco-friendly solutions, smart vehicles, and advanced temperature regulation systems, all within compact spaces. Health monitoring systems are one of the most notable applications of IoT as shown in figure (2.1).

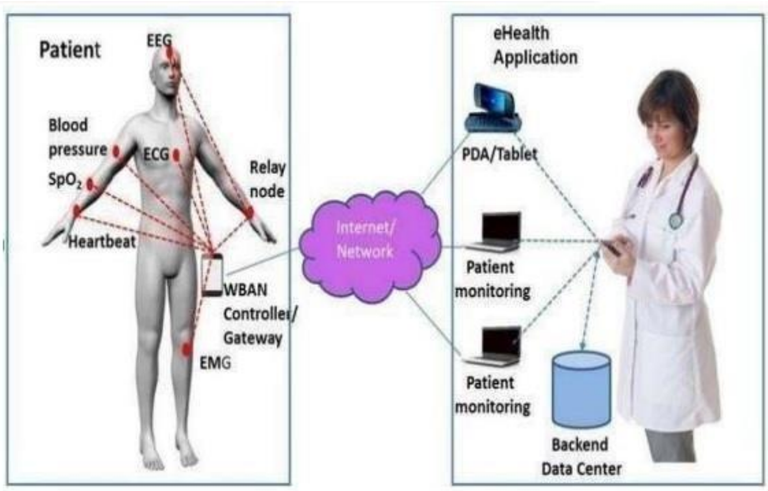

Fig (2.1) Layout of The Health Monitoring System Example of IOT

Architecture

Many types of designs and patterns have already been implemented to monitor a patient's health condition through IoT and this project is one of them. In this project we propose a smart health monitoring system which shown in figure (2.2).

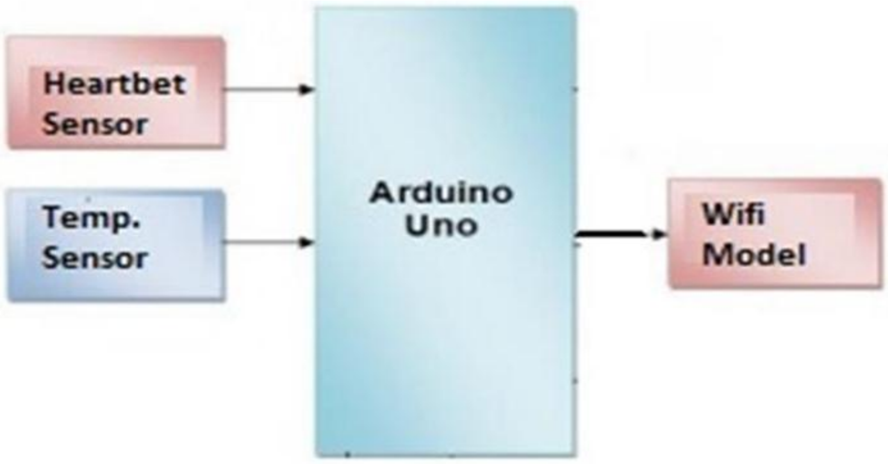

Fig (2.2) Proposed Smart Health Monitoring System

The proposed smart patient monitoring architecture consist of the following major module:

- ✓ Monitoring Unit: An intelligent sensor with micro-controller Arduino.
- ✓ Processing Unit: Arduino wireless transmission using ESP8266 Wi-Fi module that was enabled.

The Monitoring health system (MHS) consisted of:

1) Arduino Uno.
2) ESP8622 Wi-Fi.
3) Spo2 _ Heart-Rate Sensor (MAX30102).
4) Temperature Sensor (MLX90614).
5) ESP8622 Wi-Fi. 10)
6) Phone application.
7) Power Supply
8) The body of the device

2.1 Arduino Uno

Arduino is a flexible programmable hardware platform designed for artists, designers, tinkerers, and the makers of things. This microcontroller of Arduino comes from a company called Atmel with properties of 16Mhz with an 8-bit core, 32 kilobytes of storage, 2 kilobytes of RAM, and 1kilobyte EEPROM Asin figure (2.3). The Arduino platform is itself pretty useful for microcontroller projects, However, this factor alone does not suffice to drive the platform's popularity and widespread acceptance. Rather than restricting the design of the interface board and development environment, the Arduino project is fundamentally rooted in the burgeoning trend of open-source hardware. This is evident as all design files, schematics, and software are readily accessible for download, use, modification, reproduction, and even resale.[13].

