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Wireless patient monitoring system for cardiovascular diseases

A graduation project dissertation by:

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Table of Contents:

Lists of figures:

Lists of tables:

Chapter 1 : Introduction

1.1 Introduction

The present study describes a wireless patient monitoring system designed to provide real-time readings of a patient's vital measurements, with a particular focus on cardiovascular diseases (CVDs). CVDs represent a significant global health concern, accounting for an estimated 17.9 million deaths annually [1]. The system's primary function is to aid cardiologists in diagnosing and monitoring CVDs by offering accurate and timely diagnosis and warnings to medical staff. Additionally, the system's predictive capabilities allow for the assessment of a patient's future vital state based on previous readings.

The system comprises two primary components, namely hardware and software. The hardware component includes sensors capable of measuring various inputs such as ECG, heart rate, oxygen percentage in the blood, and temperature. The software component processes these readings and displays the patient's data on a web or mobile application. At our healthcare system, we understand that managing heart disease can be a challenging and ongoing process. That's why we offer a comprehensive monitoring system for heart disease that includes a convenient home service. This service allows patients to take our monitoring device with them after their hospital care, enabling them to stay connected with their healthcare provider and receive timely updates through our user-friendly app. With this feature, patients can better manage their condition and communicate with their doctor from the comfort of their own home. Overall, this wireless patient monitoring system offers an essential tool for improving the diagnosis and management of CVDs, ultimately contributing to better patient outcomes.

1.2 Problem statement

Hospitals are expected to provide patients with high-quality healthcare services, but this is hindered by a shortage of doctors, which is a major issue in most healthcare facilities. The significant difference between the number of doctors available and the number of patients to be attended to results in doctors being overburdened, which negatively impacts patient care. In addition, managing patients' sudden critical states is challenging for medical staff as there is no way to predict their condition in advance.

1.3 Objectives

Continued efforts towards the development of this system would be highly beneficial in creating a more promising system for patients. The versatility of this system has the potential to benefit a large number of people. Without a convenient wireless patient monitoring system, doctors are unable to give their full attention to patients at all times.

This system allows doctors to remotely monitor the conditions of multiple patients simultaneously using a web or mobile application that wirelessly connects to the device. It also has the ability to predict the near-future state of the patient, making it valuable in managing critical patient conditions. Medical staff can make early decisions

to prevent critical situations, thus improving patient outcomes and taking the medical service to the next level.

1.4 methodologies

The wireless patient monitoring system monitors the patients 24 hours daily by using computers so that the immediate action can be taken to help the patient. In the normal practice, Electrocardiography (ECG) machine will be used to record and send the patients' heartbeat rate data to the computer, furthermore the attached sensors on the patient's body measures the required inputs and sends it to the dashboard for the application through a wireless network to make the right diagnosis and predictions. Our system also offers a convenient home service, which allows patients to take our monitoring system for heart disease with them after their hospital care. With this service, patients can easily receive updates and communicate with their doctor through the app we have developed. This feature provides patients with greater flexibility and convenience, allowing them to monitor their condition and stay in touch with their healthcare provider from the comfort of their own home.

1.5 Report organization

The report is organized as follows. After an introduction to the report is presented in Chapter 1, a review of literatures including the previous and current alternative systems is presented in Chapter 2. In Chapter 3, the proposed system's main features and methodology are explained, the proposed system is thoroughly explained with flowcharts and diagrams is proposed. In Chapter 4, the implementation process of the proposed system which includes software and hardware. In chapter 5, the testing procedures are included. Finally, the main conclusions and the future work plan of this project are discussed in Chapter 6.

Chapter 2 : Planning and analysis

2.1 Introduction

This chapter includes history and previous projects and papers have been done in wireless monitoring systems with different technologies.

2.2 Background

According to world health organization (WHO) analytics nearly 32% of adult deaths all over the world due to cardiovascular diseases which are caused by disorders of the heart and blood vessels. These include various heart related diseases including coronary heart disease (heart attacks), rheumatic heart disease, raised blood pressure (hypertension), cerebrovascular disease (stroke), peripheral artery disease, congenital heart disease and heart failure.

These types of cardiovascular diseases need continuous monitoring of certain body parameters which need long hospital stays. In the hospitals patients are monitored continuously by hospital staff using various instruments like professionals it is difficult to continuously monitor the essential body parameters of the patients suffering from CVD bedside monitors. These instruments are bulky and immobile and thus keep patients stick to the bed. Their wired connections are very uncomfortable to patients and medical staff also. Due to mounting hospital costs and shortage of qualified healthcare.

2.3 Literature review

The use of wireless patient monitoring systems has gained significant attention in the healthcare industry in recent years, particularly in the field of cardiovascular diseases. These systems offer a convenient and cost-effective means of monitoring patients remotely, allowing for early detection and intervention in case of any adverse events. In this literature review, we will examine the existing literature relevant to the application of wireless patient monitoring systems in the context of cardiovascular diseases. Specifically, we will focus on the features, benefits, limitations, and challenges of these systems, as well as their impact on patient outcomes. This review aims to provide a comprehensive understanding of the current state of research in this field, identify gaps and limitations in the literature, and provide insights for future research directions.

2.3.1 An ML-Enabled Internet of Things Framework for Early Detection of Heart Disease [2]

Healthcare occupies a main role in sustainable societies and has a huge impact on the well-being of individuals (patients). However, over the years, different diseases have adversely affected the growth and sustainability of these societies. Among them, heart disease is escalating rapidly in both economically settled and undeveloped nations and leads to fatalities worldwide. To reduce the death ratio caused by this disease, there is a need for a framework to continuously monitor a patient's heart status, essentially doing early detection and prediction of heart disease. This paper proposes a scalable Machine Learning (ML) and Internet of Things-(IoT-) based three-

layer architecture to store and process a large amount of clinical data continuously, which is needed for the early detection and monitoring of heart disease. Layer 1 of the proposed framework is used to collect data from IoT wearable/implanted smart sensor nodes, which includes various physiological measures that have significant impact on the deterioration of heart status. Layer 2 stores and processes the patient data on a local web server using various ML classification algorithms. Finally, Layer 3 is used to store the critical data of patients on the cloud. The doctor and other care givers can access the patient health conditions via an android application, provide services to the patient, and inhibit him/her from further damage. Various performance evaluation measures such as accuracy, sensitivity, specificity, F1-measure, MCC-score, and ROC curve are used to check the efficiency of the proposed IoT-based heart disease prediction framework. It is anticipated that this system will assist the healthcare sector and the doctors in diagnosing heart patients in the initial phases.

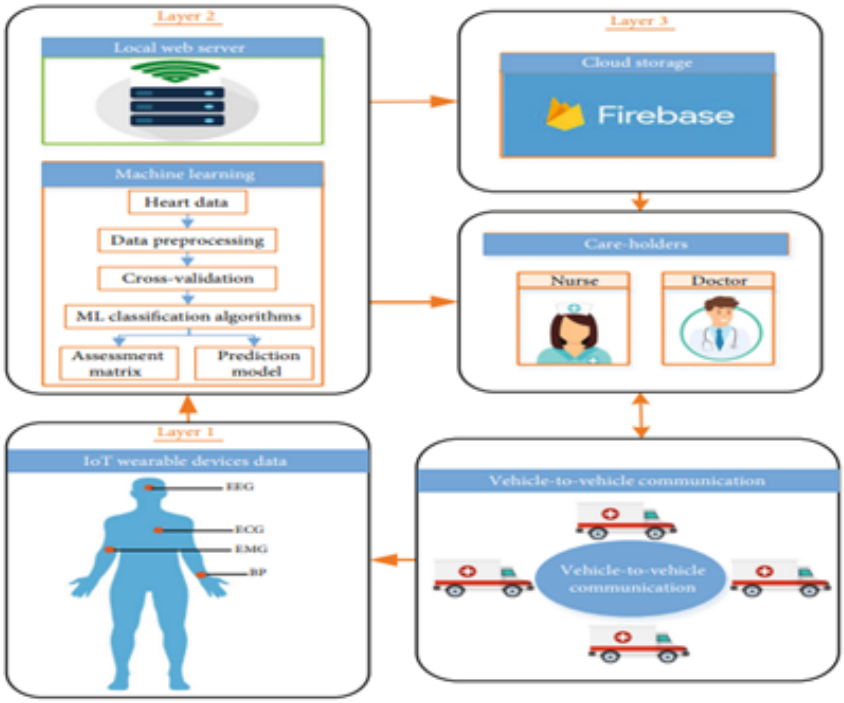

Fig. 2-1 Proposed IoT and ML based Architecture. [2]

A comparison was made between various machine learning models to decide which one is more suitable for the input data in table 1, the simulation results achieved using various machine learning models are discussed here in this section. The machine learning models used in this simulation are KNN, LR, DT, AB, RF, SVM (linear), SVM (RBF), ND, MLP.

Table 1.Performance of all classification models [2]

classifier	Accuracy	Specificity	Sensitivity	Recall	Precision	AUC	F1	MCC
MLP	84.96	80.76	88.97	88.99	83.02	91.79	0.86	0.70

LR	84.77	78.75	90.49	90.62	81.90	92.32	0.85	0.70
KNN(K=3)	96.09	95.99	96.19	96.34	96.28	99.09	0.96	0.92
DT	86.82	83.76	89.73	89.89	85.40	91.89	0.87	0.74
AB	92.09	92.38	91.82	91.89	92.84	97.92	0.92	0.84
RF	95.70	96.19	96.20	96.24	95.20	99.28	0.96	0.92
SVM(Kernell=linear)	84.19	75.95	92.01	92.09	80.27	91.46	0.86	0.69
SVM(kernel=rbf)	93.94	94.18	93.72	93.79	94.59	97.96	0.94	0.88
NB(Gausian)	82.33	78.15	86.30	86.49	80.98	90.70	0.84	0.65

KNN at “k =3” performed brilliantly and outclassed all the other models by achieving the accuracy of 96.09%, specificity of 95.99%, sensitivity of 96.19%, recall of 96.34%, 96.28% of precision, AUC of 99.09%, F1- score of 0.96, and 0.92 of MCC, and attained first position in terms of performance.

RF attained the second spot in terms of performance, and achieved 95.70%, 96.19%, and 96.20% of accuracy, specificity, and sensitivity, respectively.

The third best classifier was SVM (“kernel = rbf”). SVM (“kernel = rbf”) achieved 93.94% of accuracy, 94.18% of specificity, and 93.72% of sensitivity.

The lowest performance was observed for NB classifier, i.e., accuracy of 82.33%, specificity of 78.15%, and sensitivity of 86.30%, and stood last in the performance competition

All the simulations are carried out using laptop systems having the following specifications: model HP Elite Book G5 Intel core i7, 9th generation having 16 GB RAM and operates on Microsoft Windows 10. [2]

2.3.2 Portable Heartbeat Rate Monitoring System by WSN Using LabVIEW [4]

Cardiovascular and chronic diseases have been increasing the death rate recently. Cardiovascular diseases are certain kind of disorders that damage the heart, veins, and arteries. Heart related cardiovascular diseases are like heart attack, stroke, and heart failure. On the other hand, blood vessels related cardiovascular diseases are like coronary artery disease, which are known as vascular diseases. As cardiovascular diseases (CVDs) are the leading cause of death globally, taking an estimated 17.9 million lives each year.

Moreover, statistics in Europe, which are based on data from different health institutes such as the European Health Network, showed that in average 2 million deaths duo to cardiovascular disease yearly. Using Heart Rate Monitor is not only limited to healthcare monitors in the hospital or for the elderly. But it can be used in sport fields as well. The Heart Rate Monitor will help monitor athletes during both performance and rest periods to maximize the training benefits.

This is a prototype of heart rate monitoring device using technology of Wireless Sensor Network (WSN) and LabVIEW platform. The main idea is monitoring individuals in periodic periods using wireless technology and by determining the health status of individuals by usual monitoring. As experimental test they applied the system on football players in the field, to determining the health status of the players who

suffering from stress. As a result, medical specialists could be able to check the health of the players remotely during training sessions or real competitions. This system would save players' lives in an emergency.

The real-time monitoring of individuals suffering from heart problems can help reduce the necessity of direct monitoring by the human in the field and guarantee the monitoring of patients at urgent medical conditions without using substantial and expensive health management.

They used embedded monitoring system to implement real time monitoring system by incorporating the ECG signal detection and it's processing on dashboard. Technology developments in different fields like communication networks, signals, and data processing could help improve the performance of real-time monitoring which would provide a new smart, active medical care.

This is the block diagram of the proposed system showed in fig 2.

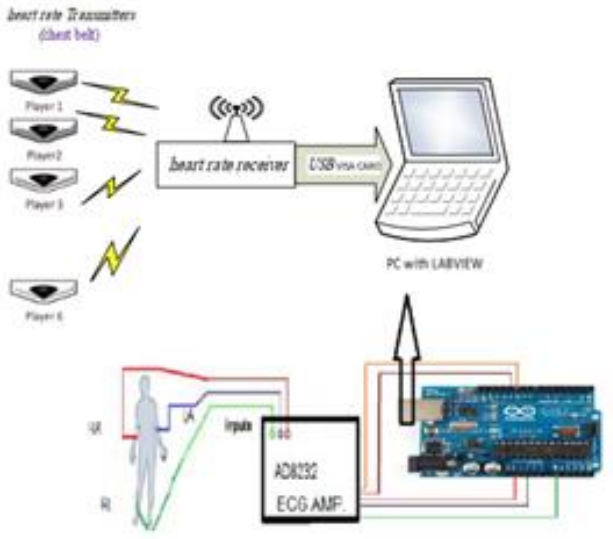

Fig. 2-2 block diagram of the wireless heart rate [4]

The system consists of two stages, first stage is to monitor heart rate continuously during stress using KYTO2816C chest belt transmitter with 2.4 GHz heart rate receiver to transfer data to LabVIEW application which shows the monitoring with real-time network settings. Using VISA IN library to send the heartbeat data to the computer.

The second stage is using the ECG sensor technology to observe and measuring the electrical activity of the heart via deployment of Arduino microcontroller combined with the ECG Module (AD8232) to connect the ECG setup to the main processing unit to be able to analyse the received data by LabVIEW application.

As mentioned, collecting the ECG signal is a two-step procedure through monitoring the heart electrical activity over a certain period using props placed right over the skin. First, using props that are able to sense even weak electrical fluctuations on the skin that are originally generated because of the heart muscles movement at every single heartbeat. Then, the collected signal is amplified using an amplifier circuit based on an operational amplifier which is AD8232 which is connected to Arduino microcontroller. Then, displaying the signal through the waveform or the personal computer and drawing the signal through the serial port. They also used integrated circuit AD8232 to remove the noise to advance the monitoring process. And to process the data they used LabVIEW software which contains large set of data receiving tools.

Advantages:

System is portable and cost effective.

Disadvantages:

System is specified for specific stakeholders

2.3.3 IRJET- Remote Health Monitoring System using Internet of Things [7]

Rising incidents of affected lives due to unpredicted heart attacks and cardiovascular diseases are one of the major concerns so an E-Health Monitoring System using internet of things(IoT) was developed, comprising of a Wi-Fi module enabled microcontroller ESP8266 and wearable sensor networks which will measure various health parameters such as heart rate, the oxygen level in the blood, body temperature and ECG as inputs, with reliable data and uploading them to cloud which can be remotely accessed by medical professionals on a user-friendly application from any location at any time. This study answers the idea behind creating an effective relationship between work and health life simultaneously. As a result, such incidents can be prevented in this paper, a prototype has been designed and implemented for real-time health monitoring using Internet of Things (IoT). This system facilitates the process of performing diagnosis and treatment of patients suffering from heart diseases. Sensors like DS18B20, MAX30100, and AD8232 are used for recording patient's health parameters like body temperature, heart rate, and ECG signals. The data gathered is transmitted to the IoT cloud which can be visualized using transmission control protocol (TCP) on a mobile application. Using this system, the physician and the family members themselves can use the cloud platform to diagnose patients at remote locations. The patient can access their medical records via this cloud service. These data can be analysed by a doctor at a remote location or can be saved and retrieved later for analysis. With this design and development, we have attempted to fill the gap which was the main reason behind the growth of death rate due to cardiac diseases

TEMPERATURE SENSOR (DS18B20) It is one-wire (requires only one data line and GND to communicate with the microcontroller) direct-to-digital temperature sensor with the resolution being user-configurable to 9, 10, 11, and 12 bits, corresponding to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively. It can measure

temperatures from the range -55°C to +125°C with an accuracy of ±0.5°C from -10°C to +85°C. Operates in a power supply range of 3.0V to 5.5V.

PULSE OXIMETER AND HEART RATE SENSOR (MAX30100) It is designed to provide the digital output of heartbeat (beats per minute) and oxygen level in the blood, when it is touched. The device has two LEDs, one emitting red light, another emitting infrared light. More Oxygenated blood results in the passing of red light and absorbing infrared and vice versa. The time difference between the oxygenated and deoxygenated blood pumps determines the heart rate. Operates in a power supply range of 1.8V and 3.3V and can be powered down through software with negligible standby current.

ECG SENSOR MODULE (AD8232) is a Single Lead, cost-effective Heart Rate Monitor Sensor which when attached to the patient measures electrical activities of heart over some time. The sensor outputs can be monitored using the serial monitor or can be sent directly to the cloud with the help of a microcontroller. It has an op-amp to help obtain a clear signal from the PR and QT Intervals easily. It can extract, amplify, & filter small bio potential signals even when accompanied by noisy conditions, such as those created by motion or remote electrode placement. The AD8232 has pins-LO+, LO-, SDN, OUTPUT, 3.3V, GND along with RA (Right Arm), LA (Left Arm), and RL (Right Leg) pins through which ECG electrodes are connected to the body.

2.3.4 IoT Based Real-Time Remote Patient Monitoring System [5]

Healthcare technology is one of the most important studies nowadays, however some people in rural area having a hard time to get professional healthcare services due to the lack of doctors.

The report from the Ministry of Rural Development Malaysia showed that 24.5% of the population are staying in rural areas and according to the statistic from the Ministry of Health Malaysia, the ratio of doctor to the population in west coast of Peninsular Malaysia is 1:482 so that Remote wireless patient monitoring system is one of the best solutions to overcome this issue through (ICT) information and communication technologies. This project idea based on IOT (Internet of Things) and real time principles.

They used ECG (electrocardiogram) as a sensor to measure the patients' heartbeat rate and used a controller by using (MQTT) Message Queuing Telemetry Transport protocol, to transmitting the real-time ECG to the webserver. The doctor can access the webserver by using smartphone or computer to show real time ECG readings or previously readings.

They tested the project in (LAN network) local area network and (WAN network) wide area network, the results show there is no package loss.

We can say this project consist of four modules:

1- Sensor
2- Main controller
3- Communication module
4- webserver

We will talk briefly on each module used in this project

The sensor: They used ECG (electrocardiogram) sensor (AD8232) to collect the ECG data from the cardiac patient. It measures and amplifies the ECG signal based on the electrical activity of the heart muscle

The main controller: They used (Arduino ESP 32) as a controller which provide Wi-Fi data transmission, the main controller collected real-time ECG data and processed it

The communication module: The collected data from the ECG sensor (electrocardiogram) with the controller and after processed it, the data transmitted via Wi-Fi by MQTT (Message Queuing Telemetry Transport protocol)

The webserver: It host a real time database where the ECG signal (electrocardiogram) stored in a database simultaneously so that doctors or nurses can access the database server to view the recorded history ECG data.

The doctor can view the real-time ECG signal via Android mobile application (App), The App can display both heartbeat rate (BPM) and a real-time ECG chart, the heartbeat rate is extracted from the received real-time ECG data, it updates every 3 seconds.

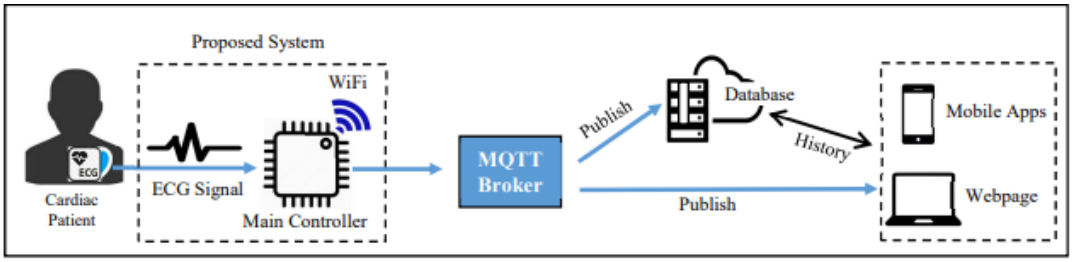

Fig. 2-3 block diagram of the wireless heart rate [5]

They used MQTT network protocol (Message Queuing Telemetry Transport protocol) instead of HTTP (Hypertext Transfer Protocol) because MQTT requires low bandwidth, low power consumption and suitable for IoT development.

The webserver was implemented by using JavaScript programming language and the ECG signals data are packed into a JSON Format string before sending it to the webserver and database. This greatly improves the efficiency of data converting at the

client side because both webserver and database have a built-in function that can process the JSON format data.

To test the project, they made two experiments the first experiment is set up in a private network or local area network (LAN) and the second experiment is set up in the public network or Wide Area Network (WAN).

The first experiment all components (system, database, and the computer) are connected to the same access point, assuming the patients in the hospital, the collected ECG data are stored in the in-house server. Doctors monitor their patients' real-time or previously recorded ECG data from their office.

The second experiment assuming the system is connected to the home Wi-Fi. The collected real-time ECG data is transmitted to the cloud server via internet. Doctors access the cloud server for observing the patient real-time ECG through their own mobile cellular network.