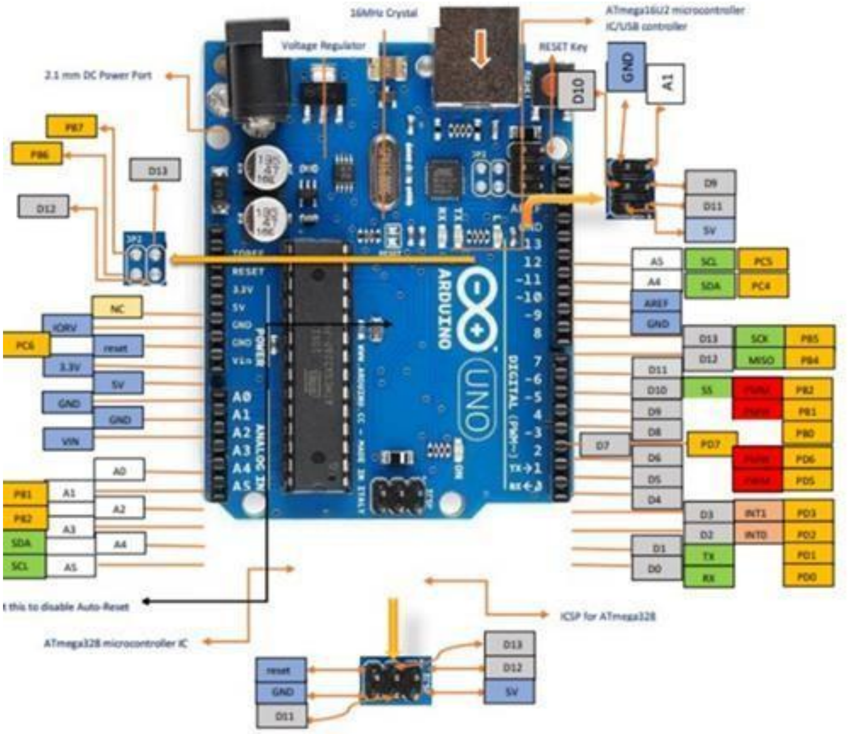

Fig (2.3) Arduino UNO

2.2. ESP8266 Wi-Fi Unit

The ESP8266 Wi-Fi which is shown in figure (2.4) is low-cost standalone wireless transceiver that can be used for end-point IoT developments. ESP8266 Wi- Fi module enables internet connectivity to embedded applications [14].

It uses TCP/UDP communication protocol to connect with the server/client. To communicate with the ESP8266 Wi-Fi module, microcontroller needs to use set of AT commands. The microcontroller communicates with ESP8266-01 Wi-Fi module using UART having specified Baud rate (Default 115200) [15]. It is mostly used for development of IoT (Internet of Things) embedded applications. ESP8266 comes with capabilities of [16]:

- ✓ 2.4 GHz Wi-Fi (802.11 b/g/n, supporting WPA/WPA2),
- ✓ general-purpose input/output (16 GPIO),
- ✓ Inter-Integrated Circuit (I^2C) serial communication protocol,
- ✓ analog-to-digital conversion (10-bit ADC)
- ✓ Serial Peripheral Interface (SPI) serial communication protocol,
- ✓ I^2S (Inter-IC Sound) interfaces with DMA (Direct Memory Access) (sharing pins with GPIO),
- ✓ UART (on dedicated pins, plus a transmit-only UART can be enabled on GPIO2), and
- ✓ pulse-width modulation (PWM).
- ✓ Operating voltage is 3.3V.

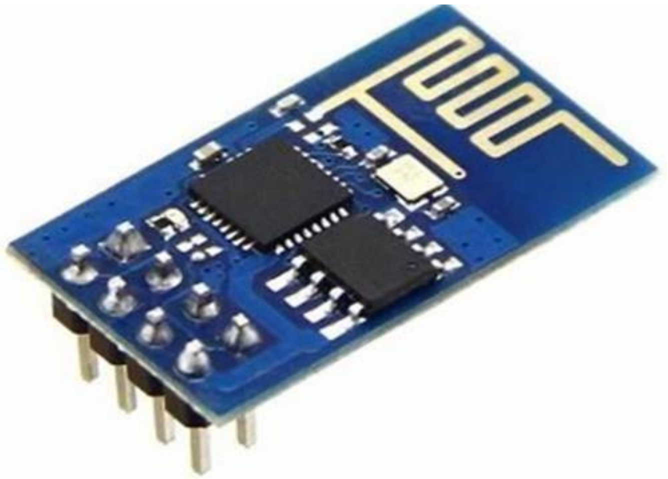

Fig (2.4) ESP8266

2.3 MAX30102 Sensor

MAX30102 Pulse Oximeter and Heart-Rate Sensor as shown in figure (2.5). The MAX30102 sensor is utilized for the measurement of blood oxygen levels and heart rate. Initially, infrared light is emitted and reflected off the finger, allowing for the determination of blood oxygen content through wave amplitude measurement. The heart rate is derived from the analysis of the time series response of this emitted radiation. The MAX30102 is a compact module that is compatible with both Arduino and STM32 platforms. It features a red LED alongside an infrared LED, a photoelectric sensor, an optical component, and a low-noise electronic circuit designed to minimize ambient light interference. Data regarding heart rate and blood oxygen levels is transmitted to the Arduino or other microcontrollers using I2C communication.[17].

Fig (2.5) MAX30102 Sensor

2.3.1 How MAX30102 Work

To determine the percentage of blood oxygen concentration, it is essential to understand that hemoglobin in the blood is responsible for transporting oxygen. When an individual uses a pulse oximeter, the device emits light that passes through the blood in the fingers. This process measures the variations in light absorption between oxygenated and deoxygenated blood to ascertain the oxygen levels.

The MAX30102 sensor as shown in figure (2.6) consists of two LEDs (Red and IR) and a photodiode. Both of these LEDs are used for SpO2 measurement. These two LEDs emit lights at different wavelengths, ~660nm for the red led and

~880nm for the IR LED. At these particular wavelengths, the oxygenated and deoxygenated hemoglobin have vastly different absorption properties. Figure (2.6) below represent the difference between HbO2 which is oxygenated hemoglobin and Hb which is deoxygenated hemoglobin at two different wavelengths [18].

The oxygenated hemoglobin absorbs more infrared light and reflects back the red light whereas the deoxygenated hemoglobin absorbs more red light and reflects back the infrared light.

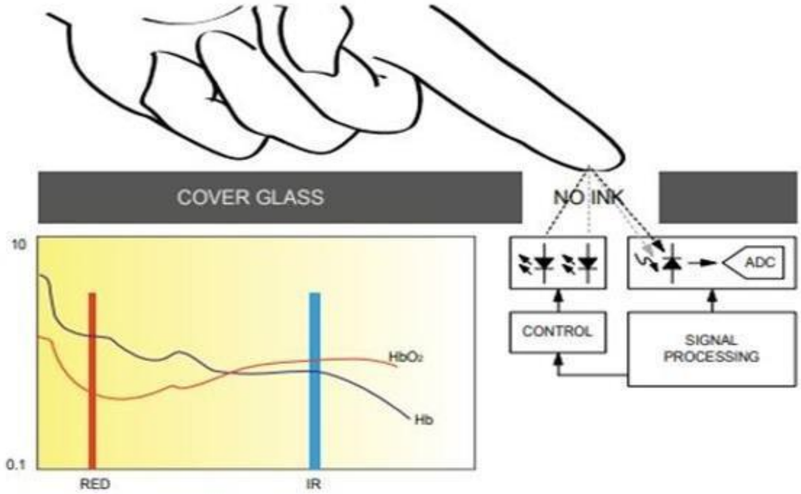

Fig (2.6) MAX30102 System Block Diagram

2.4 MLX90614 Sensor

At the heart of the module is a high precision non-contact infrared temperature sensor – MLX90614 as shown in figure (2.7) Unlike most temperature sensors, this sensor measures temperature without being physically touched. This can be very useful for monitoring the temperature of something moving like a spinning motor shaft or objects on a conveyor belt for example. Simply point the sensor at what you want to measure and it will detect the temperature by absorbing the emitted IR waves [19].

Fig (2.7) MLX 90614 Sensor

2.4.1 How MLX90614 Work

Infrared thermometers like MLX90614 take advantage of the fact that any object, including humans, above absolute zero (0°K or -273°C) temperature, emits (not visible to the human eye) light in the infrared spectrum that is directly proportional to its temperature. Refer to the Stefan–Boltzmann law. Internally, the MLX90614 is a pair of two devices:

An infrared thermopile detector and an ASSP (Signal-Conditioning Application Processor). Figure (2.8) shows the internal block diagram of the MLX90614 which showing both the thermopile and the ASSP.