As it shows in the figure for the second experiment

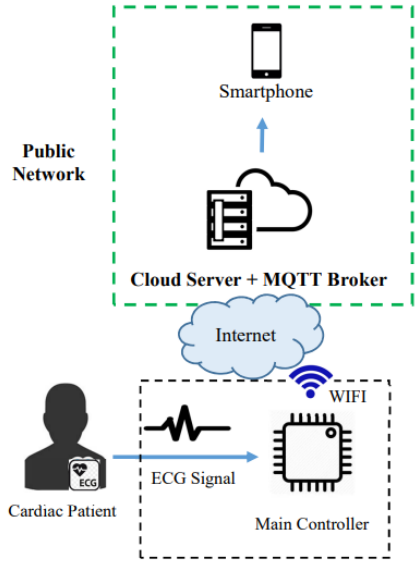

Fig. 2-4 Experiment setup in the public network [5]

To further verify there is no packet error or loss, they compared the total value of ECG data of the selected range of 5000 packets between sender (main controller) and subscriber (database system or webserver). The results show that both the sender and subscriber have an identical sum of ECG values.

The following tow table proved that there is no packet loss or error either in first experiment (private network) or in second experiment (public network).

Table 2.Performance of the proposed system private network [5]

Module	Number of ECG packages	Sum of ECG values	Average Jitter Delay, A_{JD} (ms)
ECG packets sent by main controller	5000	9511560	5.714
ECG packets received by Webserver	5000	9511560	

Table 3.Performance of the proposed system public network [5]

Module	Number of ECG packages	Sum of values	Average Jitter Delay, A_{JD} (ms)
ECG packets sent by main controller	5000	9477828	50.0832
ECG packets received by Webserver/database	5000	9477828	

Advantage:

1- The doctors or nurses can observe the ECG signal of any patients at any time any place through the computer or smartphone.
2- There are no package loss and package errors during transmission of ECG packages in both private and public networks.

Disadvantage:

1- The system is just monitoring the data from the sensors to the doctor, no processing on the data (they didn't used any AI or machine learning in the project).
2- They use only one sensor that is ECG.

2.3.5 Health Monitoring System by Using IoT [6]

In this paper, they use IOT; the IOT including several of concepts from pervasive, ubiquitous, and ambient computing, which are evolved in last 20 years and present time it's now reached at some level of maturity. The IOT is conceive as a network of Lacks people, objects, machines-interacting to one other, invisibly connected with sensors, actuators, making useful in everyday lives. The future will be dominated by the 'Internet of Things' which will serve as all world platform to interconnected physical objects, things, humans, thus, enabling new ways of working, communicating, interacting, entertaining, and livings.

The IOT is a new paradigm in which every physical object. Individuals with the heart condition who have been advised by their physicians to participating in a regular exercise program and it would be beneficial from using the heart monitor so that they

can be aware of their heartbeat rate condition and adjust the level of intensity of their exercise to maintaining a safe and good heart beat rate. Individuals who are advised to exercise for weight losing, for treatment of high blood pressure also will enjoy this device because it may be an effective meaning of measuring progress in achieving exercise goals. Healthy individuals who are interested in improving their cardiovascular condition can also use the heart monitor to guide their exercise program and increase the intensity of their exercise in a controlled manner. Thus, anyone who exercises regularly can benefit from the heart monitor.

Parameters to be monitored

1. Body Postural & Movements
2. Heart rate & Blood oxygen level Heart rate
3. Galvanic Skin Response

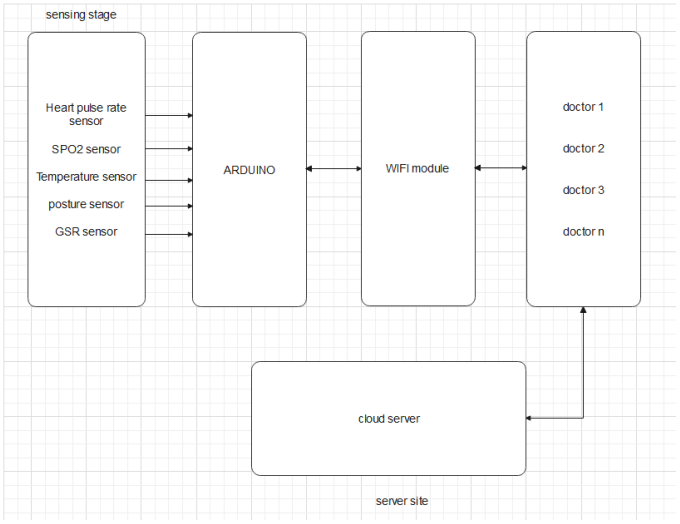

Fig. 2-5 Functional block diagram of the system [6]

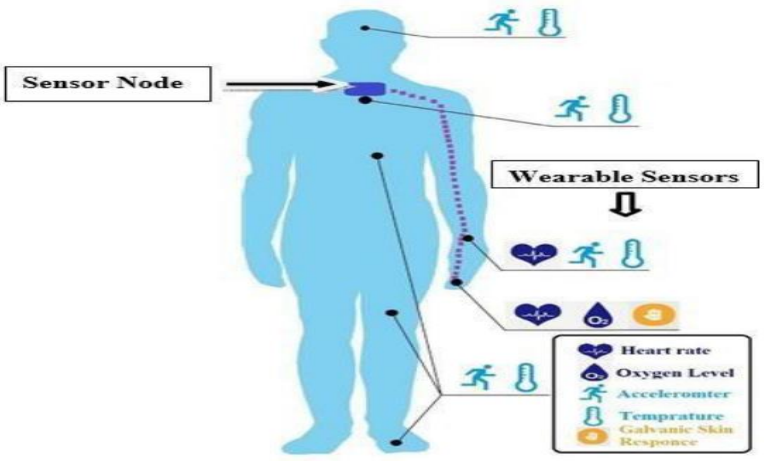

Fig. 2-6 Various sensors and their placement on human body [6]

Wireless sensor network & selection of network: WNS is a promising field that integrates sensor technologies, embedded system and wireless communication together to produce small, low cost, low power and reliable system capable of monitoring specific events. The IEEE standard 802.11 a/b/c is developed targeting specifically for this application domain. It has been used in a variety of applications including commercial and industrial monitoring, home automation and networking, consumer electronics, personal computer peripherals, home security, personal healthcare, toys and games, automotive sensing, agriculture etc. The communication between sensor node and coordinator unit is wireless, data from the sensor node is monitor on IOT platform at the internet accessed host computer by building a network between the sensor node and the coordinator unit for that communication Wi-Fi wireless network technology is used. In our system design Wi-Fi technology take into account because it is commonly used for the wireless local area networking (WLAN) of devices which is based around the IEEE 802.11 family of standards Wi-Fi uses multiple parts of the IEEE 802 protocol family and is designed to seamlessly interwork with its wired sensor protocol Ethernet.

Advantages:

1- It gives alert to caregivers.
2- Using Internet, data can be made available for remote use and only to authorized users like remote specialist doctors for special advice.
3- The system uses wearable sensors.

Disadvantages:

They didn't use any AI in their project; they can't predicate any upcoming disease through the attributes.

2.4 Analysis of the new system

A successful wireless patient monitoring system for cardiovascular diseases must meet a range of requirements, including functional and non-functional performance requirements, as well as security requirements. In this section, we will analyse the new wireless patient monitoring system for cardiovascular diseases, focusing on its system requirements, functional and non-functional performance requirements, and security requirements. We will examine the design and functionality of the system, as well as its ability to meet the performance and security requirements necessary for effective patient monitoring. Specifically, we will evaluate the system's ability to collect and transmit data accurately and reliably, its compatibility with existing healthcare infrastructure, and its adherence to security standards and protocols. Additionally, we will analyse the potential benefits and limitations of the system and provide insights on how these can be addressed. This analysis aims to provide a comprehensive understanding of the new wireless patient monitoring system for cardiovascular

diseases and its ability to meet the requirements necessary for effective patient monitoring and improved healthcare outcomes.

2.4.1 System requirements

1. System should read sensed vital measurements accurately.
2. Exchange of the data between server and sensors should be real time with no delay to achieve the functionality of the monitoring.
3. ML model should predict if the patient is going to have heart failure or not with high accuracy.
4. Users should access and use the website and the mobile application in an easy way.

2.4.2 Functional requirements

1. Sensors should read patient's vital measurements.
2. Vital measurements should be send by the wife module to the server.
3. ML model should process the data to get the predicted output.
4. Doctor should follow up patients through the application.
5. Doctor should write the required instructions from nurses in the app.
6. Doctor should document the detailed case, medications, laps and any other rays in the app to complete patient's profile and to follow up treatment plan.
7. Doctor can add or remove patients.
8. Admin and doctor are the only allowed users to edit in patient's data.
9. Admin can add or remove patient, doctor, and nurse.
10. Admin can access any account and edit it.
11. Nurse should monitor patient's case through the given instructions and treatment plan from the doctor.
12. Patient could benefit from home service feature but only when the doctor activates it.

2.4.3 Non-functional requirements

In addition to the functional requirements, a wireless patient monitoring system for cardiovascular diseases must also meet specific non-functional requirements. These requirements include performance and security requirements, which are critical to ensuring the system's effectiveness, reliability, and security.

2.4.3.1 Performance requirements

1. Faster data exchange.
2. Faster data processing.
3. Accuracy of sensed data.
4. Accuracy of ML model.
5. Faster usage of the website and the mobile app.

2.4.3.2 Security requirements

1. The exchange of data between sensors and system should be secured against attacks.

2.5 conclusion

The results of this study demonstrate that we are planning to build a project to be used in hospitals to monitor patients with cardiovascular diseases, and to predict their future state through processing the measured data, to help the doctors and medical staff to consciously monitor multiple patients, for the hardware part we are using the measurements of ECG to be transmitted through Wi-Fi or ZigBee connection to assure real time data transmission to the application. The application has a dashboard for all patients and specific page for each patient. Through this, the medical staff can make right decisions and be fast to respond any critical state.

Chapter 3 : Wireless patient monitoring system for cardiovascular diseases (Software design)

3.1 Introduction

This chapter include system stages and the main features of the project and the methodology of how to achieve the fully functional state of this project.

In this chapter we will divide the system to blocks, each block or stage has its own feature and do some important tasks to produce outputs that help the other stages to do their tasks and achieve the system goal.

The main stages in our system:

1- Sensing stage.
2- Processing stage.
3- Supervisory stage.
4- Monitoring stage.

We will talk about each stage in details later on this chapter, but now we can intrudes briefly this stages.

1-Sensing stage

The initial stage of our system involves the direct connection to the patient through sensors that detect vital signs, including body temperature, blood pressure, heart rate, and other essential measures. The collected data is then transmitted to the subsequent stage. As this stage forms the foundation for the following stages and the reliability of the output data is crucial, it must be error-free.

2-Processing stage

The second stage involves the microcontroller, which receives raw data from the sensors. The microcontroller plays a significant role in processing this data by converting it into useful information, which is then classified or analysed with the help of software implemented on the microcontroller. This process enables the assigned doctor to understand the patient's state and determine the necessary medical care.

Additionally, the microcontroller facilitates wireless data transmission and storage in the server, making it easily accessible to the assigned doctor and medical staff via the web or mobile application.

3-Supervisory stage

Once the data has been stored in the server, the doctor can access it anytime and anywhere. This feature enhances the doctor's work performance by enabling them to supervise more patients with greater accuracy simultaneously than the old systems. Furthermore, the stored information facilitates future predictions, increasing the system's reliability.

4-Monitoring stage

Nurses play a critical role in this stage as they are assigned tasks by the doctor based on the information received from the system via the web or mobile application. They are responsible for carrying out tasks such as administering medication, monitoring the patient's vital signs, and providing general care. Their role is essential in ensuring that the patient receives appropriate and timely care.

3.2 Main features

The system boasts several key features, including the use of various sensors to continuously monitor patient vital signs, such as heart rate, temperature, and blood pressure, to enhance medical staff efficiency. The system transmits this data wirelessly to the microcontroller, which in turn sends it to the servers for storage and processing. The transmitted data undergoes significant processing, including classification via machine learning algorithms. This process aids in displaying an accurate diagnosis of the patient and early detection of critical situations, saving the doctor valuable time. The associated mobile and web applications display this data, facilitating continuous monitoring of cardiac patients by the doctor.

Furthermore, machine learning models and patient history are used to predict the patient's future health state. These features combine to provide an efficient system for monitoring patients' vital signs, making it a valuable tool for medical staff.

3.3 System description

As shown in the block diagram the system is consisted of five stages, those stages work together to achieve the purpose of the system which is wirelessly monitoring the cardiovascular patients and apply analysis on their readings thus delivering them a better healthcare service first, the sensing stage, in this stage the system measures all the required inputs from the patients using the attached sensors on the patient’s body, then these measurements are then transferred to the processing stage which is responsible for the analysis and classification of the measured parameters using the trained machine learning model in use then these data are then transferred to the third stage the server site for storage and also transferred to the supervisory stage where the doctor supervise these readings, then the doctor can transfer these data to the nursing stage and the last stage where the nurses monitor the state of the patient.

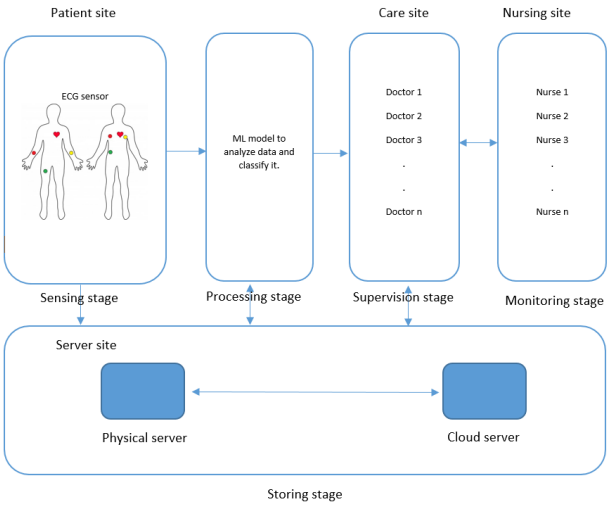

Fig. 3-1 Functional block diagram of the whole system

3.3.1 Sensing stage

Patient site is the only part of our system that connected to the patient (user) at sensors.

We will talk about what is a sensor first,

A sensor is a device that detects and responds to some type of input from the physical environment. The input can be light, heat, motion, moisture, pressure, or any number of other environmental phenomena. The output is generally a signal that is converted to a human-readable display at the sensor location or transmitted electronically over a network for reading or further processing.

Sensors can be categorized in multiple ways. One common approach is to classify them as either active or passive. An active sensor is one that requires an external power source to be able to respond to environmental input and generate output.

A passive sensor, on the other hand, doesn't require an external power source to detect environmental input. It relies on the environment itself for its power, using sources such as light or thermal energy.

Another way in which sensors can be classified is by whether they're analog or digital, based on the type of output the sensors produce. Analog sensors convert the environmental input into output analog signals, which are continuous and varying in contrast to analog sensors, digital sensors convert the environmental input into discrete digital signals that are transmitted in a binary format (1s and 0s). Digital sensors have become quite common across all industries, replacing analog sensors in many situations.

Sensors react to changing physical conditions by altering their electrical properties. Thus, most artificial sensors rely on electronic systems to capture, analyse, and relay information about the environment. These electronic systems rely on the same principles as electrical circuits to work, so the ability to control the flow of electrical energy is very important.

Put simply, a sensor converts stimuli such as heat, light, sound, and motion into electrical signals. These signals are passed through an interface that converts them into a binary code and passes this on to a computer to be processed.

Now we will talk about how does the sensor works, sensors react to changing physical conditions by altering their electrical properties. Thus, most artificial sensors rely on electronic systems to capture, analyse, and relay information about the environment. These electronic systems rely on the same principles as electrical circuits to work, so the ability to control the flow of electrical energy is very important.

Put simply, a sensor converts stimuli such as heat, light, sound, and motion into electrical signals. These signals are passed through an interface that converts them into a binary code and passes this on to a computer to be processed.

The stage of sensing the vital signs measure is the first stage and the most important stage since all the following stages depend on how much accurate this stage is, because this measurements will used as an input for the next stage that will process this data classify it and send this important information to The specialist doctor, so that any error or any false reading in this stage will affect all next stages.

This stage Consisting of number of sensors that connected directly to the patient that send continuous readings of vital signs measure as (temperature of the body, blood pressure heartrate and many other vital measures) and sending it to the next stage as an input the next stage process the data to convert it to useful information.

We will use number of sensors that will produce number of outputs this is better than use one sensor or depend on one reading because many input for the next stage will make the accuracy of the processing this data and classify it become more reliable.

Because this readings is not used only in the next stage only but all stages depend on this reading as the doctor receive this processed data as information that help him to provide the best medical care plan for the patient and the doctor can assignee to the nurses something to do for the patient based on the information that he received, this information is as sensor reading after it processed, this data is saved in the server (database) , so that If the patient is discharged and readmit again the saved data will help the medical staff (doctors) classify and diagnose patient quickly according to the history saved in the server (database).

3.3.2 Processing stage

After receiving the inputs from the sensors attached to the patients to the microcontroller, some processing should be done on those readings, first those readings should be classified or analysed by the machine learning model in use after the training of this machine learning model on known labelled dataset, there are many candidates machine learning models that can be used depending on the accuracy each model will provide, a selection will be made on those models to decide which one will be used to classify the readings of the sensors that will clarify the state of the patient to the medical staff, secondly after the classification the microcontroller will transfer

these data wirelessly to the server to be stored and to the web and mobile application that are used by the doctors in charge.

About the machine learning models, as mentioned before, there are many candidates for the machine learning models to be used, there are many types for the machine learning algorithms but most importantly the supervised and unsupervised machine learning models, since we need to classify the patient's disease (if any), so the supervised machine learning models will be very useful in such system, supervised machine learning models deals with datasets that contains a labelled results, those labels are the names of the diseases in our case, the candidate supervised machine learning models are K-Nearest Neighbour, Decision tree, Perceptron, Support Vector Machine , Naïve Bayes, Random forest, depending on the accuracy each one will provide, a decision will be made on which one will be used.

3.3.3 Supervisory stage

A remote patient monitoring system is more than a device that tracks a patient's vital signs and symptoms at a distance. It can also improve analytics, automate routine tasks, help organizations optimize expenses, and improve the quality of medical care.

Measurement of patients' vital signs through different devices and sensors helps in tracking patients all the time, besides any previous patients' data extracted from their medical history in the electronic medical record (EMR) or electronic health record (EHR).

EMR refers to everything you'd find in a paper chart, such as medical history, diagnoses, medications, immunization dates, and allergies but EHR may include past medical history, vital signs, progress notes, diagnoses, medications, immunization dates, allergies, lab data, and imaging reports. It can also contain other relevant information, such as insurance information, demographic data, and even data imported from personal wellness devices. So, the analysis of these data using the best techniques of machine learning algorithms helps doctors detect erratic patterns in patients' health early on to adjust the care regimen as necessary.

This wireless monitoring system gives doctors a lot of advantages such as:

1. It reduces the visits required by the doctor which reduces work hours.

2. Narrows the diagnosis of the patient's case as it gives him all possible diagnoses with percentages.

3. Continuous monitoring helps in predicting the near future state of the patient which helps the doctor to make the best decisions with the least error percentage.

4. Full access for the doctor to add, remove or edit any data in EHR or EMR using the user interface as a web-based application or mobile application

5. Monitoring the state of the patient and the care provided to him by the nursing staff.

6. Provides doctor with all details he might need to put a proper treatment plan and instructions for nursing staff for any emergency case.

After retrieving the required data from the sensing stage using different sensors, the data is processed by a machine learning model to narrow the diagnosis and the predicted case, then the data will be sent to 2 sites, the first site is the server to be stored, second is the doctor's stage who supervise these data, then it will be sent to the monitoring stage where nurses monitor patient's state and make required instructions, there is also a two-way channel between doctor stage and server to exchange data.

3.3.4 Monitoring stage

As individuals, nurses directly influence the health and wellbeing of patients every day. Through frequent contact, nurses are best placed to encourage lifestyle changes in communities and offer education on healthy living – particularly to the most vulnerable in society.

All nurses complete a rigorous program of extensive education and study, and work directly with patients, families, and communities using the core values of the nursing process.

Nurses have the potential to lead the way in improving health and health care for all, but to realize that potential they must operate in an environment that is safe, empowering, and satisfying.

Nurses can use this new technology in nursing wireless patient monitoring to measure multiple parameters from a single device.

This includes parameters such as:

1- Blood oxygen (SpO2)
2- Pulse rate and HRV
3- Respiratory rate
4- Activity
5- Sleep patterns

Nursing home caregivers can get automated real-time readings without having to wake or disturb patients. For nurses and caregivers managing multiple patients at a crowded nursing facility, data can be collected and monitored from a single remote location.

Wireless patient monitoring system can significantly increase the discovery of adverse conditions and improve care for all patients. It enables nursing home caregivers to more quickly identify trends or changes that lead to exacerbations to provide an early warning for deteriorating medical conditions.

The nurses receive the information of the patients from the doctors who get the information from the patient through sensors and to be analysed and classified to be supervised by the doctors and nurses and if any error or anything happened to the

patient will appear on the doctors' screen and subsequently it also appears on the nurses' screen; it will be as alert to help them.

Suppose that you are taking readings a few times day. You may notice that a patient's oxygen saturation has dropped. It could be because the patient was busy and active. Sure enough, ten minutes later, their oxygen saturation is back where it should be because it was just activity, not necessarily an exacerbation so that the nurses have big role in the wireless patient monitoring system.