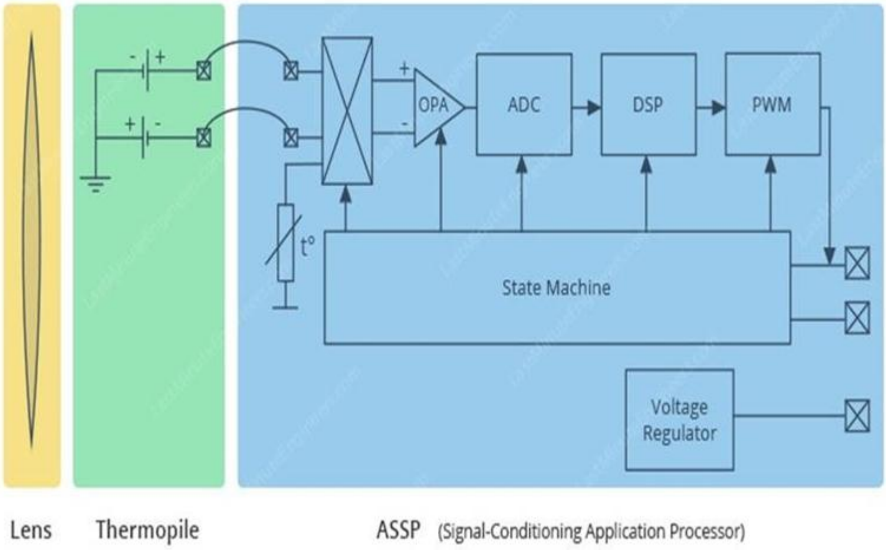

Fig (2.8) Internal block Diagram of MLX9061

Infrared radiation emitted by an object or a person is initially concentrated by a converging (convex) lens onto a specialized infrared detector known as a Thermopile. The thermopile detects the amount of infrared energy emitted by objects within its field of view (FOV) and produces an electrical signal that is proportional to this energy. The voltage generated by the thermopile is captured by the ASSP's 17-bit ADC, which processes it before transmitting it to the microcontroller. Remarkably, this entire procedure occurs in a matter of milliseconds.

2.4.2 Field of View (FOV)

An IR thermometer's field-of-view (FOV) is one of the most important metrics to be aware of. It is determined by the angle in which the sensor is sensitive to thermal radiation. This means that the sensor will detect all objects in the field-of- view and return the average temperature of all objects in it. It is important that the measured object completely fills the field-of-view.

Otherwise, the sensor may detect objects that are not supposed to be measured, resulting in inaccurate measurements.

The field-of-view of the MLX90614 is cone-shaped and relatively wide: 90°. This means that for every 1cm you move away from an object, the sensing area increases by 2cm. If you are one-foot 30cm (approx. 1 foot) away from an object, the sensing area will be 60cm (approx. 2 feet) as shown in figure (2.9).

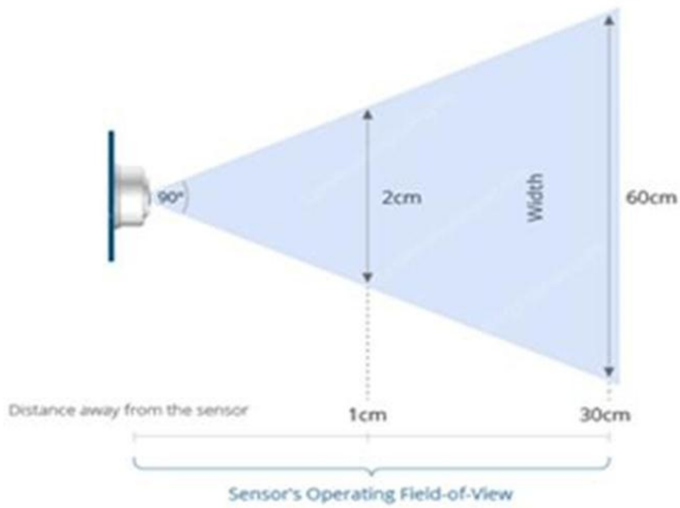

Fig (2.9) Field of View for MLX906

2.5 LCD Display

The LCD (Liquid Crystal Display) is a type of display that uses the liquid crystals for its operation. Here, we will accept the serial input from the computer and upload the sketch to the Arduino. The characters will be displayed on the LCD. Liquid Crystal Display (Fig 2.10) display is an electronic device. A 16x2 LCD presentations 16 characters according to line and there are 2 such strains. This LCD includes Command registers and Data registers. The command registers keep the command commands given to the LCD. The information registers shop the records to be displayed on the LCD. It is used for consumer interface [20].

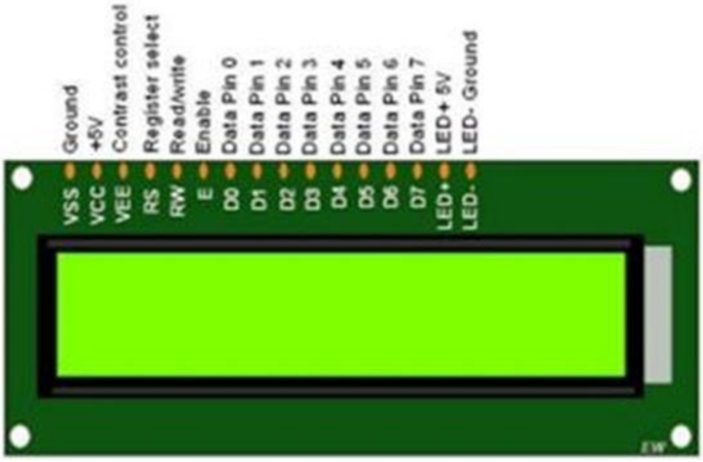

Fig. (2.10) LCD

2.6 Remote XY Android Application

Arduinos are some of the most popular microcontrollers in the maker movement and are also prevalent in science, technology, engineering, and mathematics (STEM) education. These boards integrate and link controls (such as buttons) to real-world actions (turning a motor, for example) through a control program. Yet, as you might expect, it’s sometimes desirable to eliminate physical controls from a project in favor of wireless interaction through an intuitive, electronics-free user interface (UI). That’s where Remote XY comes into play. Remote XY is a free package that allows non-programmer users to generate UIs for Arduino projects. Remote XY integrates seamlessly with various Arduino boards and communication methods, such as Wi-Fi, Bluetooth, and Ethernet, and comprises two main components.