3.3.5 Storing stage

The storing stage is concerned with storing the data that was measured from the sensors attached to the patients, it also stores the medical history of the patients for further analysis, helping the doctor to retrieve the stored data (patient's medical history) and add notes or extra data to it, using the web and mobile application is one of its functions too.

3.4 Software design

In this section, we will analyse the software design of the new wireless patient monitoring system for cardiovascular diseases. Specifically, we will examine the system's architecture, design patterns, and programming languages used to develop the software. Additionally, we will evaluate the system's ability to handle data, process information, and generate alerts and notifications. We will also examine the system's user interface design and its ability to support user interactions. This analysis aims to provide a comprehensive understanding of the software design of the new wireless patient monitoring system for cardiovascular diseases and its ability to meet the requirements necessary for effective patient monitoring and improved healthcare outcomes.

3.4.1 Flowchart diagram

The following flowchart illustrates the sequential stages of the system's operations, which commence with the attachment of measurement sensors to the patient's body by the medical staff. Subsequently, the sensors begin sensing the required measurements, which undergo several processes during the processing phase, including machine learning algorithms that analyse the patient's data.

The output of this phase comprises processed data that provides insights into the patient's current and future states. The doctor is granted full access control to the patient's data, enabling them to make well-informed decisions with the aid of ML suggestions, devise an appropriate treatment plan, and provide nursing staff with all necessary instructions. Ultimately, the nursing staff is responsible for monitoring the patient's condition.

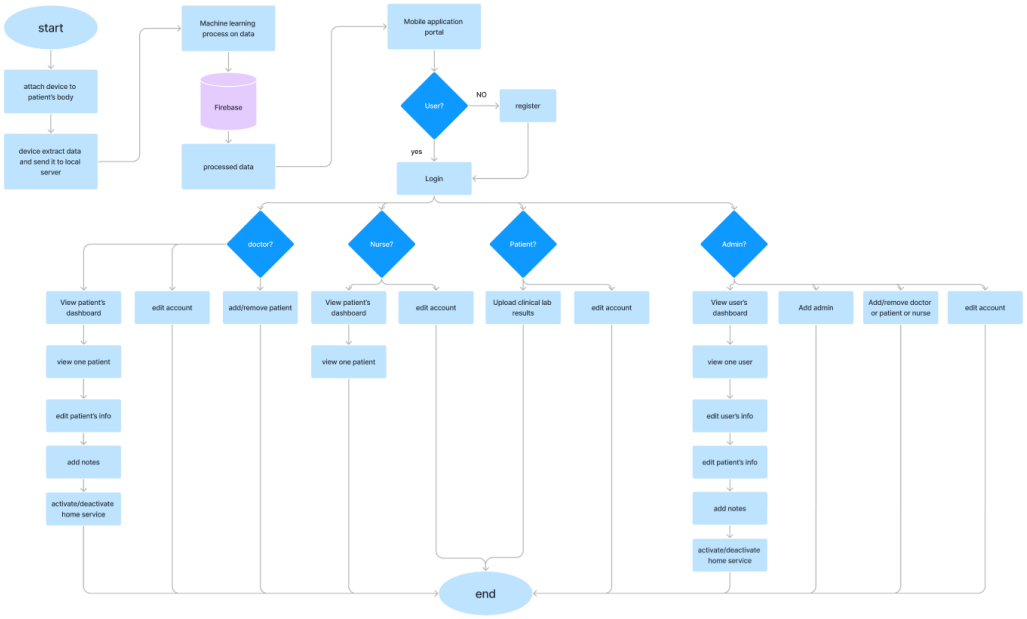

Fig. 3-2 flow chart diagram

3.4.2 Process diagram

The presented process diagram depicts the sequential stages of a comprehensive process, starting from the attachment of a sensor to the body for the measurement of relevant parameters. The obtained data is then subjected to pre-processing to ensure its suitability for use in various algorithms, such as DT, KNN, CNN, and perceptron, during the machine learning phase.

The processed output of this phase includes the patient's measurements, potential diagnosis, and intelligent suggestions generated using ML. This valuable information can assist doctors in making swift and informed decisions, thereby reducing both effort and time required for the diagnosis and treatment of patients. Additionally, doctors have full accessibility to modify the data and provide clear instructions to the nursing staff, ensuring that the patient receives all necessary care in emergency situations.

Fig. 3-3 Process diagram

3.4.3 Entity Relationship Diagram

The Entity Relationship Diagram (ERD) is a graphical representation of how entities in a database are related to each other. In this particular ERD, there are three entities, each containing various attributes.

The first entity is the role ID, which represents the user's role as either a doctor or a nurse. This entity has only one attribute, which is the name of the role.

The second entity is the user, which represents the doctor or nurse. This entity has attributes such as a unique ID, name, email, password, and phone number.

The user entity and the role entity are related to each other, as each user has a role with a role ID acting as a foreign key.

The third entity is the patient, which has a unique ID, name, phone number, age, gender, cholesterol level, exercise habits, angina status, fasting blood sugar levels, type of angina, description of the case, and prediction of the heart state in the near future.

The user entity and the patient entity have a relationship, as the user (doctor or nurse) manages the patient's case and data, with the doctor ID acting as a foreign key.

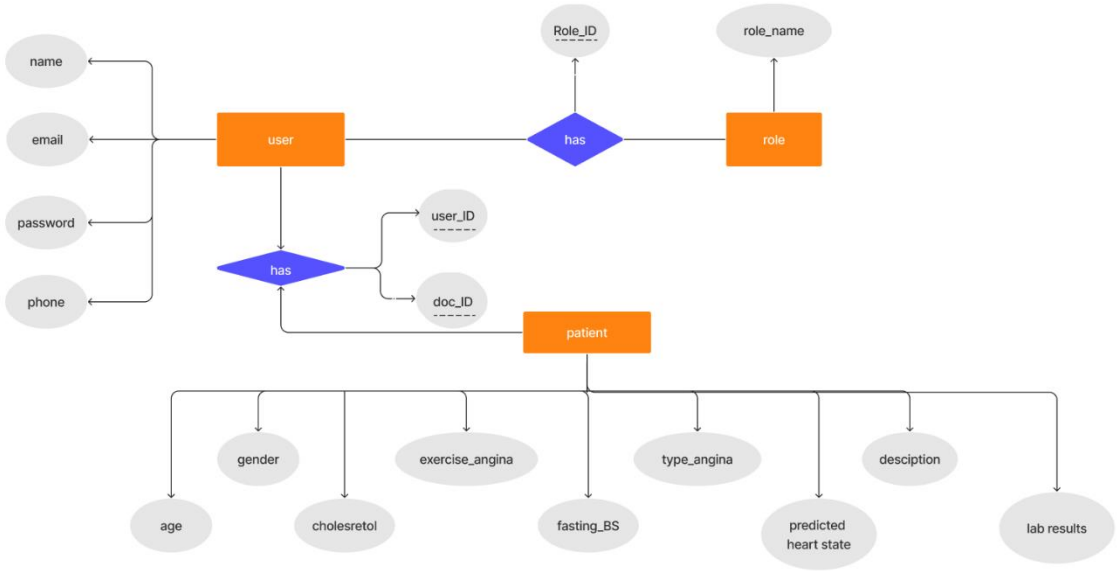

Fig. 3-4 Entity relationship diagram

3.4.4 Relational model schema

This model clarifies the relationship between database tables which are established through the use of foreign keys. By using foreign keys, the Relational Model clarifies the relationships between tables and ensures data consistency and integrity.

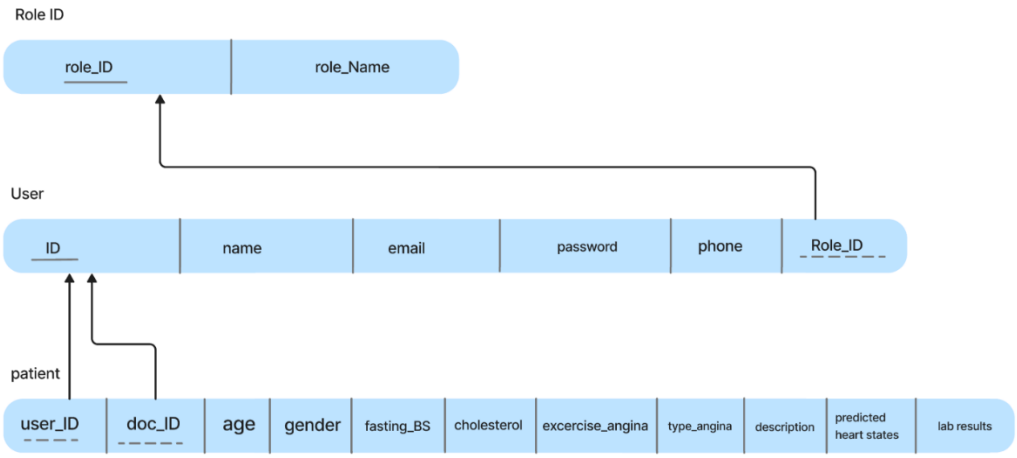

Fig. 3-5 Relational model

3.4.5 Class diagram

The class diagram is a visual representation of the organization of a system or application, depicting the classes, interfaces, methods, and attributes of the objects within it, as well as the connections between them.

When implementing the Singleton design pattern, the classes of User, Patient, and Admin are linked to the Database class to allow for the retrieval and sending of data. The Admin class has the ability to manage both User and Patient objects, including adding, removing, and editing them, which creates an association relationship between them. Additionally, the Doctor and Nurse classes are derived from the User class, while the Patient object is accessible by the User class.

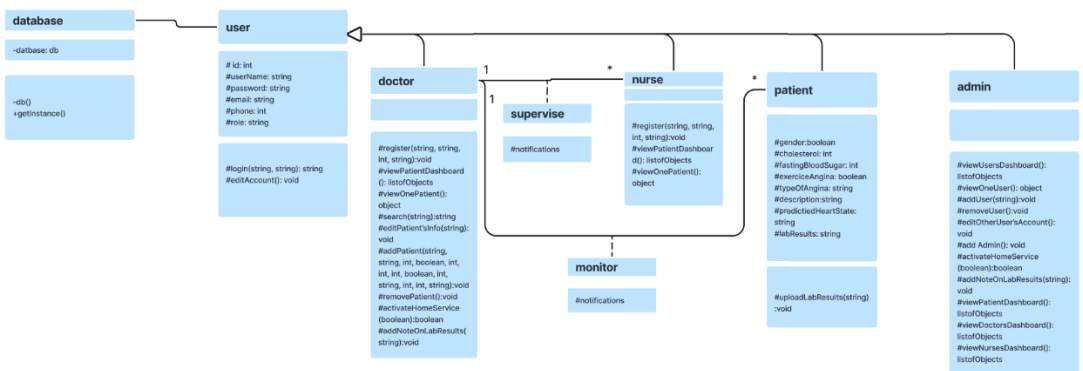

Fig. 3-6 Class diagram

3.4.6 Use case diagram

The use case diagram provides an overview of the system's functionalities for different user types, including doctors, nurses, and administrators.

Users are able to log in, register, and view patient information, with the level of access varying depending on their role. Specifically, doctors are authorized to edit patient information, as well as add or remove patient records.

Nurses, on the other hand, are limited to viewing patient information and are not authorized to edit or add/remove patient records. Administrators have access to all functionalities of the system and can add, remove, or edit user accounts for doctors, patients, and nurses.

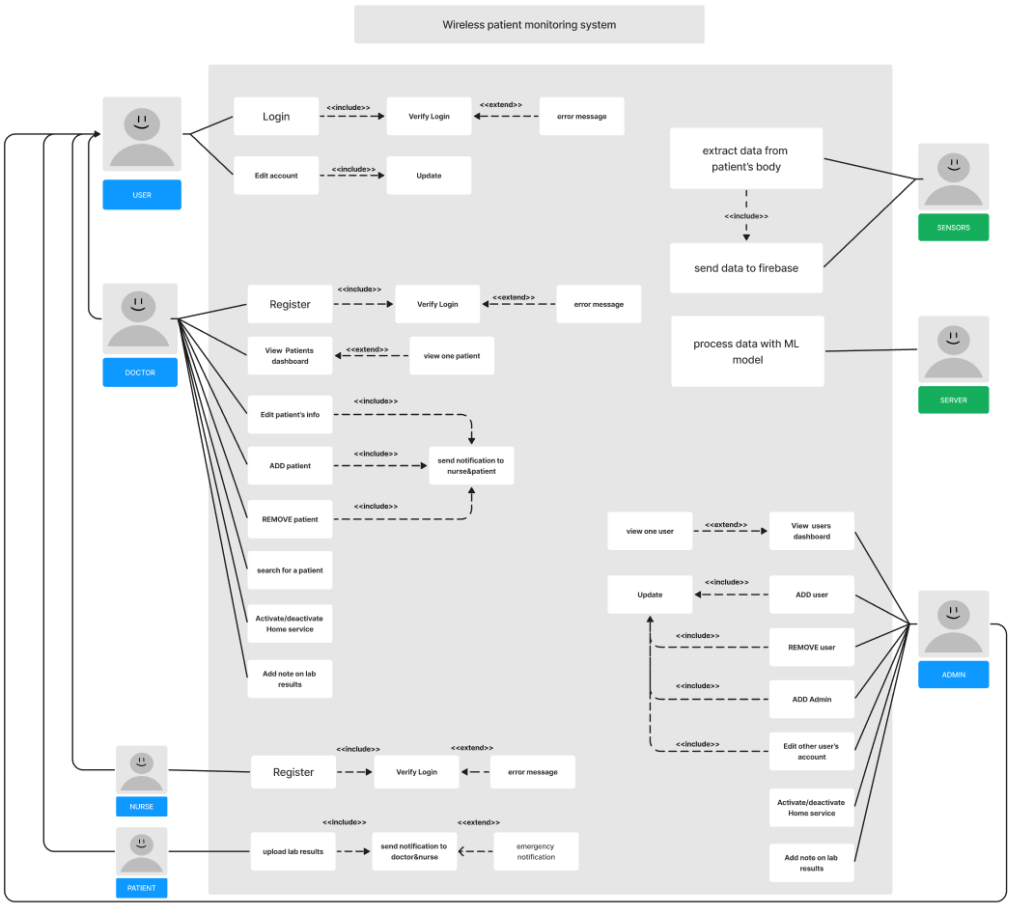

Fig. 3-7 Use case diagram

3.4.7 Sequence diagram

A sequence diagram summarizes the flow of events or actions that take place in a particular use case or scenario in a visual and easy-to-understand manner. It provides a clear and concise representation of the system's behaviour and shows how objects or components interact with each other over time.

This sequence diagram depicts the registration and login process for doctors, including an alternative case where the doctor is already registered. If the doctor is already registered, the diagram shows that the user interface will prompt the doctor to enter their credentials. If the credentials are correct, the user interface will send a verification message to the Firebase database, which will reply with a confirmation message. The user interface will then reply with a message to indicate that the doctor has been logged in. If the credentials are incorrect, the Firebase database will reply with a message indicating that the user is not verified, and the user interface will reply with a message to indicate that the email or password is invalid.
In the alternative case where the doctor is not registered, the diagram shows that the user interface will prompt the doctor to register. The user interface will then verify the doctor's information with the Firebase database, which will reply with a verification message. The user interface will then reply with a message to indicate that the doctor has been registered and logged in. Overall, the sequence diagram provides a clear and concise representation of the registration and login process for doctors, including the necessary interactions between the user interface and the Firebase database.

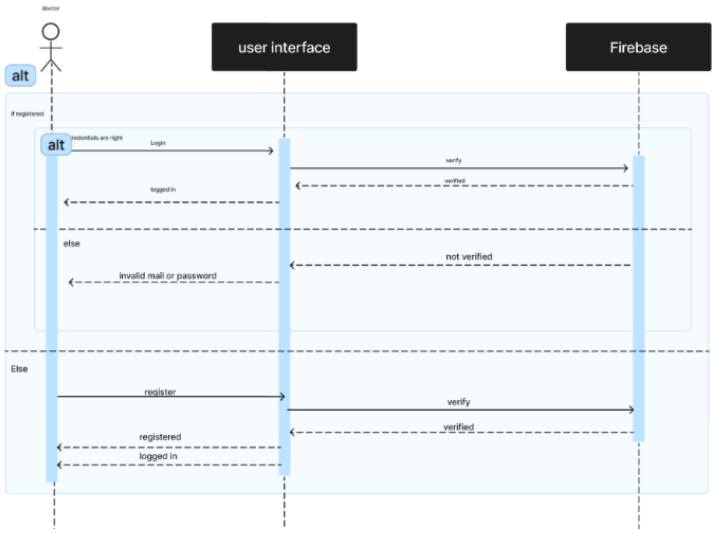

Fig. 3-8 doctor's login

In this sequence diagram, the doctor requests to view the list of patients. The diagram shows that the user interface initiates the request to retrieve the list from the Firebase database. The Firebase database then retrieves the list and sends it back to the user interface. The user interface will then display the list of patients to the doctor. This sequence demonstrates the interaction between the user interface and the Firebase database to retrieve and display patient data to the doctor.

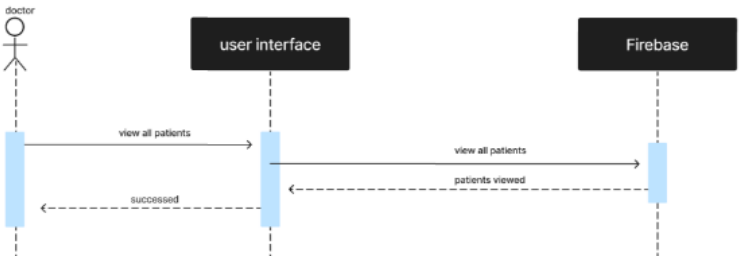

Fig. 3-9 doctor views patients list

In this sequence diagram, the doctor requests to view the information page of a specific patient. The diagram shows that the user interface initiates the request to retrieve the patient's information from the Firebase database. The Firebase database then retrieves the requested information and sends it back to the user interface. The user interface will then display the patient's information page to the doctor. This sequence demonstrates the interaction between the user interface and the Firebase database to retrieve and display specific patient data to the doctor.

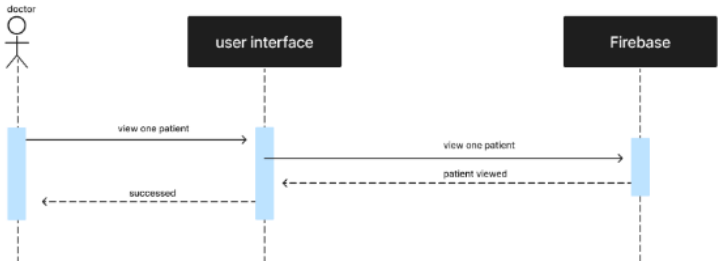

Fig. 3-10 doctor views one patient

In this sequence diagram, the doctor requests to edit the information of a specific patient. The diagram shows that the user interface initiates the request to edit the patient's information in the Firebase database. The Firebase database then receives the edit request and updates the patient's information accordingly.

After the Firebase database updates the patient's information, it sends a confirmation message back to the user interface. The user interface will then confirm to the doctor that the patient's information has been successfully edited. This sequence demonstrates the interaction between the user interface and the Firebase database to edit and update specific patient data by the doctor.

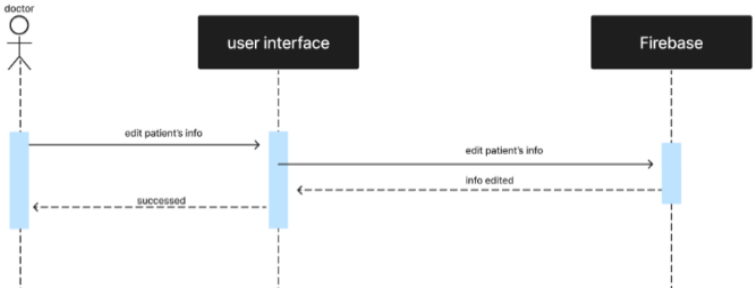

Fig. 3-11 doctor edits patient's info

In this sequence diagram, the doctor requests to add a new patient to the system. The diagram shows that the user interface initiates the request to add the patient to the Firebase database. The Firebase database then receives the request and adds the new patient to its database.

After the Firebase database adds the new patient, it sends a confirmation message back to the user interface. The user interface will then confirm to the doctor that the

patient has been successfully added to the system. This sequence demonstrates the interaction between the user interface and the Firebase database to add new patient data by the doctor.

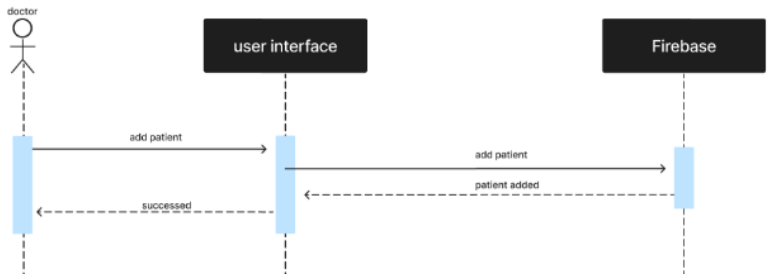

Fig. 3-12 doctor adding patient

In this sequence diagram, the doctor requests to remove the patient from the system. The diagram shows that the user interface initiates the request to remove the patient from the Firebase database. The Firebase database then receives the request and removes the patient from its database.