The first component is a web interface, in which the UI is designed utilizing a friendly drag-and-drop environment to create buttons and switches, among other controls. The second is some code, which needs to be uploaded to the microcontroller. In fact, the code is what generates the app on the mobile device.[21].

2.6.1 Basics of Remote XY

Remote XY as shown in figure (2.11) is constructed to be as simple as possible. Requiring only a few steps, setting it up is very easy. A detailed tutorial can be found on the official website, but here’s an overview of the main steps required to get started.

1) Build a UI on the Website

2) Configure the Communication Method

3) Generate Source Code and Copy to Arduino IDE

4) Download the Remote XY App and Connect to the Arduino

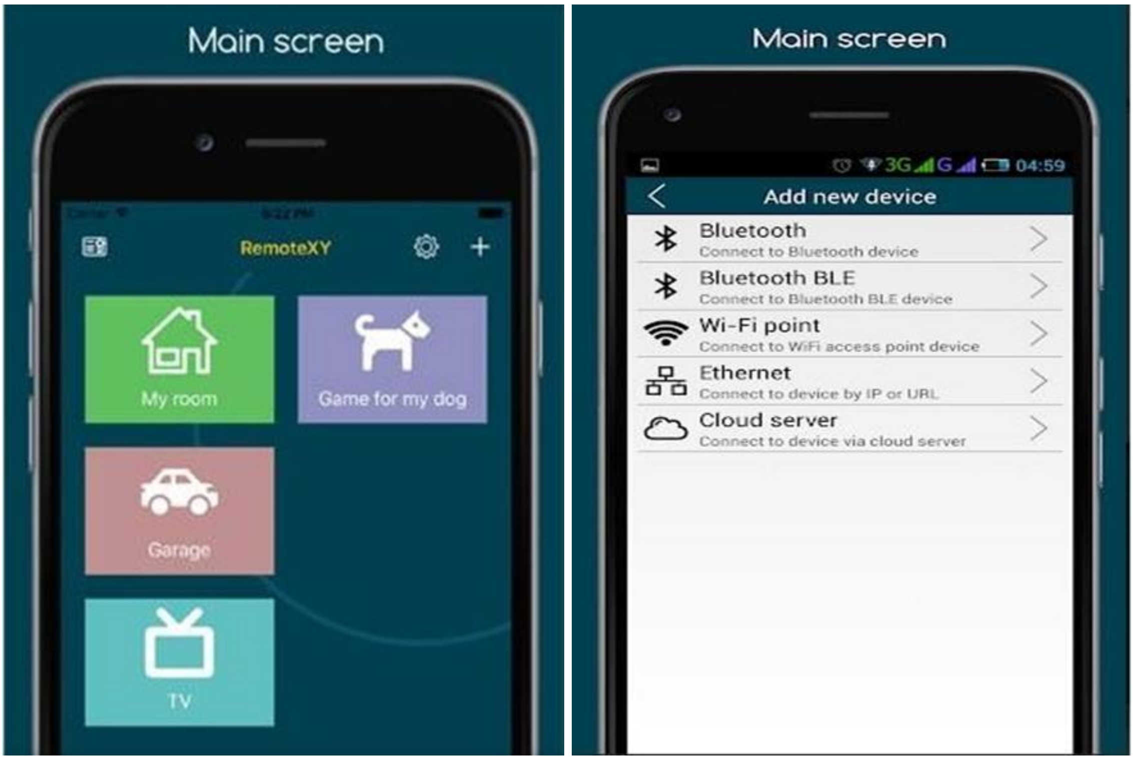

Fig (2.11) Remote XY application Main Screen

2.7. Power Supply

The power supply unit of this device is rechargeable, consisting of a Li-ion battery, and a charger.

2.7.1 LI-ION Battery

We used two li-ion batteries with 3.7 volts and a capacity of 3800 mAh as shown in figure (2.12).

Fig (2.12) LI-ION BATTERY

2.7.2 Battery charger

A battery charger as shown in figure (2.13), or recharger, is a device used to put energy into a secondary cell or rechargeable battery by forcing an electric current through it.

Fig (2.13) DC Power Supply Adapter

2.7.3 Main power Switch

Power switch that controls the power of the device which is shown in figure (2.14).

Fig (2.14) Power Switch

2.8 The body of the device

The body of the device is made from plastic with dimensions of 15cm in width, 18cm in length and 10cm in height as shown in figure (2.15).

Fig (2.15) The Plastic Box

3. Methodology and System Connection

In this project we proposed and design smart health monitoring system to monitor patients' health status and solve the drawbacks of old systems. The proposed system consisted of two sensors, LCD and ESP8266.It has functions of measuring a patient's health status, include body temperature, Oxygen saturation, and heart rate. It provides to send patient's data through Wi-Fi system. It enables nurses or doctors to monitor the patient's condition at all times without supervising the patient. Figure (3.1) shows the connection of the proposed system.