After the Firebase database removes the patient, it sends a confirmation message back to the user interface. The user interface will then confirm to the doctor that the patient has been successfully removed from the system. This sequence demonstrates the interaction between the user interface and the Firebase database to add new patient data by the doctor.

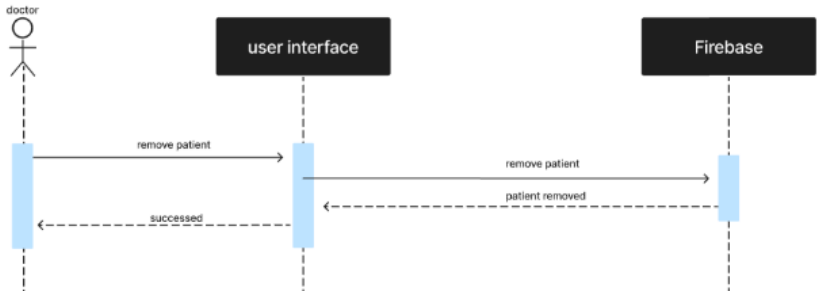

Fig. 3-13 doctor removing patient

In this sequence diagram, the doctor initiates a request to edit his own information. The user interface receives the request and communicates with Firebase to modify the necessary data. Firebase updates the doctor's information in its database and sends a confirmation message back to the user interface. The user interface then confirms to the doctor that his information has been successfully updated. This sequence demonstrates the interaction between the doctor, user interface, and Firebase database to edit the doctor's information.

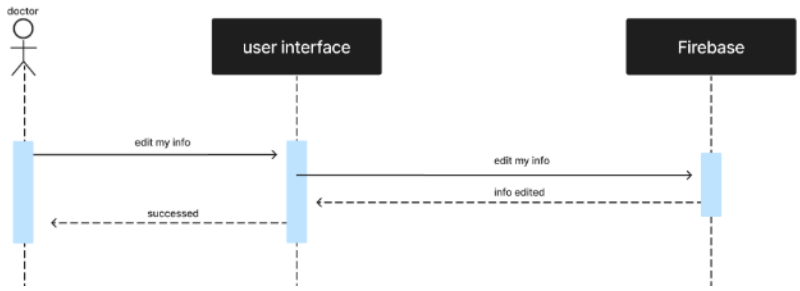

Fig. 3-14 doctor edits his info

This sequence diagram demonstrates the process of a doctor requesting the activation of home services for a patient in the system. The doctor initiates the request from the user interface to activate home services for the patient in the Firebase database. The user interface communicates with Firebase to activate the home services for the patient in the database. Firebase responds with a confirmation message to the user interface, indicating that the home services have been successfully activated. The user interface then confirms to the doctor that the home services have been activated for the patient. This sequence demonstrates the interaction between the doctor, user interface, and Firebase database to request and activate home services for a patient in the system. The feature for activating home services is an important aspect of the system, as it allows for efficient and convenient healthcare services to be provided to patients in the comfort of their own homes, which can be especially beneficial for patients who are unable to travel to a healthcare facility due to their condition.

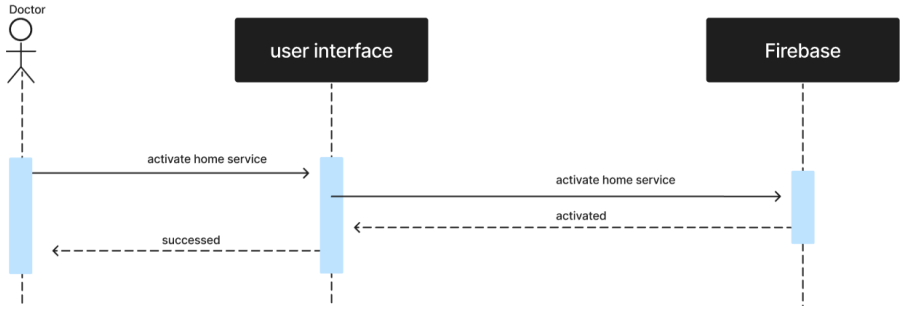

Fig. 3-15 doctor activating home service

In this sequence diagram demonstrates the process of a doctor adding notes to a patient's lab results in the system. The doctor initiates the request from the user interface to add notes to the patient's lab results in the Firebase database. The user communicates with Firebase to add the note to the patient's lab results in the database. Firebase responds with a confirmation message to the user interface, indicating that the note has been successfully added. The user interface then confirms to the admin that the note has been added to the patient's lab results. This sequence demonstrates the interaction between the doctor, user interface, and Firebase database to add notes to a patient's lab results in the system. The feature for adding notes is an important aspect of the system, as it allows for efficient and accurate

communication between healthcare providers and ensures that patient data is up-to-date and comprehensive.

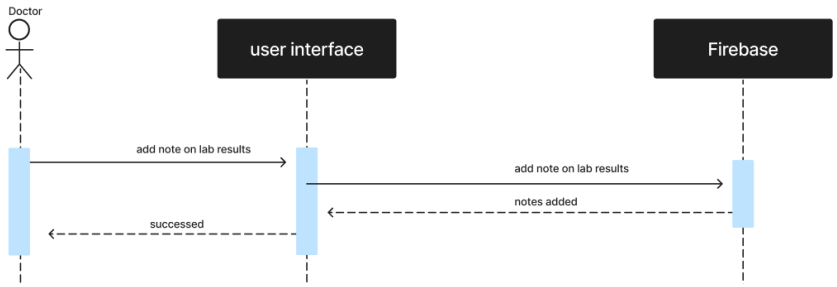

Fig. 3-16 doctor adding notes on lab results

This sequence diagram illustrates the registration and login process for nurses, which includes an alternative case where the nurse is already registered. If the nurse is already registered, the user interface prompts them to enter their credentials. If the credentials are correct, the user interface sends a verification message to the Firebase database, which responds with a confirmation message. The user interface then confirms that the nurse has been logged in. If the credentials are incorrect, the Firebase database sends a message indicating that the nurse is not verified, and the user interface responds with a message indicating that the email or password is invalid. In the alternative case where the nurse is not registered, the user interface prompts them to register. The user interface verifies the nurse's information with the Firebase database, which responds with a verification message. The user interface then confirms that the nurse has been registered and logged in. Overall, the sequence diagram provides a clear and concise representation of the registration and login process for nurses, including the necessary interactions between the user interface and the Firebase database.

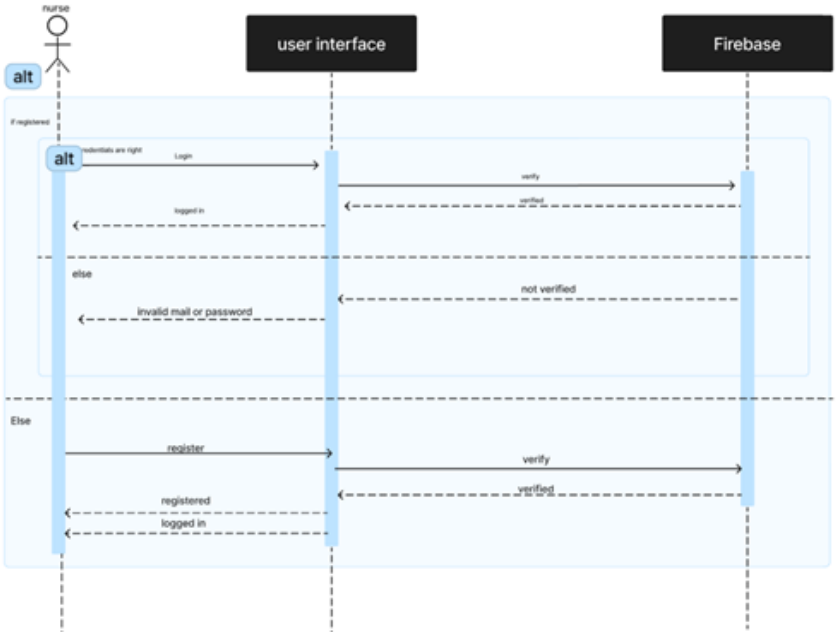

Fig. 3-17 nurse's login and register

This sequence diagram depicts the process of a nurse requesting to view the list of patients. The user interface initiates the request to retrieve the list from the Firebase database. The Firebase database retrieves the list and sends it back to the user interface. The user interface then displays the list of patients to the nurse. This sequence demonstrates the interaction between the nurse, user interface, and Firebase database to retrieve and display patient data for the nurse.

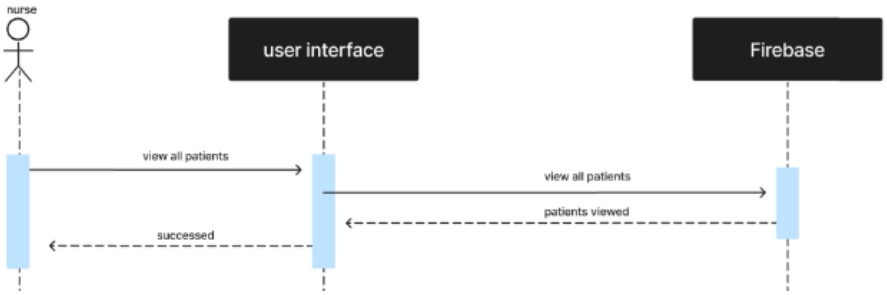

Fig. 3-18 nurse views list of patients

This sequence diagram illustrates the process of a nurse requesting to view the information page of a specific patient. The user interface initiates the request to retrieve the patient's information from the Firebase database. The Firebase database then retrieves the requested information and sends it back to the user interface. The user interface displays the patient's information page to the nurse. This sequence demonstrates the interaction between the nurse, user interface, and Firebase database to retrieve and display specific patient data for the nurse.

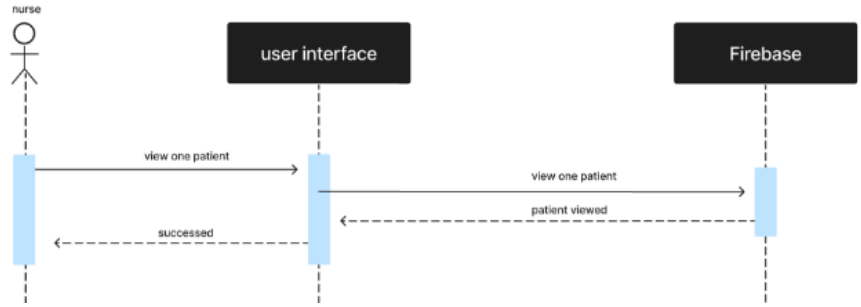

Fig. 3-19 nurse views one patient

This sequence diagram shows the process of a nurse initiating a request to edit their own information. The user interface receives the request and communicates with Firebase to modify the necessary data. Firebase updates the nurse's information in its database and sends a confirmation message back to the user interface. The user interface then confirms to the nurse that their information has been successfully updated. This sequence demonstrates the interaction between the nurse, user interface, and Firebase database to edit the nurse's information.

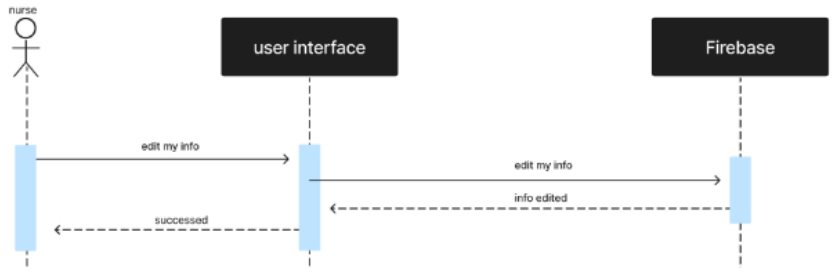

Fig. 3-20 nurse edits her info

In this sequence diagram depicts the login process for admins, including an alternative case where the admin is already registered. If the admin is already registered, the user interface prompts them to enter their credentials. If the credentials are correct, the user interface sends a verification message to the Firebase database, which responds with a confirmation message. The user interface then confirms that the admin has been logged in. If the credentials are incorrect, the Firebase database sends a message indicating that the admin is not verified, and the user interface responds with a message indicating that the email or password is invalid. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to authenticate and log in the admin.

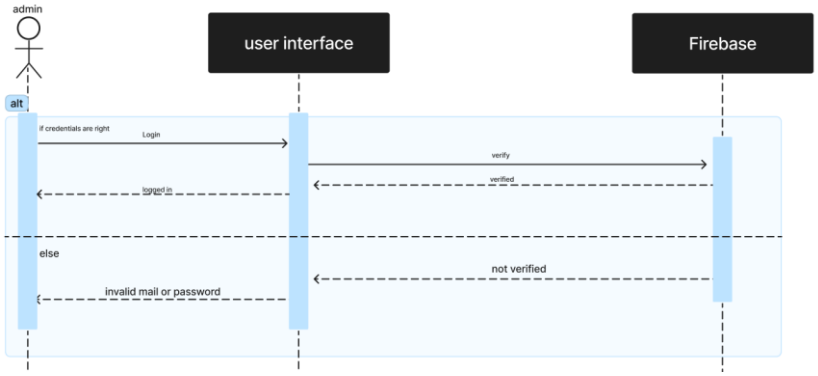

Fig. 3-21 Admin's login

This sequence diagram demonstrates the process of an admin requesting to view the dashboard of all users. The admin initiates the request from the user interface, which communicates with Firebase to retrieve the necessary data. Firebase responds to the request by sending a confirmation message back to the user interface. This sequence shows the interaction between the admin, user interface, and Firebase database to retrieve and display all users' dashboard information.

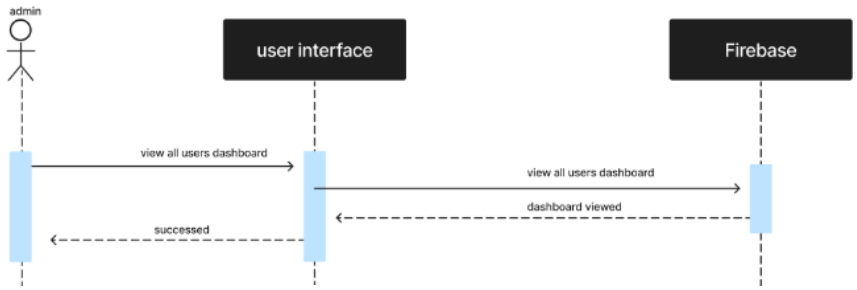

Fig. 3-22 Admin views all users dashboard.

This sequence diagram illustrates the process of an admin requesting to view the dashboard of all patients. The user interface initiates the request to retrieve the dashboard information from the Firebase database. The Firebase database retrieves the necessary data and sends it back to the user interface. The user interface then displays the dashboard information of all patients to the admin. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to retrieve and display all patients' dashboard information.

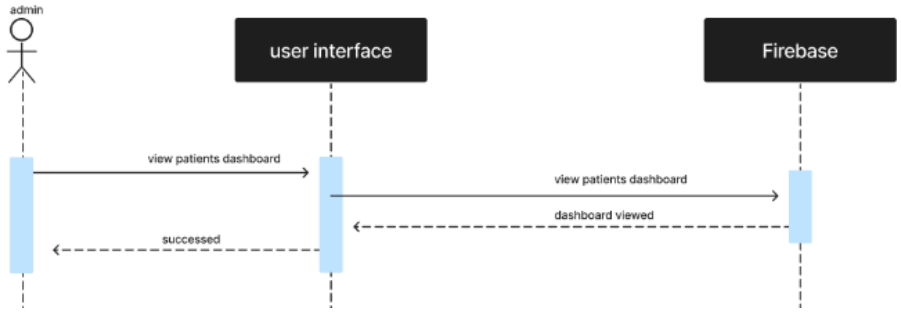

Fig. 3-23 Admin views patients' dashboard

This sequence diagram depicts the process of an admin requesting to view the dashboard of all nurses. The user interface initiates the request to retrieve the dashboard information from the Firebase database. The Firebase database retrieves the necessary data and sends it back to the user interface. The user interface then displays the dashboard information of all nurses to the admin. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to retrieve and display all nurses' dashboard information.

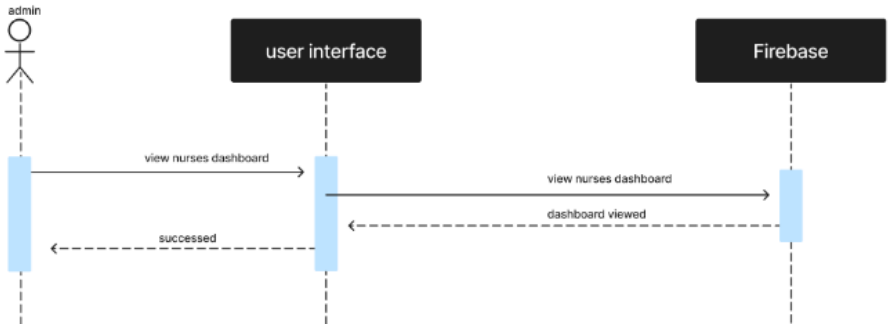

Fig. 3-24 Admin views nurses' Dashboard

This sequence diagram illustrates the process of an admin requesting to view the dashboard of all doctors. The user interface initiates the request to retrieve the dashboard information from the Firebase database. The Firebase database retrieves the necessary data and sends it back to the user interface. The user interface then displays the dashboard information of all doctors to the admin. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to retrieve and display all doctors' dashboard information.

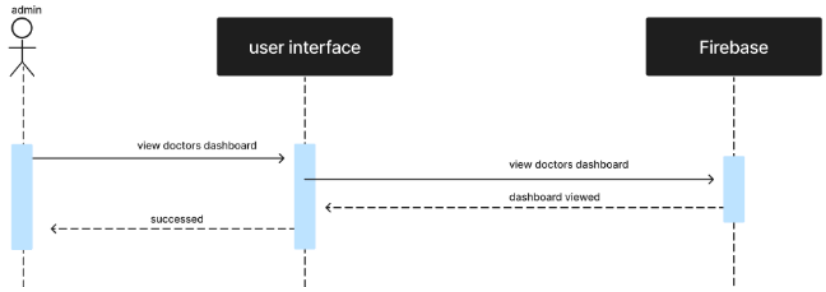

Fig. 3-25 admin views doctors' dashboard

This sequence diagram illustrates the process of an admin requesting to view the info of a specific user. The user interface initiates the request to retrieve the information for the selected user from the Firebase database. The Firebase database retrieves the necessary data and sends it back to the user interface. The user interface then displays the dashboard information of the selected user to the admin. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to retrieve and display the dashboard information of a single user.

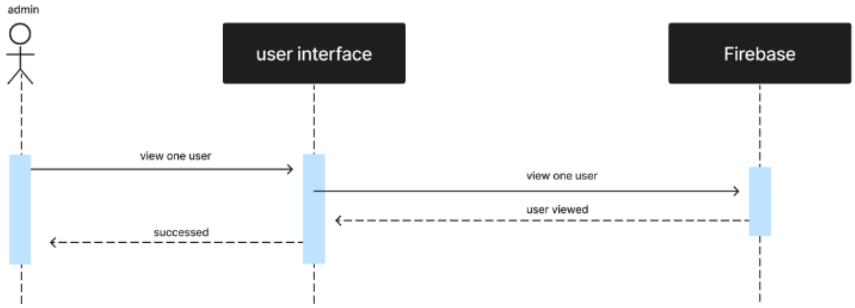

Fig. 3-26 admin views one user

This sequence diagram depicts the process of an admin adding a new user. The admin initiates the request from the user interface to add a new user to the Firebase database. The user interface collects the necessary information from the admin and communicates with Firebase to add the new user's information to the database. Firebase responds with a confirmation message to the user interface, indicating that the new user has been successfully added. The user interface then confirms to the admin that the new user has been added. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to add a new user to the system.

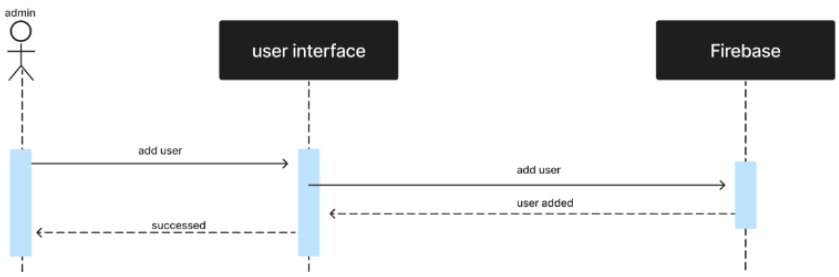

Fig. 3-27 admin adding user

This sequence diagram illustrates the process of an admin removing a user. The admin initiates the request from the user interface to remove a user from the Firebase database. The user interface communicates with Firebase to remove the user's information from the database. Firebase responds with a confirmation message to the user interface, indicating that the user has been successfully removed. The user interface then confirms to the admin that the user has been removed from the system. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to remove a user from the system.

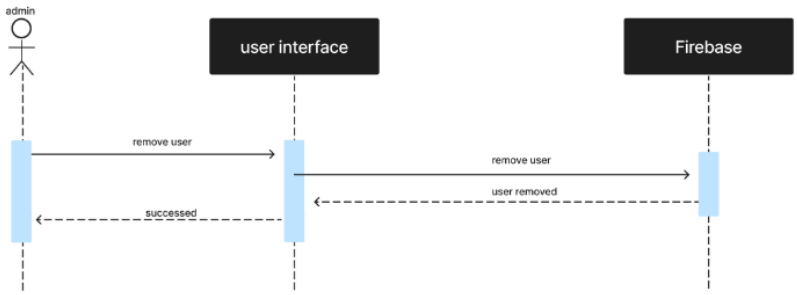

Fig. 3-28 admin removing user

This sequence diagram depicts the process of an admin editing a user's information. The admin initiates the request from the user interface to modify a user's information in the Firebase database. The user interface collects the updated information from the admin and communicates with Firebase to modify the user's information in the database. Firebase responds with a confirmation message to the user interface, indicating that the user's information has been successfully updated. The user interface then confirms to the admin that the user's information has been modified. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to edit a user's information in the system.

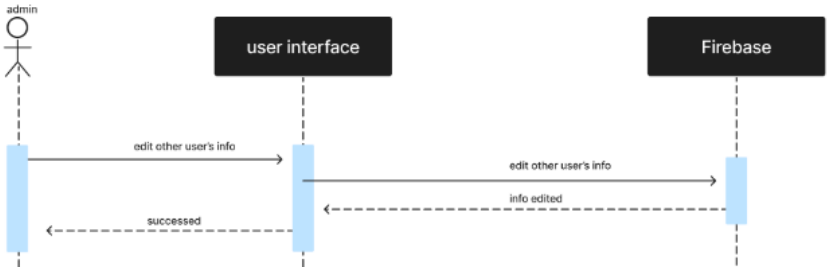

Fig. 3-29 admin edits user's info

This sequence diagram illustrates the process of an admin editing their own information. The admin initiates the request from the user interface to modify their information in the Firebase database. The user interface collects the updated information from the admin and communicates with Firebase to modify their information in the database. Firebase responds with a confirmation message to the user interface, indicating that the admin's information has been successfully updated. The user interface then confirms to the admin that their information has been

modified. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to edit the admin's own information in the system.

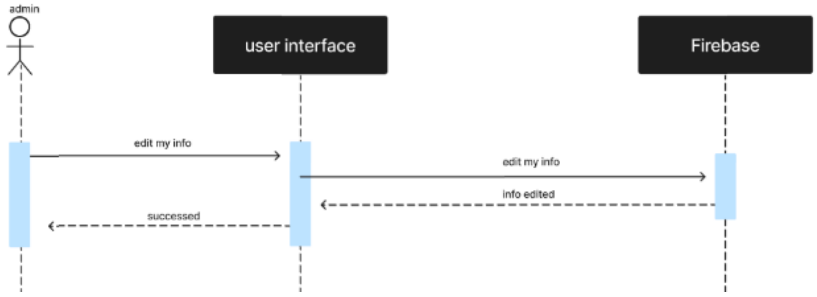

Fig. 3-30 admin edits his info

This sequence diagram demonstrates the process of an admin activating home services for a patient in the system. The admin initiates the request from the user interface to activate home services for the patient in the Firebase database. The user interface communicates with Firebase to activate the home services for the patient in the database. Firebase responds with a confirmation message to the user interface, indicating that the home services have been successfully activated. The user interface then confirms to the admin that the home services have been activated for the patient. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to activate home services for a patient in the system. The feature for activating home services is an important aspect of the system, as it allows for efficient and convenient healthcare services to be provided to patients in the comfort of their own homes.

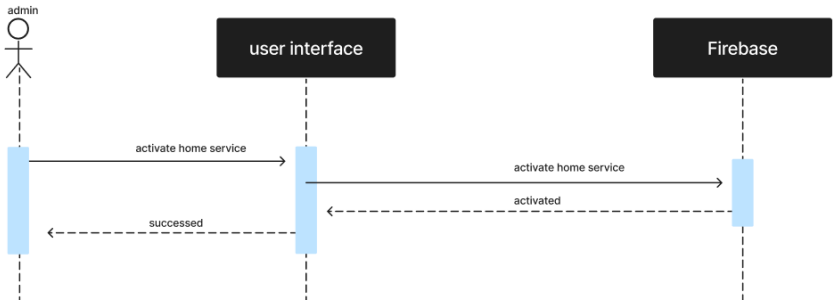

Fig. 3-31 Admin activates home service

In this sequence diagram demonstrates the process of an admin adding notes to a patient's lab results in the system. The admin initiates the request from the user interface to add notes to the patient's lab results in the Firebase database. The user communicates with Firebase to add the note to the patient's lab results in the database. Firebase responds with a confirmation message to the user interface, indicating that the note has been successfully added. The user interface then confirms to the admin that the note has been added to the patient's lab results. This sequence demonstrates the interaction between the admin, user interface, and Firebase database to add notes to a patient's lab results in the system. The feature for adding notes is an important aspect of the system, as it allows for efficient and accurate

communication between healthcare providers and ensures that patient data is up-to-date and comprehensive.

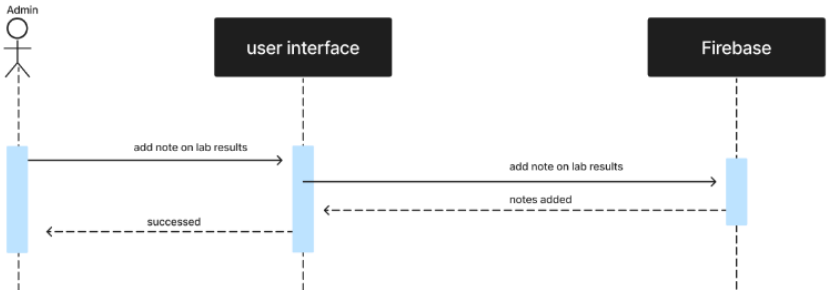

Fig. 3-32 Admin adds note on lab results

This sequence diagram depicts the login process for patients, including an alternative case where the patient is already added by the doctor. The user interface prompts them to enter their login credentials. If the credentials are correct, the user interface sends a verification message to the Firebase database, which responds with a confirmation message. The user interface then confirms that the patient has been logged in. If the credentials are incorrect, the Firebase database sends a message indicating that the patient is not verified, and the user interface responds with a message indicating that the email or password is invalid. This sequence demonstrates the interaction between the patient, user interface, and Firebase database to authenticate and log in the patient.

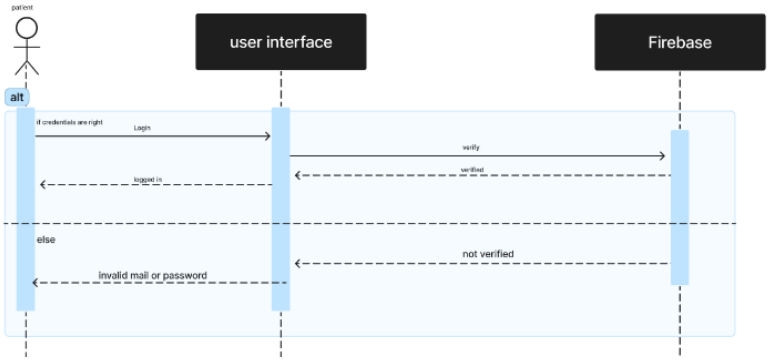

Fig. 3-33 patient login

This sequence diagram illustrates the process of an patient editing their own accessible information. The patient initiates the request from the user interface to modify their information in the Firebase database. The user interface collects the updated information from the patient and communicates with Firebase to modify their information in the database. Firebase responds with a confirmation message to the user interface, indicating that the patient's information has been successfully updated. The user interface then confirms to the admin that their information has been modified. This sequence demonstrates the interaction between the patient , user interface, and Firebase database to edit the patient's own information in the system.

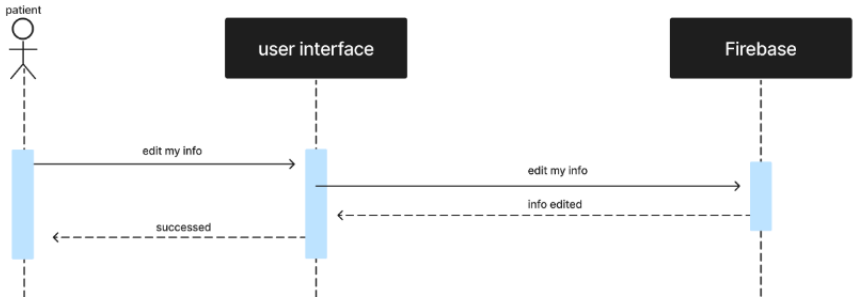

Fig. 3-34 patient edits his accessible info

This sequence diagram depicts the process of a patient uploading their lab results using an opt function, with the condition that home services are activated in the system. If the home services are activated, the user interface provides the patient with an option to upload their lab results. The patient initiates the request by selecting the upload lab results option, which prompts the user interface to collect the necessary information from the patient, such as the test type and results. The user interface then communicates with Firebase to upload the lab results to the database. Firebase responds with a confirmation message to the user interface, indicating that the lab results have been successfully uploaded. The user interface then confirms to the patient that the lab results have been uploaded to the system.

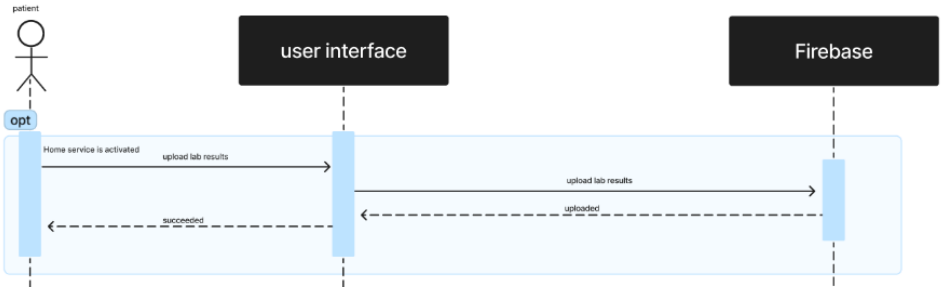

Fig. 3-35 patient uploading lab results

3.4.8 Activity diagram

The activity diagram provides a visual representation of the flow of the system and the user's journey through it, starting from the on boarding pages and leading to the login or registration page. From there, the user is directed to the home page, where the available functionalities are dependent on the user's specific role, whether it be admin, doctor, or nurse.

The diagram can help to clarify the sequence of steps and decision points in the user's journey, allowing for a better understanding of the system's behaviour and potential areas for optimization or improvement. It also provides a clear overview of the different roles and their associated functionalities, ensuring that users are directed to the appropriate pages and actions.

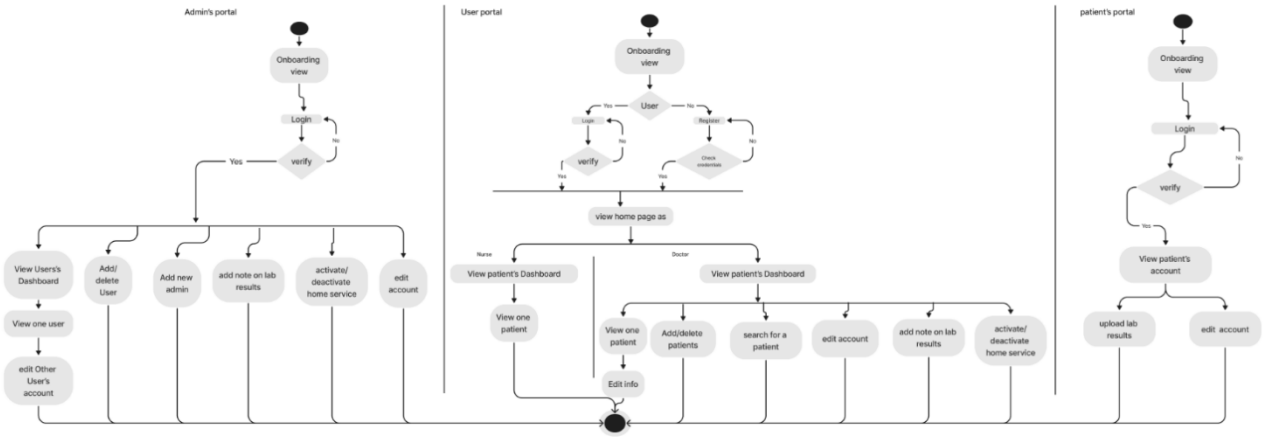

Fig. 3-36 Activity diagram

3.5 Components list

1. A generic idea of how heart sensors and measuring the heart rate works

• These sensors are capable of measuring the heart rate and the oxygen percentage in the blood, its main idea is based on the infra-red light that is emitted from the sender passing through the finger all the way to the receiver, knowing that the oxygenated blood absorbs more infra-red light than the deoxygenated one, in other words, when the receiver gets a small amount of infra-red light it indicates that the blood is oxygenated properly and when the receiver senses a small amount of infra-red light it indicates that the blood is deoxygenated (it also can calculate a percentage of how much infra-red got absorbed and accordingly calculate the oxygen percentage), which leads to the ability of calculating the heart rate of the patient according to that difference in the concentration of the received infra-red light, in other words, with every small amount of infra-red received it means that the blood is oxygenated which indicates a new heart pulse, there are few candidates in the market.(MAX30100, ECG AD8232, heart rate sensor for Arduino & raspberry pi)

2. Arduino Uno as microcontroller

• The Arduino Uno is a low cost, credit-card sized computer that plugs into a computer monitor. Besides the main microcontroller chip, a microcontroller will require many different parts to work. What Arduino did was take away all the essential components of a microcontroller and design it so that it is effortless to operate on a piece of Printed Circuit Board (PCB) — making it very

welcoming to all beginners. In our design the main functionality of Arduino is to be used as transmitter and receiver between the medical sensors and the virtual server to send the output to be analysed and possessed by machine learning algorithm to start the phase of diagnosis, classification and prediction.

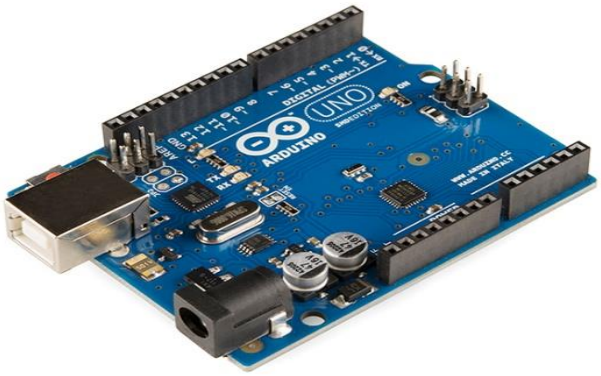

Fig. 3-37 Arduino Uno

3. Wi-Fi module

• The Wi-Fi module (ESP8266) will provide the ability to transmit data that was previously read from the sensors attached to the patient to the servers for processing and displaying afterwards there are multiple candidates in the markets such as RN-XV WiFly Module - U.FL Connector that would be a good example of the Wi-Fi module that can be used as it is compatible with most of the micro controllers such as the raspberry pi.

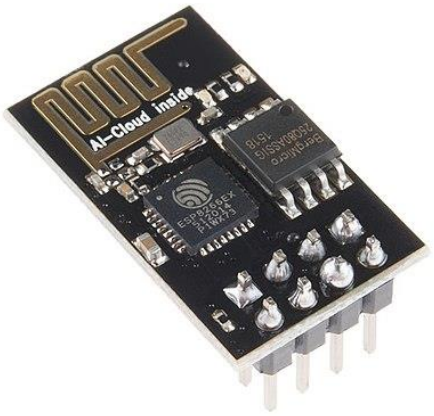

Fig. 3-38 Wi-Fi module

4. Switches

- The primary purpose of a switch is to control the flow of electric current within a circuit, and to allow the user to turn the circuit on and off as needed.

Chapter 4 : System Design and Implementation

4.1 Hardware design

The schematic diagram describes the hardware simplified model we are working on, which is an Arduino function as our microcontroller to receive the data from sensors and send it to the server to start the processing phase.

The main sensor in this model is AD8232 which is known commercially as the electrocardiogram (ECG) to monitor heart activity by recording electrical signals in the heart as it will help in diagnosis if there is any heart failure that might happen or not usually for 24 to 48 hours.

Also, the Wi-Fi module (ESP8266) connects the Arduino and the server to exchange data and different processes.

All these components will make a small, portable, and usable model to monitor heart activity with variable usages, a patient may use it at home to monitor his health under the supervision of his doctor, and it also may be used in an ambulance car with a patient who suspected to have a problem in heart to have all the possible information before they reached the hospital and in this way the medical staff can prepare any required preparations until the patient arrives to start immediately without any waste of time, or the basic use in hospital rooms to monitor the patients.

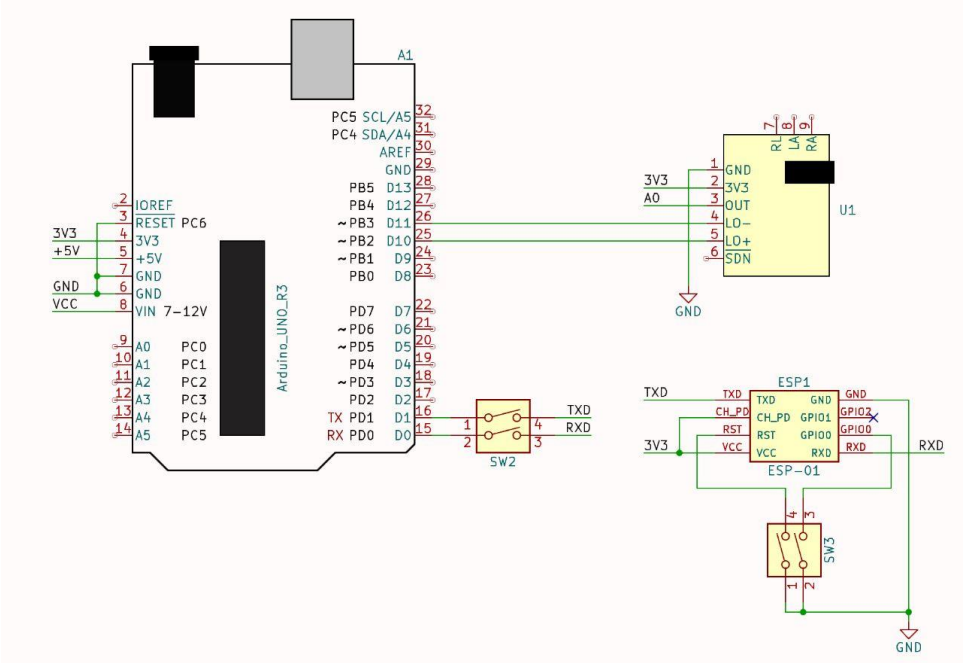

Fig. 4-1 Schematic diagram

The 3D model in the following figure shows the device's external structure, including its shape, size, and contours. It also displays the internal components and their arrangement within the device

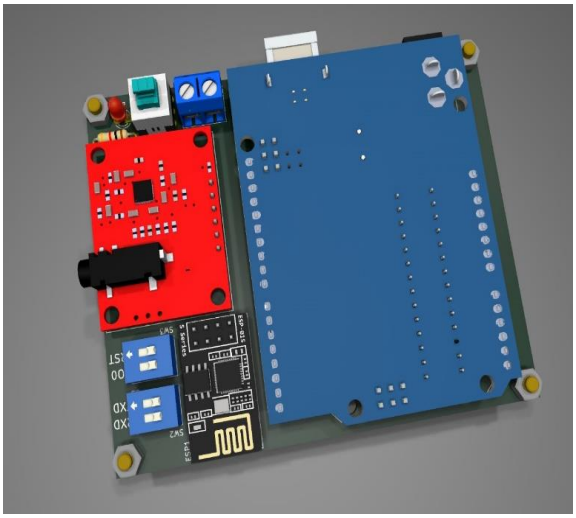

Fig. 4-2 3D model

And this is the Printed Circuit board (PCB) for the device.

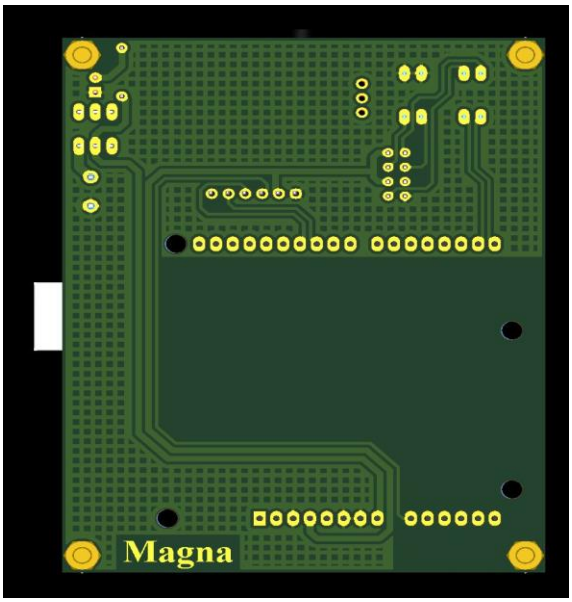

Fig. 4-3 PCP board

4.2 Machine learning

In order to facilitate the early diagnosis and treatment of potential heart failure, it was necessary to identify a suitable supervised machine learning model that could be integrated into our system. As cardiovascular diseases represent a leading cause of death worldwide, accurate early prediction is crucial in saving countless lives. To this end, we evaluated several different machine learning models, including KNN, DT, and MLP, in order to determine the most effective approach.

After careful consideration, we determined that the Random Forest model was the most suitable option for our needs, offering a high level of accuracy at 94.16%. This algorithm is commonly used in classification and regression problems in machine learning, and is based on the concept of ensemble learning. Essentially, this involves

combining multiple classifiers to solve complex problems and improve overall model performance.

The Random Forest model is composed of numerous decision trees, each trained on different subsets of the given dataset. By taking the average of these trees, the model is able to improve its predictive accuracy and problem-solving ability. Following training on a heart failure dataset, we were able to achieve an accuracy of 94.16%. This dataset can be found at the following link: dataset.

Overall, the use of the Random Forest model represents a significant step forward in accurately predicting potential heart failure, and has the potential to save countless lives through early diagnosis and treatment. And this dataset could be found here dataset .