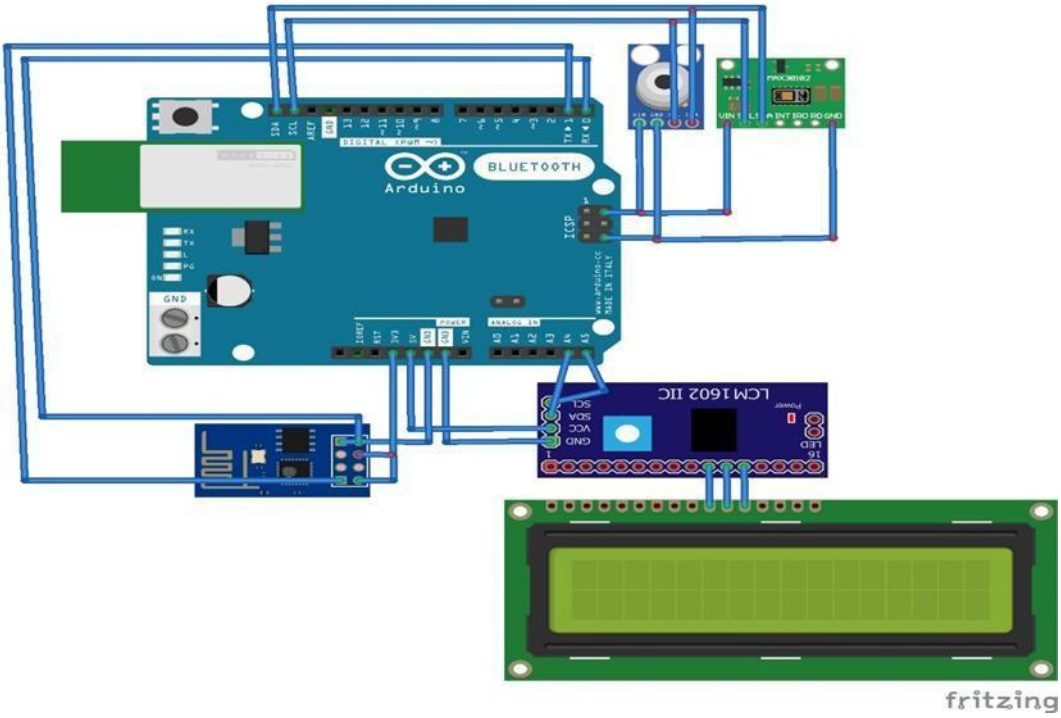

Fig (3.1) Proposed System Connection

The system is supplied with a power supply that consists of two lithium batteries (3.7 volt) sum (8.4volt) with regulators to produce (5v) and (3.3v) and one switch as shown in figure (3.2).

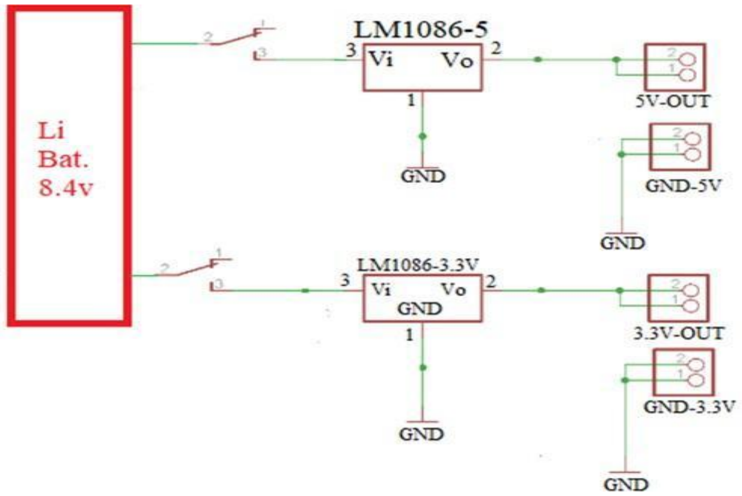

Fig. (3.2) Power Supply

These sources provide power to the circuit including all the sensors mentioned in chapter two. The power source is connected to the Arduino uno. Figure (3.3) shows the External Appearance of the device.

Fig (3.3) The External Appearance of The Device

Figure (3.4) shows the internal Appearance of the device.