4.3 software application

Our software is designed to cater to the needs of patients, doctors, and nurses with a mobile app, while admins can manage the entire process through a website. The mobile app provides patients with easy access to their healthcare information and allows them to interact with healthcare providers. The website provides admins with the ability to control the entire system, including managing user accounts, accessing patient data, and overseeing the overall process. This multi-platform approach ensures that our software is accessible and user-friendly for all stakeholders involved in the healthcare process.

4.3.1 Admin's website portal

Within the website's initial user interface, the primary page that is presented to the user is an on-boarding page which serves the purpose of introducing the user to the website's various features and functions, as well as providing an overview of the app's overarching vision and mission statement. This initial page is designed to provide the user with a comprehensive understanding of the application's purpose and functionality, allowing them to become better acquainted with the app's interface and ensuring that they are well-equipped to navigate the application with ease and confidence.

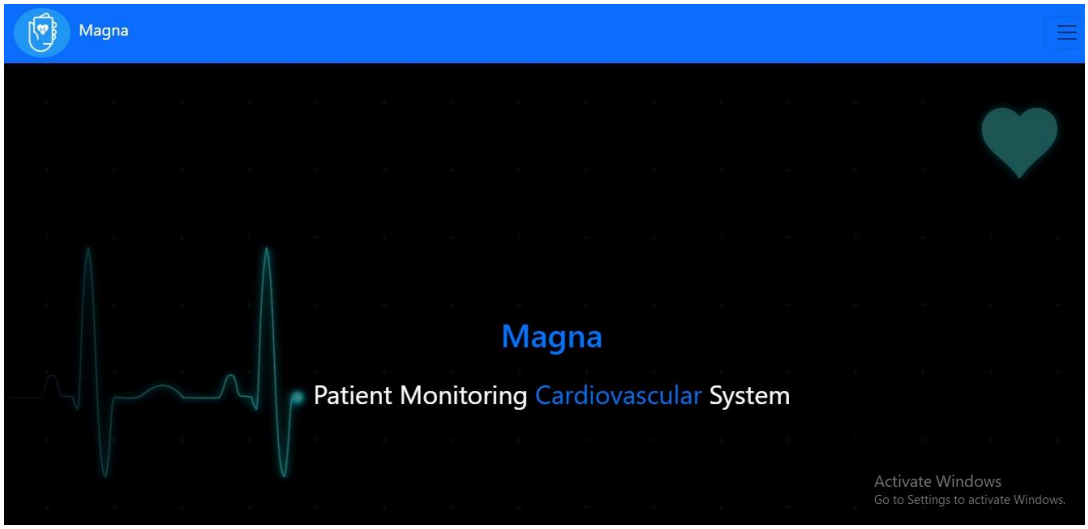

Fig. 4-4 On-boarding page 1

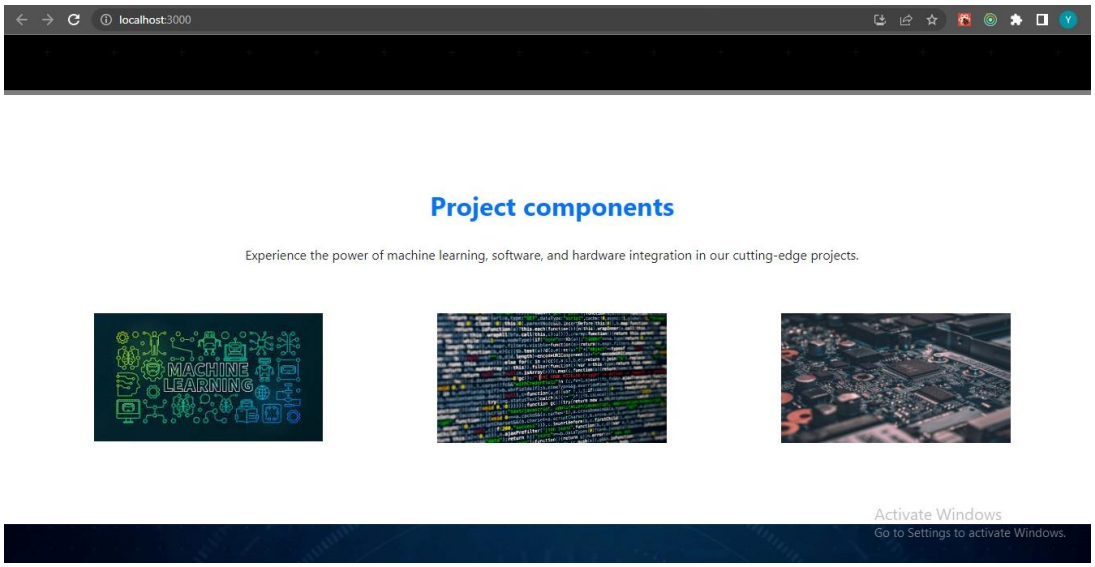

Fig. 4-5 On-boarding page 2

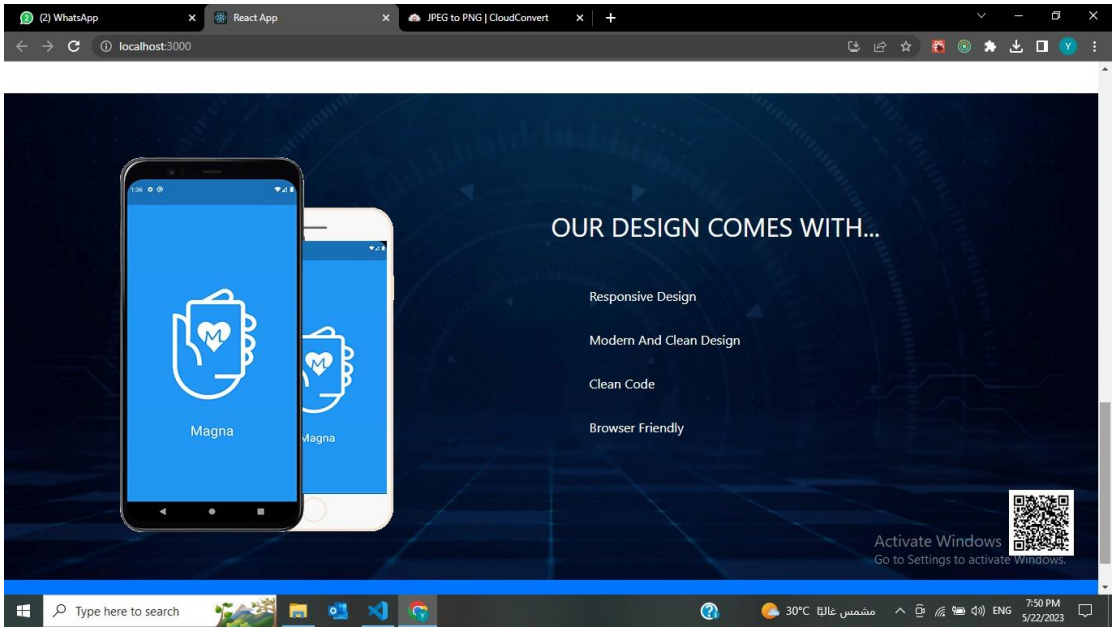

Fig. 4-6 On-boarding page 3

Our 'About' page is a section of our website that provides an overview of our project and its goals. We have included a problem statement, an overview of the project, objectives, and vision and mission statements. The problem statement highlights the issues our project aims to address, while the overview provides details on our approach and technologies used to create a scalable and efficient system. Our objectives focus on innovation, user-friendliness, and improving patient outcomes. Finally, our vision and mission statements provide insight into our core values and beliefs, which include leveraging technology to improve lives and promote a better future.

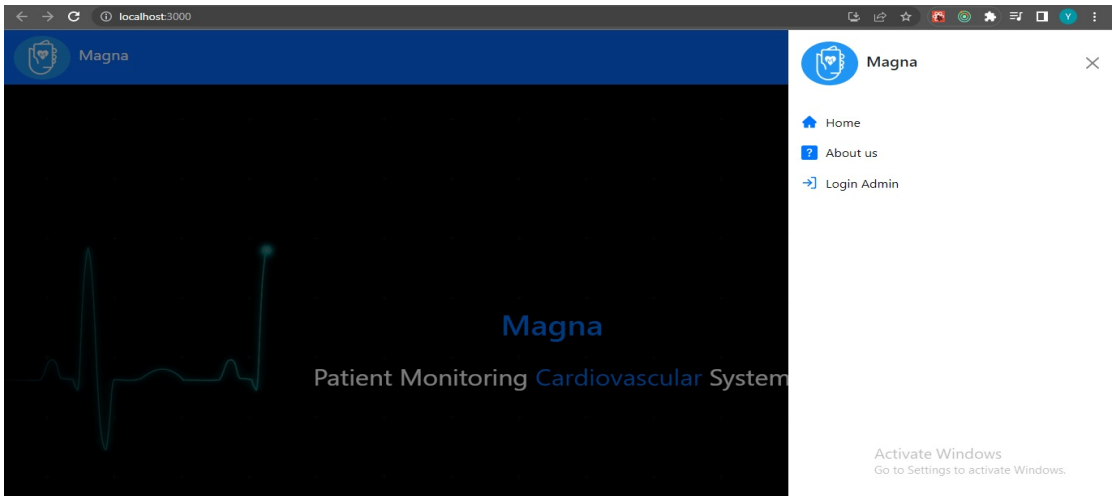

Fig. 4-7 About us page 1

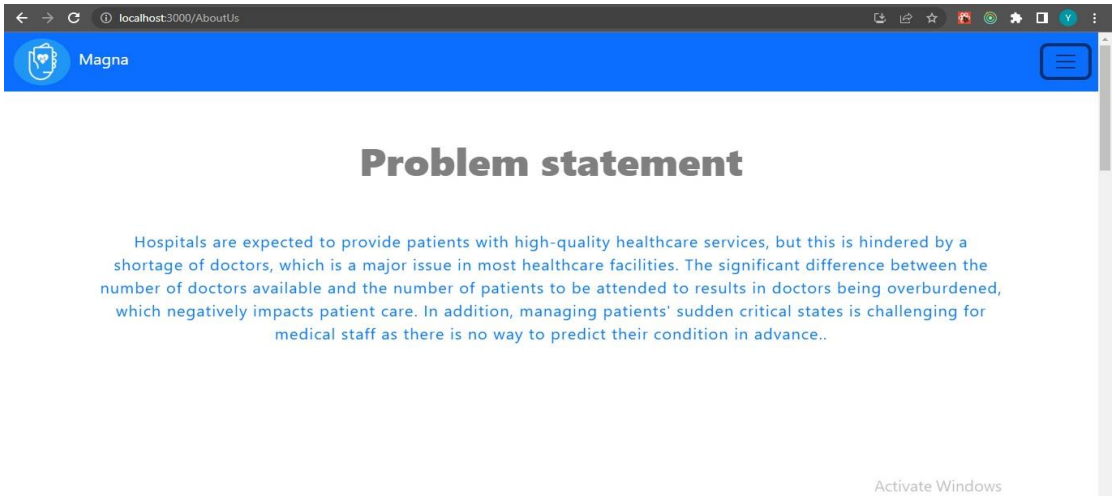

Fig. 4-8 About us page 2

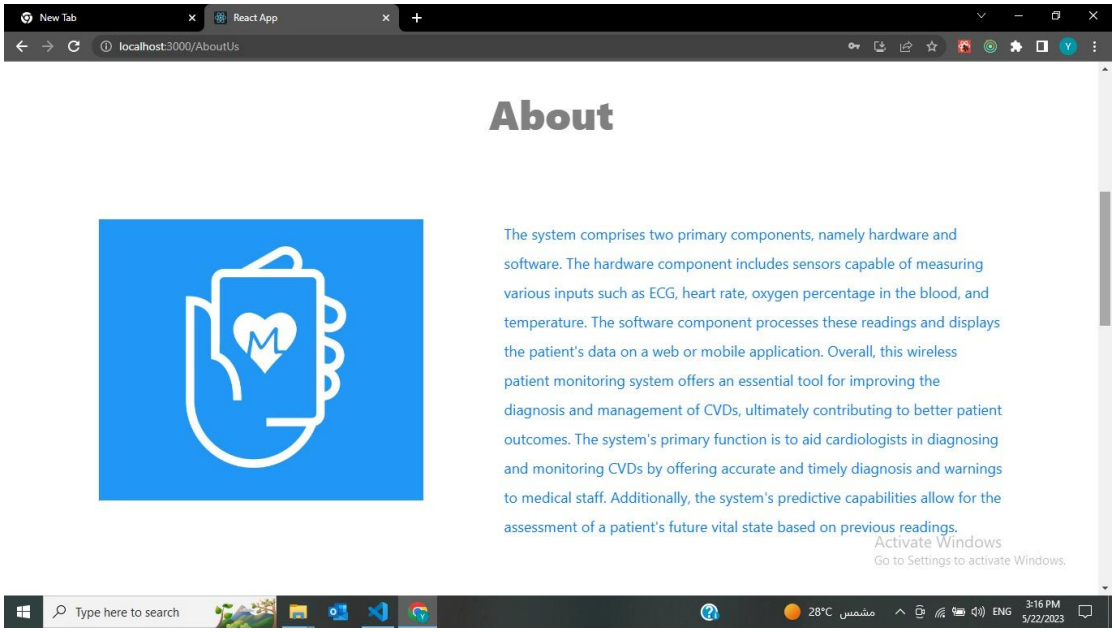

Fig. 4-9 About us page 3

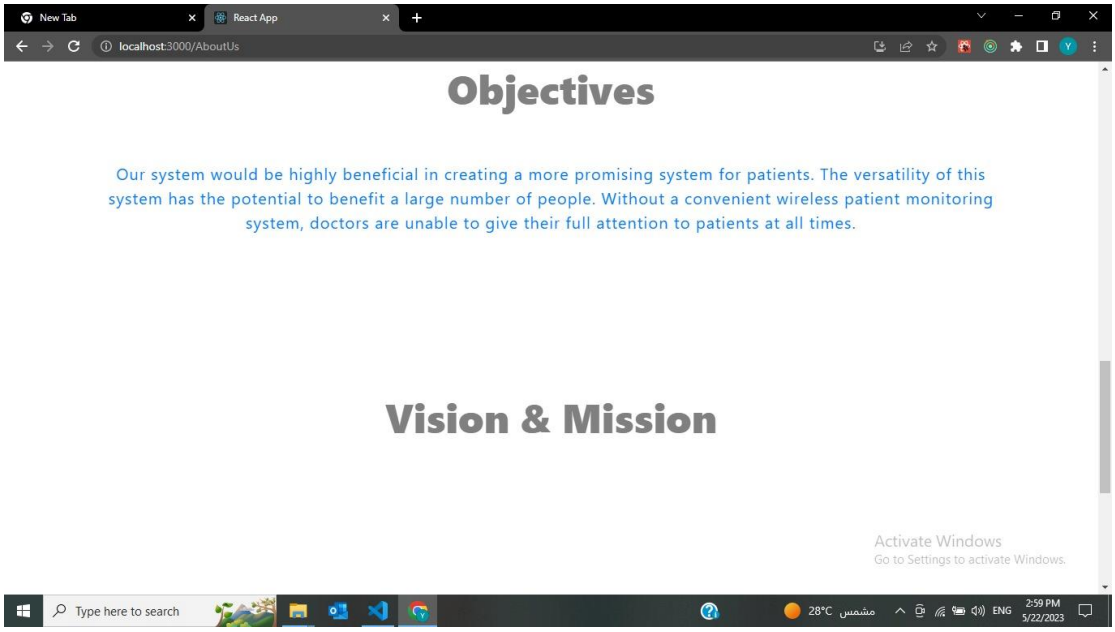

Fig. 4-10 About us page 4

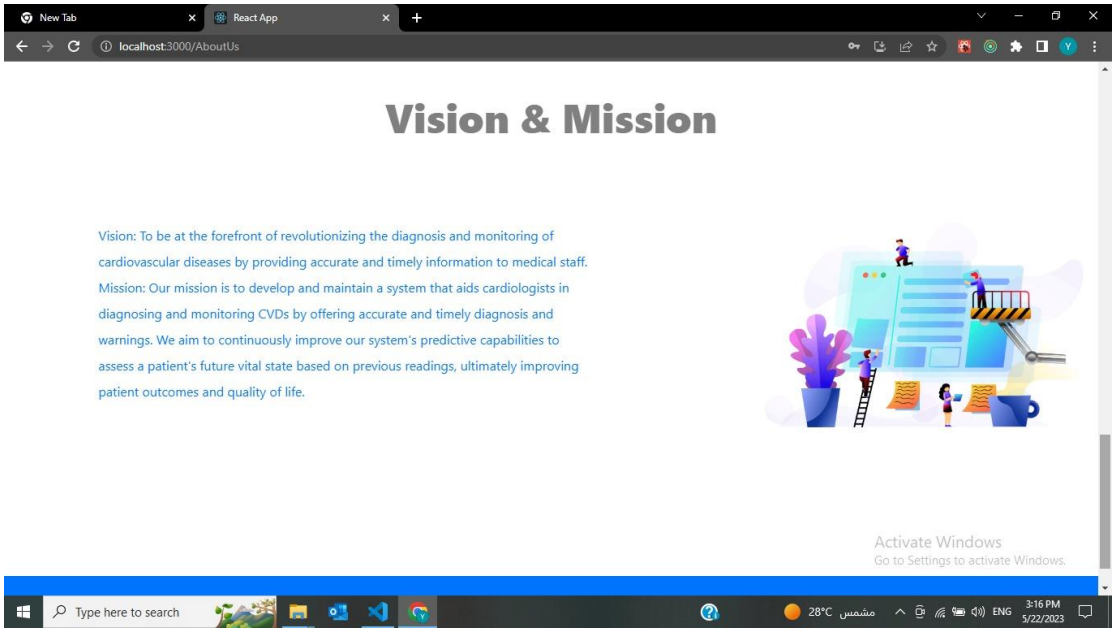

Fig. 4-11 About us page 5

Once the user has gained access to the main page of the application, the administrator is presented with two options: they may either log in to their existing account by entering their registered email and password credentials.

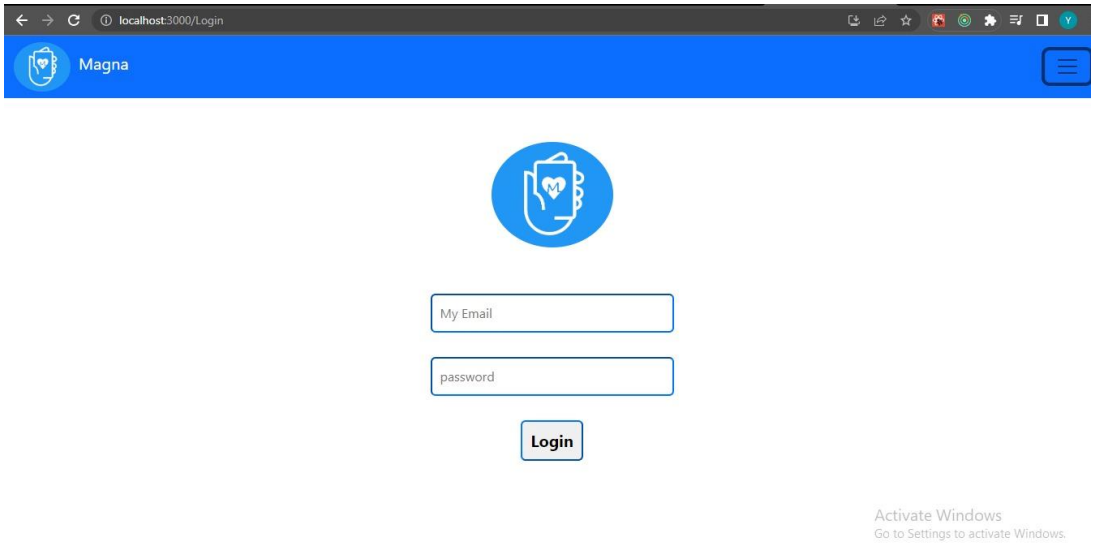

Fig. 4-12 Admin's login page

In order to ensure the security and validity of the login process, the website leverages the Firebase authentication mechanism. This serves to authenticate the admin's login credentials, as well as to verify that the provided user information and constraints meet the required criteria. If the admin happens to provide invalid or incomplete information, or if they enter incorrect login credentials, the authentication process will fail and an error message will be displayed, indicating the nature of the error and providing guidance on how to rectify the issue. Some of the common types of error cases that may arise during the login process include incorrect login credentials, incomplete user information, or invalid passwords. By implementing this robust authentication mechanism, the application is able to ensure that all user actions are secure and valid, thereby promoting the safe and efficient operation of the system as a whole.

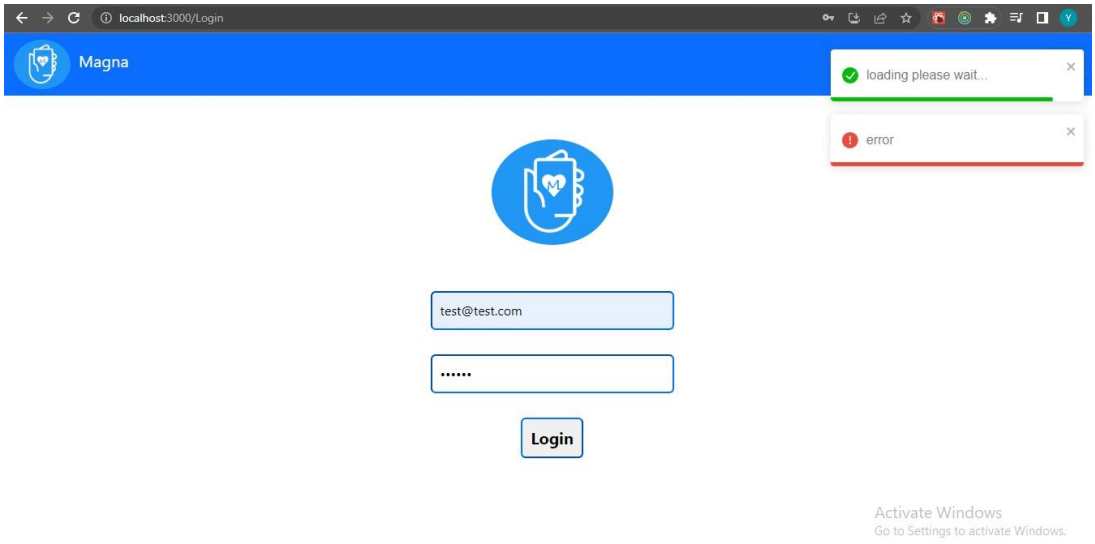

Fig. 4-13 login possible error message for wrong credentials

Our website also has been designed to allow only admins to log in. The Firebase authentication mechanism is utilized to verify the validity of the admin's login credentials. This helps to ensure that only authorized personnel have access to the system, promoting the security and integrity of the application.

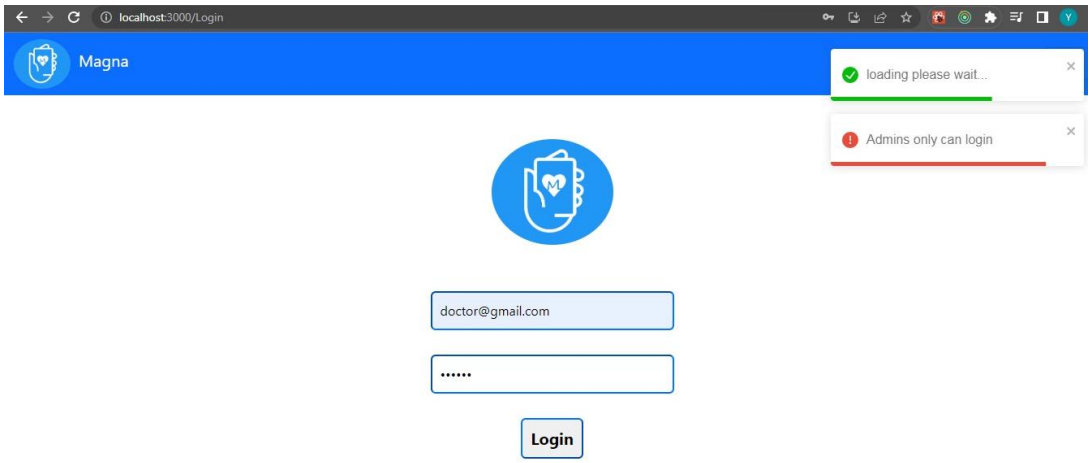

Fig. 4-14 login possible error message for unauthorized

Once the administrator has successfully logged into the application, they are redirected to the home page. This page provides a central hub for accessing all of the various features and functionalities that are available within the application. One such feature is the navigation bar, which serves as a gateway to different sections of the application. One of the key sections accessible through the navigation bar is the Dashboard. The Dashboard is a comprehensive tool that provides the administrator with access to a wide range of statistics and data related to the overall performance and health of the system. This includes information on the number of users registered within the system, as well as the number of doctors, nurses, and patients that are currently active within the system. By providing this level of detailed insight into the application's operations, the Dashboard empowers the administrator to make informed decisions and to take proactive steps to optimize the performance and efficiency of the system as a whole.

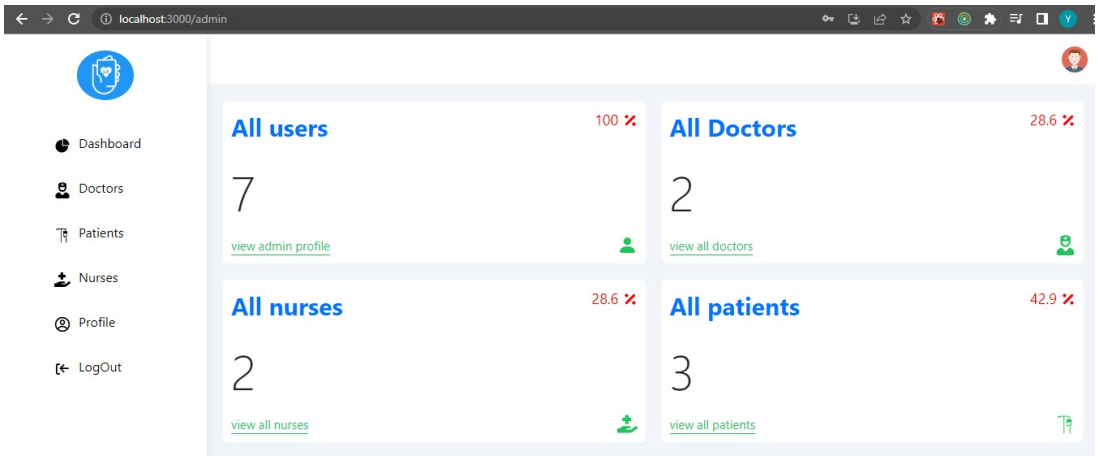

Fig. 4-15 Admin's Dashboard 1

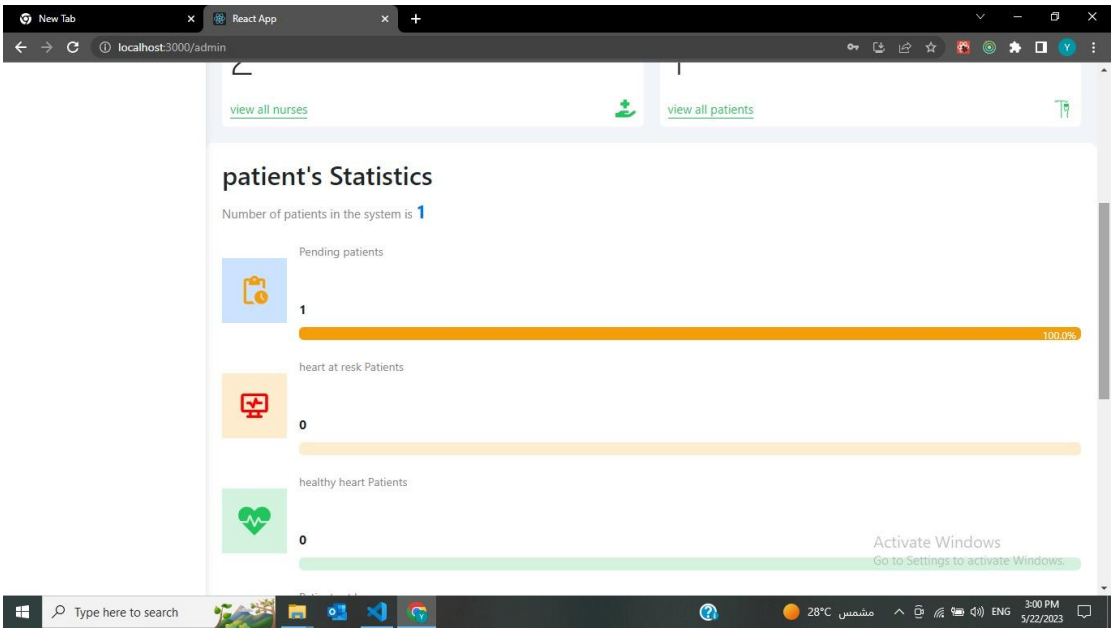

Fig. 4-16 Admin's dashboard 2

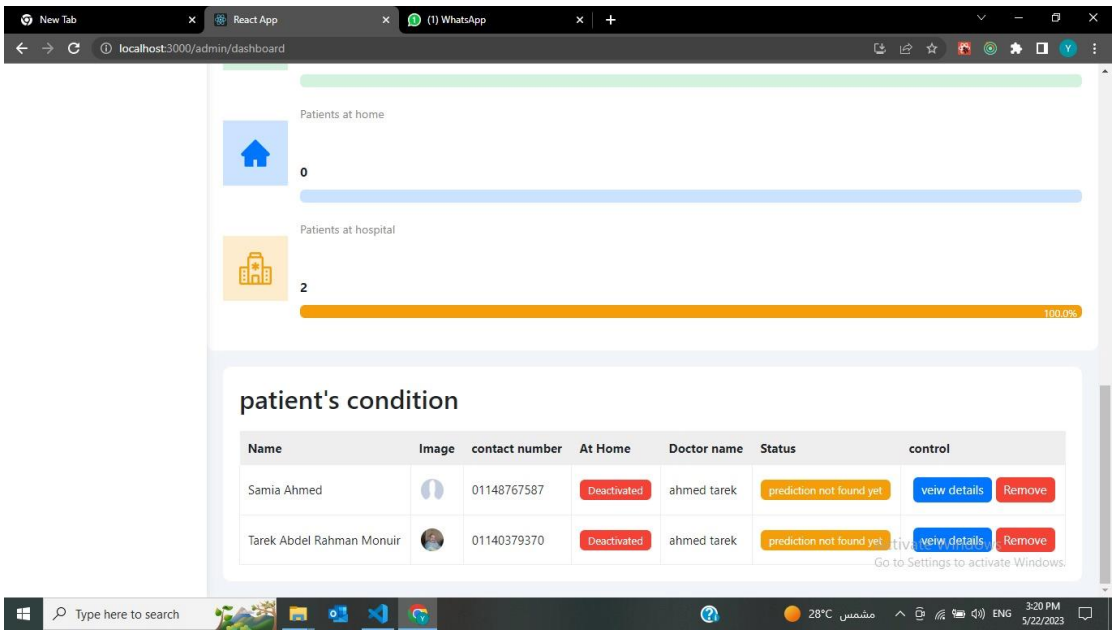

Fig. 4-17 Admin's dashboard 3

In addition to the Dashboard, the navigation bar also provides the administrator with access to the Doctors List. This section of the application serves as a centralized repository of information related to all of the doctors that are registered within the system. Within the Doctors List, the administrator is able to view comprehensive information about each doctor, including their patient lists and other relevant account details. Additionally, the administrator is given the ability to add new doctors to the system, to remove existing doctors from the system, or to make edits to any existing doctor's account information. This level of control and flexibility allows the administrator to effectively manage the doctors within the system, ensuring that they are properly registered and authorized to carry out their duties within the application.

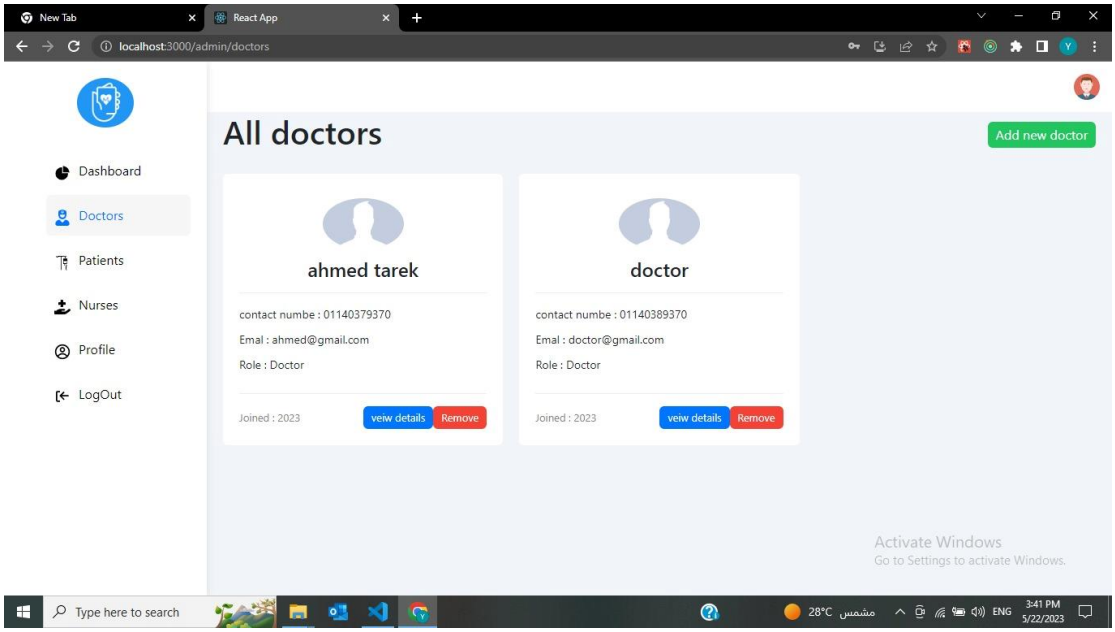

Fig. 4-18 Doctors list

By clicking on ‘add new doctor’ button it navigates to a page where we can add a new doctor with all his details.

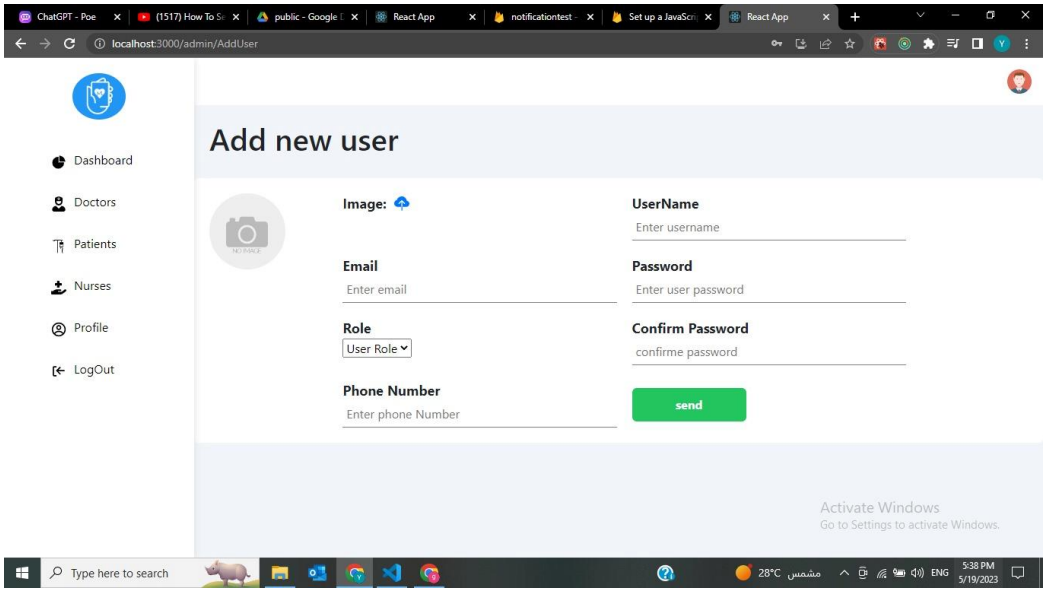

Fig. 4-19 Adding new doctor

By clicking on the 'view details' button, users can navigate to a page where they can view all the details of the doctor.

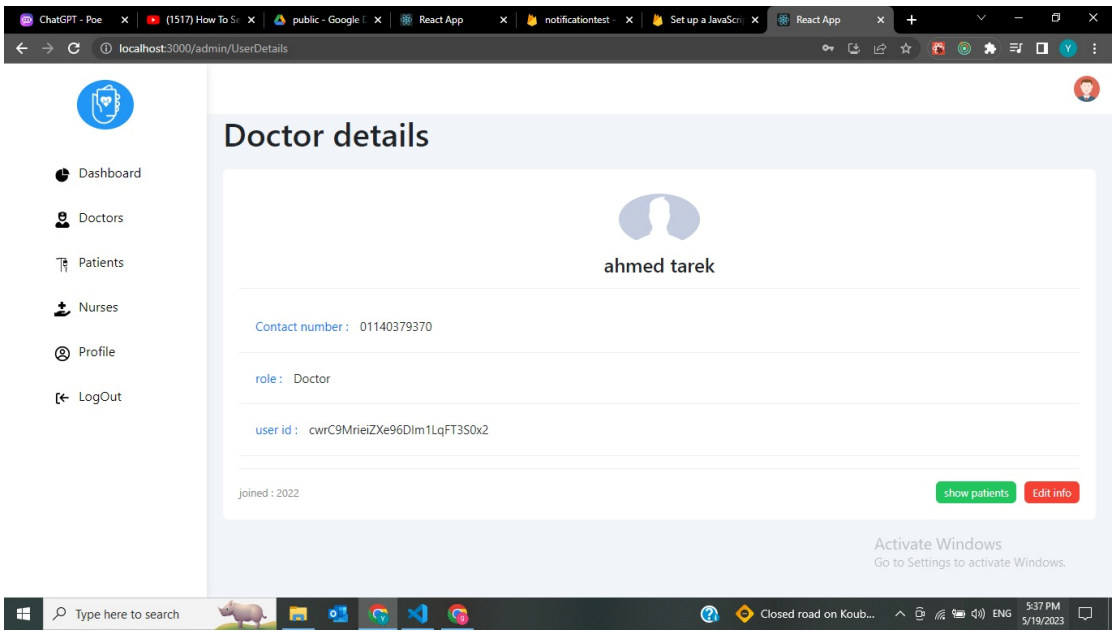

Fig. 4-20 Doctor's details

By clicking on the 'edit info' button allows users to navigate to a page where we can edit this doctor’s data.

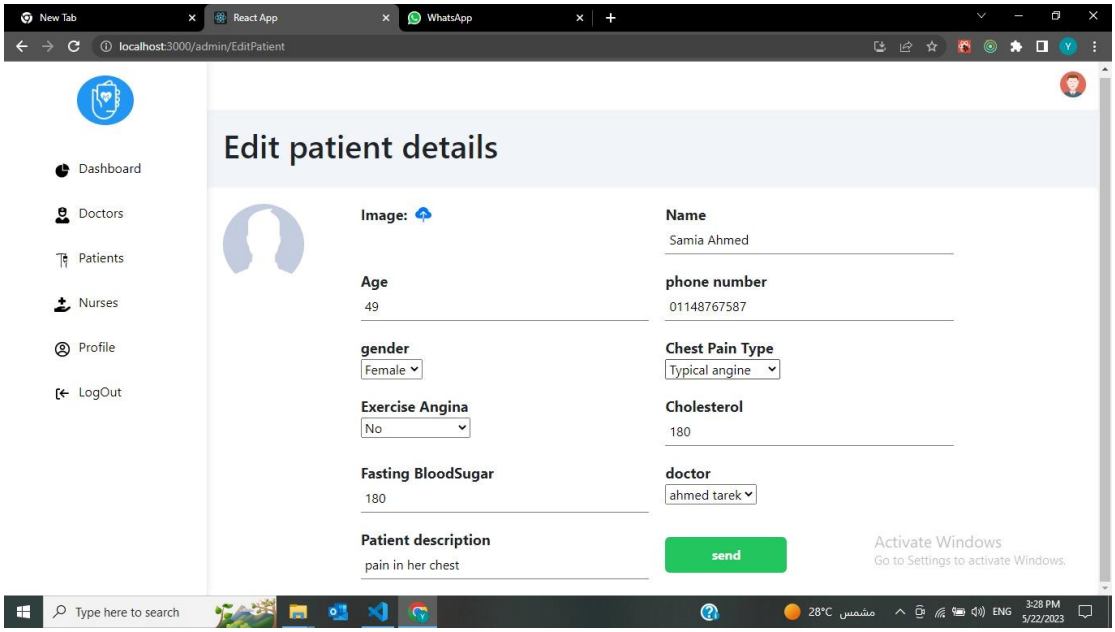

Fig. 4-21 Edit patient's details

By clicking on the 'show patients' button allows users to navigate to the patient list of the selected doctor.

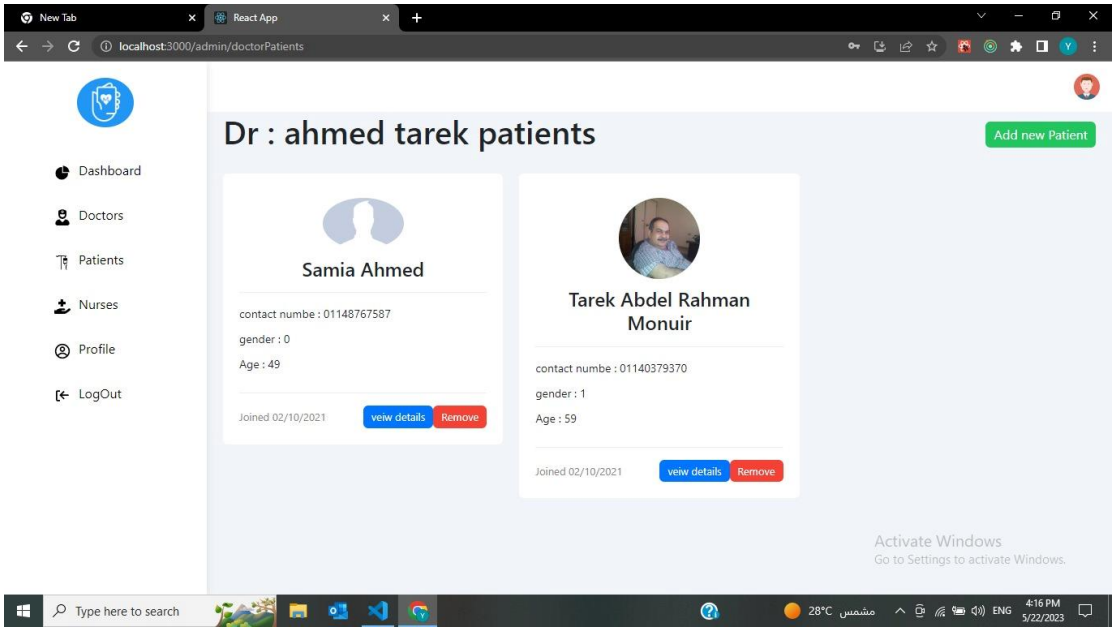

Fig. 4-22 Doctor's patients

By clicking on the 'edit info' button allows users to navigate to a page where we can edit this doctor’s data.