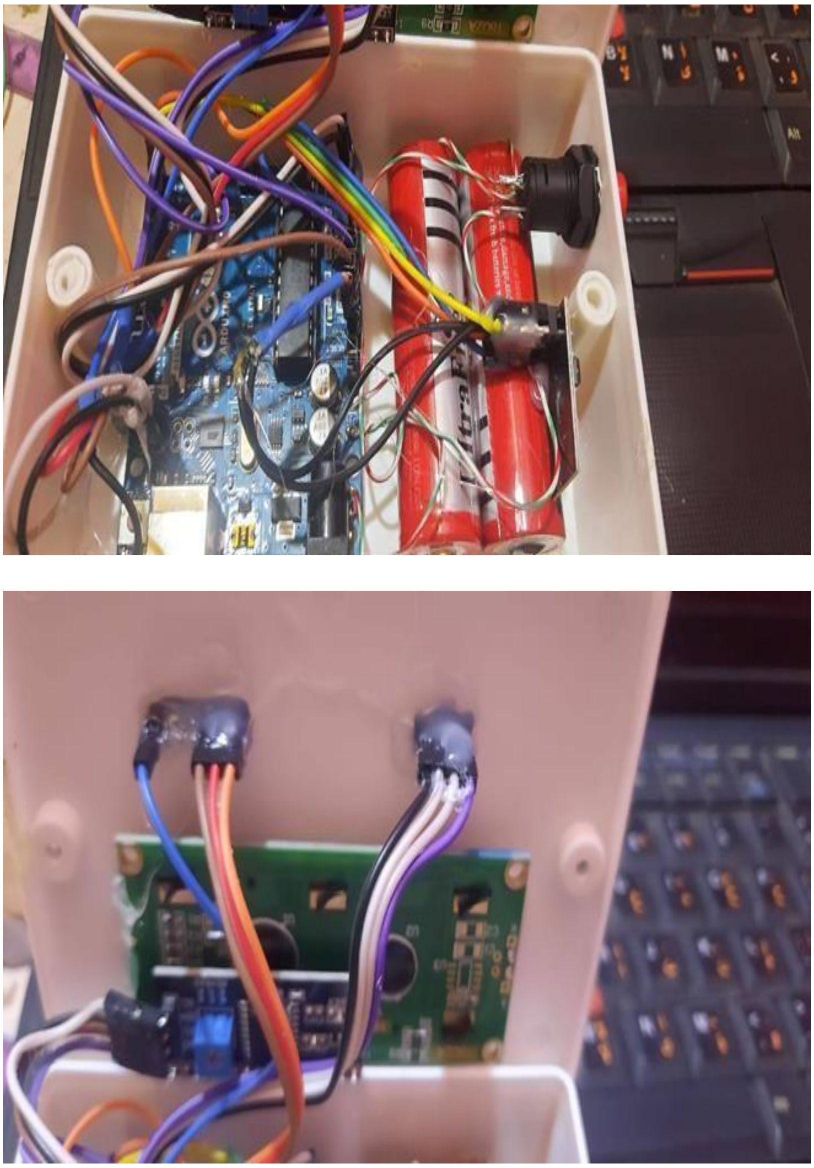

Fig (3.4) The Internal Appearance of The Device

3.1 Analysis and Flowchart

In Medical Devices project using IoT System has two processes as shown in figure (3.5), namely:

1. collect data from the sensor and display on LCD
2. collect data from the sensor and send data to Wi-Fi device

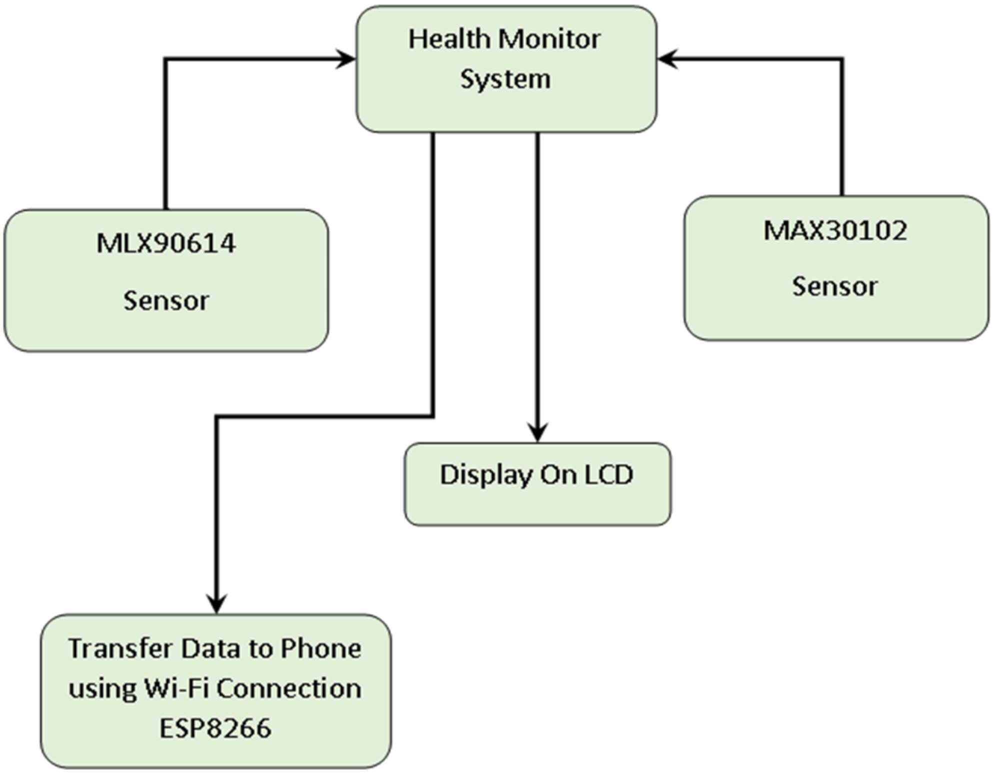

Fig. (3.5) Flowchart Health Monitor System

3.1.1 Collect data from the sensor and display on LCD

As shown in the figure (3.6) the data that read from the temperature sensor, heartbeat and oxygen sensor are display by Arduino on the LCD display.

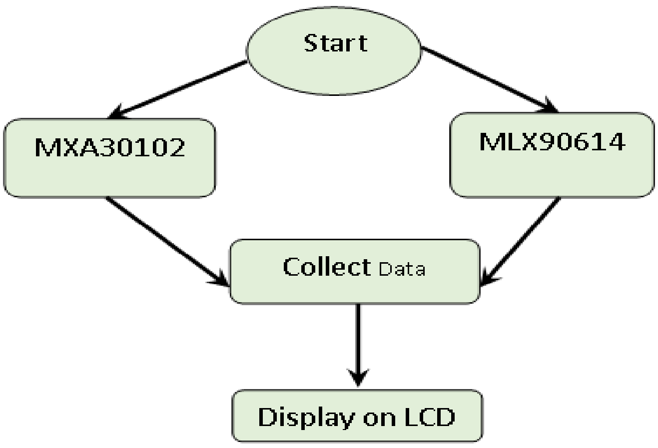

Fig (3.6) Flowchart For LCD

3.1.2 Collect data from the sensor and send data to Wi-Fi device

First done when Arduino in the lighted position of Wi-Fi module ESP8266 connected to the phone using Wi-Fi network in order to display data on phone using Remote XY application. After that, the heartbeat &oxygen sensor and body temperature sensor will work to detect the heartbeat and body temperature of the patient. After detecting the patient through the sensor, data is sent via ESP8266 to the phone using wireless as sin figure (3.7).

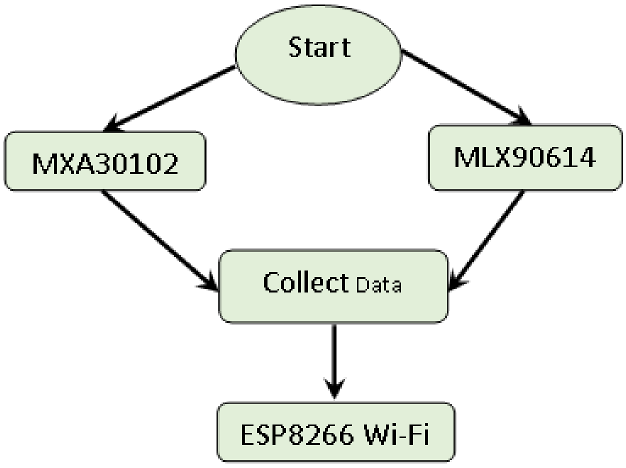

Fig. (3.7) Flowchart of ESP8266 Wi-F

4. Results and Discussion

4.1 Results

The apparatus was constructed and laboratory trials were conducted on it, wherein the findings revealed the device's effectiveness, achieving a 98% success rate in detecting temperature, heart rate, and blood oxygen levels. These outcomes were exhibited on the display and simultaneously transmitted to a mobile device, where they were exhibited on the phone utilizing the Remote XY application as shown in figurers below. figure (4.1) illustration depicts the utilization of a temperature sensor for measuring body temperature, with the corresponding reading displayed on a screen.

Fig (4.1) Display Temperature on LCD

5. Conclusion and Future Work

5.1 Conclusion

In the present study, a sophisticated monitoring system has been developed that enables healthcare professionals and family members to observe the health status of patients or loved ones at any time and from any location. This project utilized Arduino technology, integrating sensors to measure body temperature, blood oxygen levels, and heart rate, all connected to a network via ESP8266. The device has undergone testing, yielding outstanding results with an accuracy rate of up to 98%. Authorized medical personnel can access and monitor the data in real-time, even when conducting tests outside of a hospital setting. This system also provides significant advantages for nurses and doctors.

5.2 Future Work

Recommendation for Future Work is:

- Using Mobile App and Web Application to monitor patients' situation by sending an alert message and SMS to doctors.
- Using more sensor like ECG sensor and blood pressure sensor like (all in one).
- We can add GPS module in IOT patient monitoring.
- try sending SMS using SIM900A which has been used with fellow provider, for example from provider sympathy to provider sympathy

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