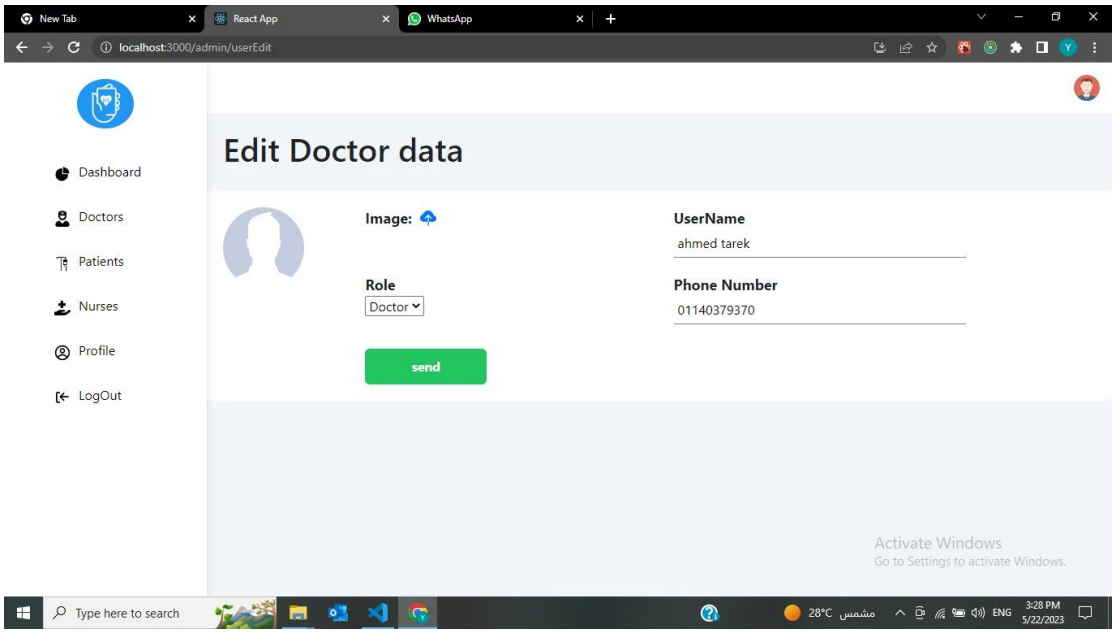

Fig. 4-23 edit doctor's data

By clicking on ‘view details’ button at doctor’s patient list it navigates to this patient’s profile page.

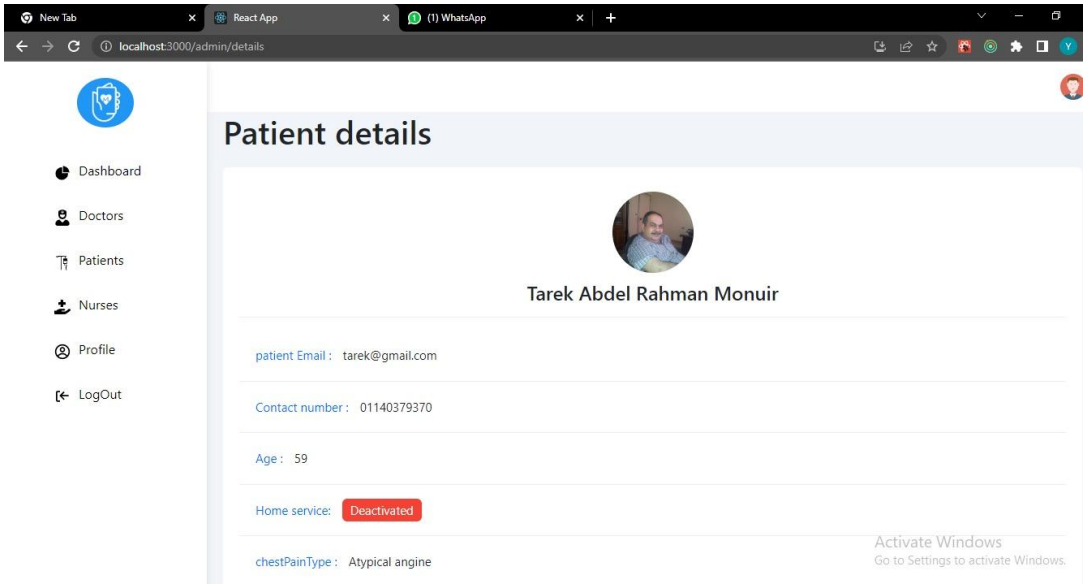

Fig. 4-24 patient's profile page 1

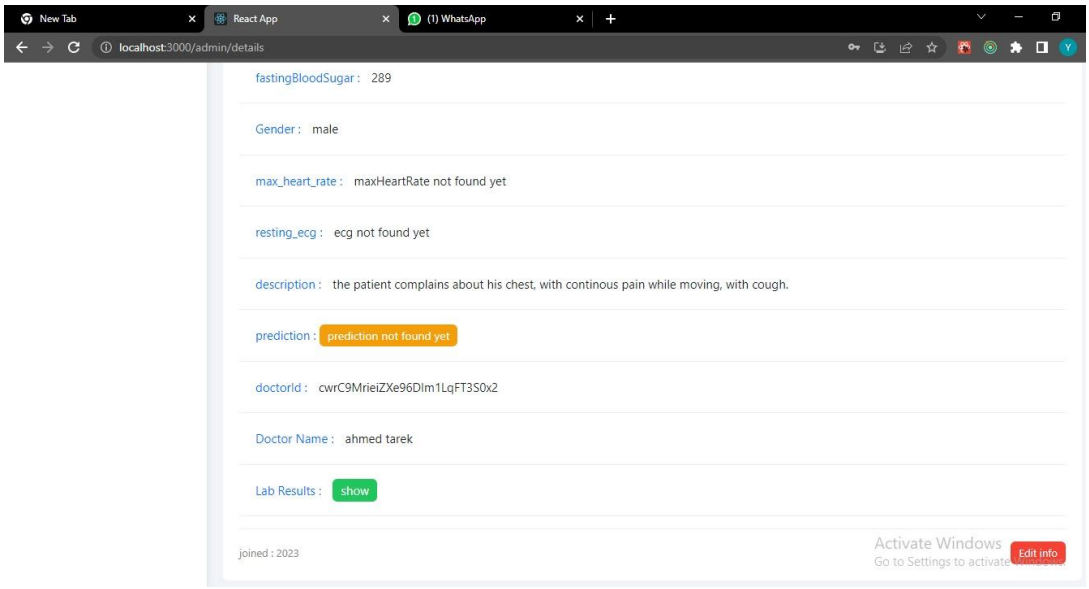

Fig. 4-25 patient's profile page 2

By clicking on ‘show’ button it navigates to the lab results that the patient uploaded.

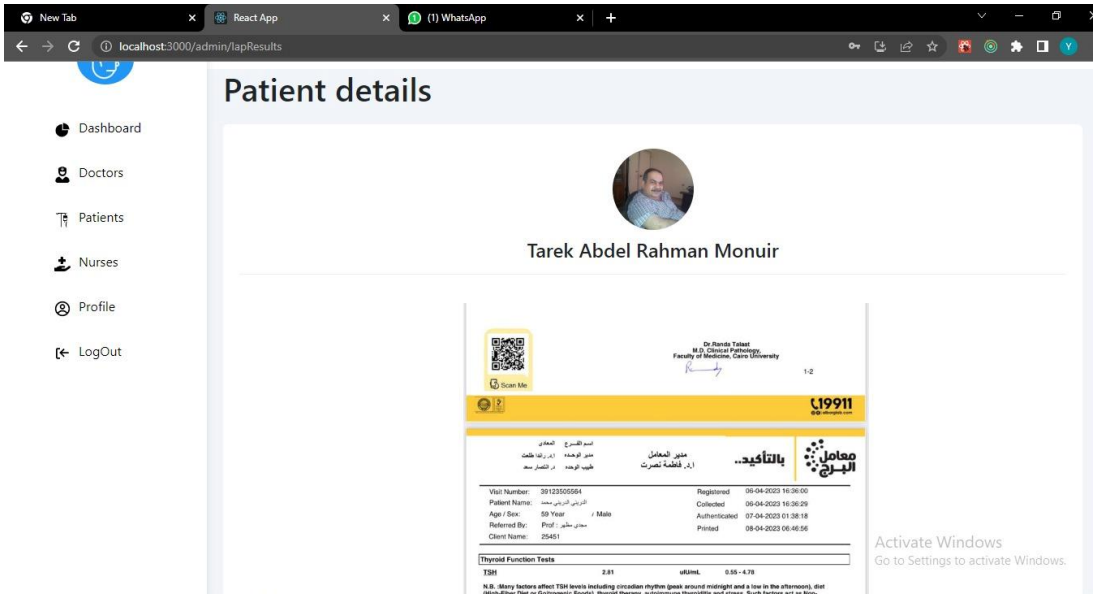

Fig. 4-26 lab results

Another section accessible through the navigation bar is the Patients List. This section provides the administrator with a comprehensive overview of all the patients that are registered within the system, including their personal details and relevant medical information. Within the Patients List, the administrator is given the ability to add new patients to the system, remove existing patients from the system, or make edits to any existing patient's account information. This level of control and flexibility allows the administrator to effectively manage the patients within the system, ensuring that their medical information is accurate and up to date. By having access to this centralized repository of patient information, the administrator is empowered to make informed decisions about the overall management of the system and to ensure that all patients are receiving the care and attention that they require.

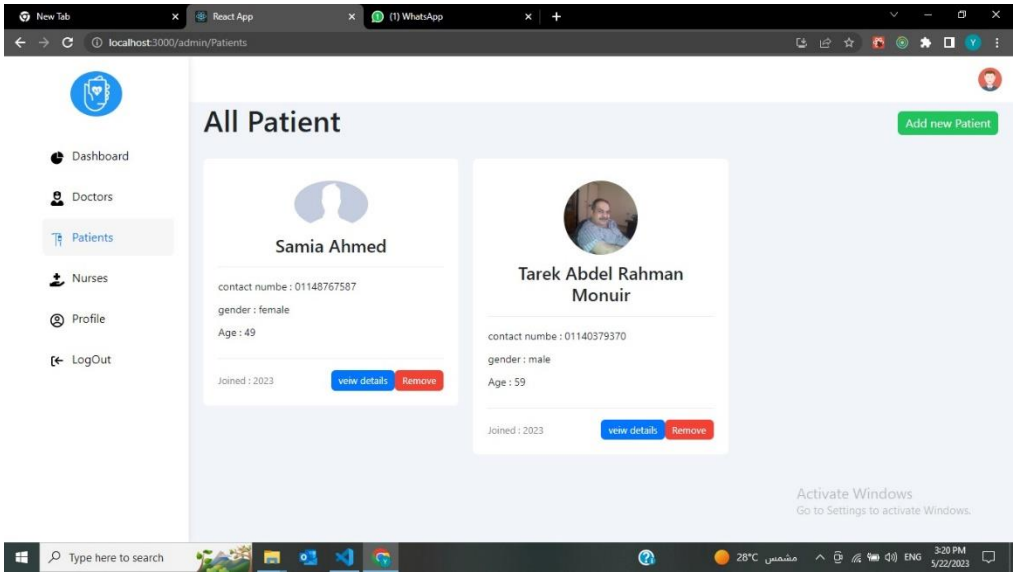

Fig. 4-27 Patients list

By clicking on ‘add new patient’ button it navigates to a page where we can add a new patient with all his details.

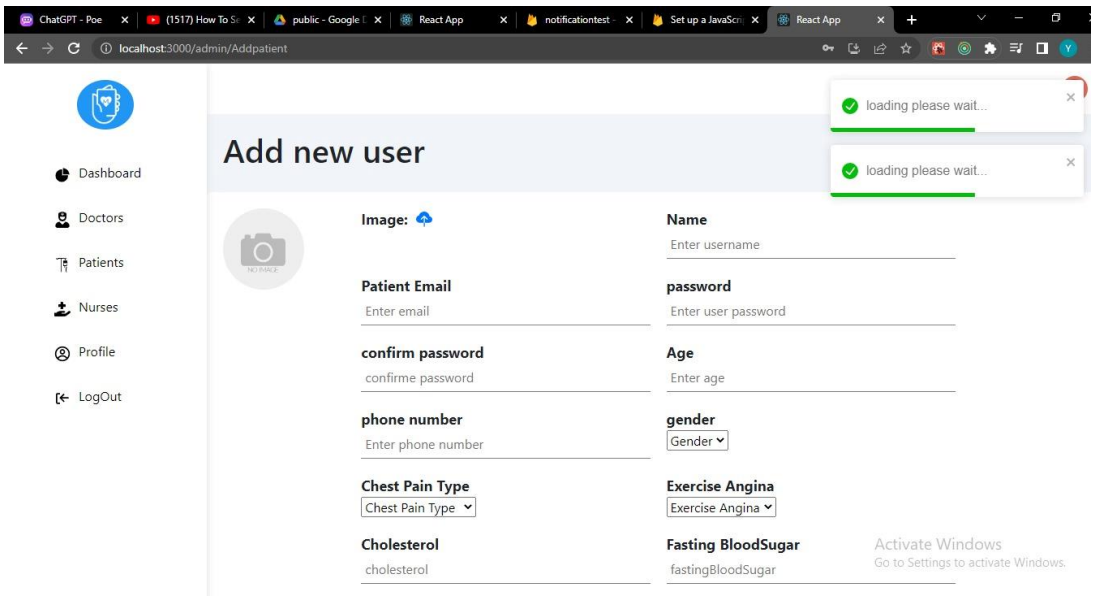

Fig. 4-28 adding new patient page 1

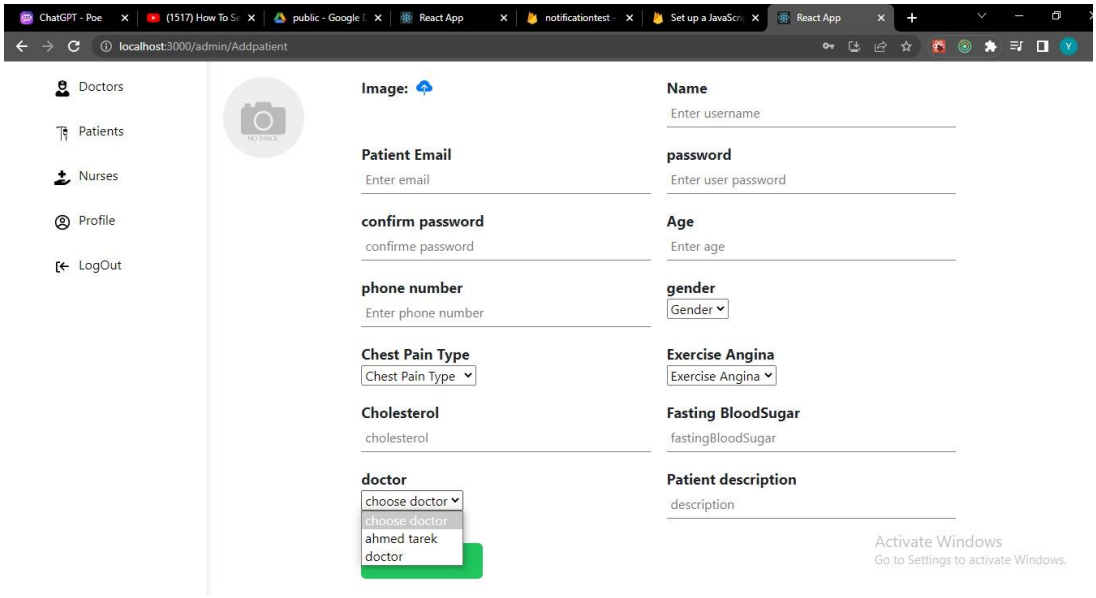

Fig. 4-29 adding new patient page 2

The navigation bar also provides the administrator with access to the Nurses List, which serves as a centralized repository of information related to all of the nurses that are registered within the system. Within the Nurses List, the administrator is able to view comprehensive information about each nurse, including their personal details and relevant account information. Additionally, the administrator is given the ability to add new nurses to the system, remove existing nurses from the system, or make edits to any existing nurse's account information. This level of control and flexibility allows the administrator to effectively manage the nurses within the system, ensuring that they are properly registered and authorized to carry out their duties within the

application. By having access to this centralized repository of nurse information, the administrator is empowered to make informed decisions about the overall management of the system and to ensure that all nurses are properly trained and equipped to provide high-quality care to all patients within the system.

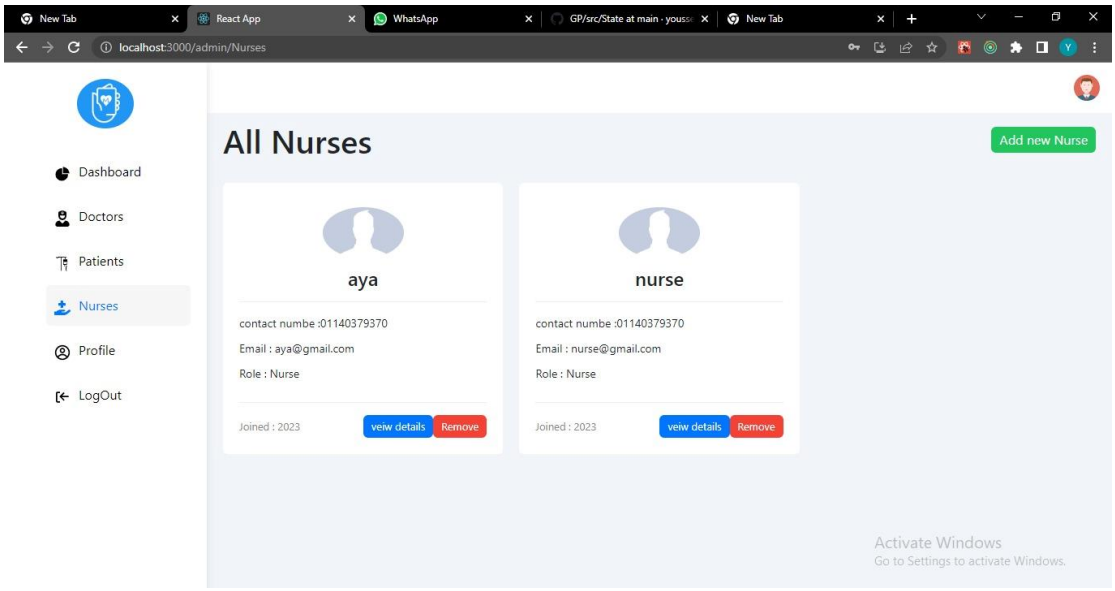

Fig. 4-30 Nurses list

By clicking on 'add new nurse' button it navigates to a page where we can add a new nurse with all her details.

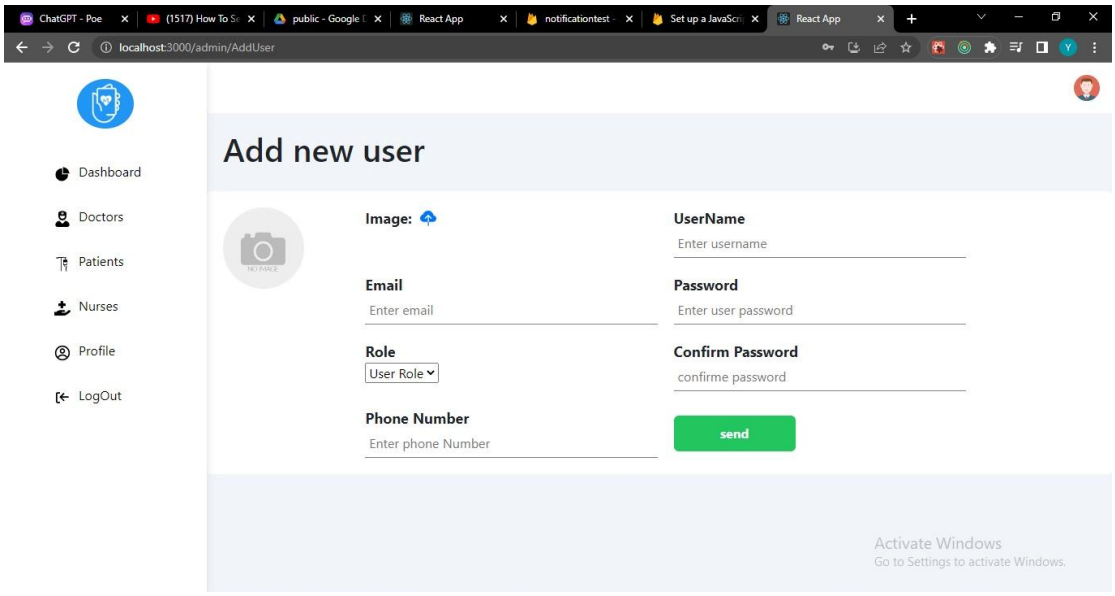

Fig. 4-31 adding new nurse

By clicking on ‘view details’ button it navigates to this nurse’s profile page.

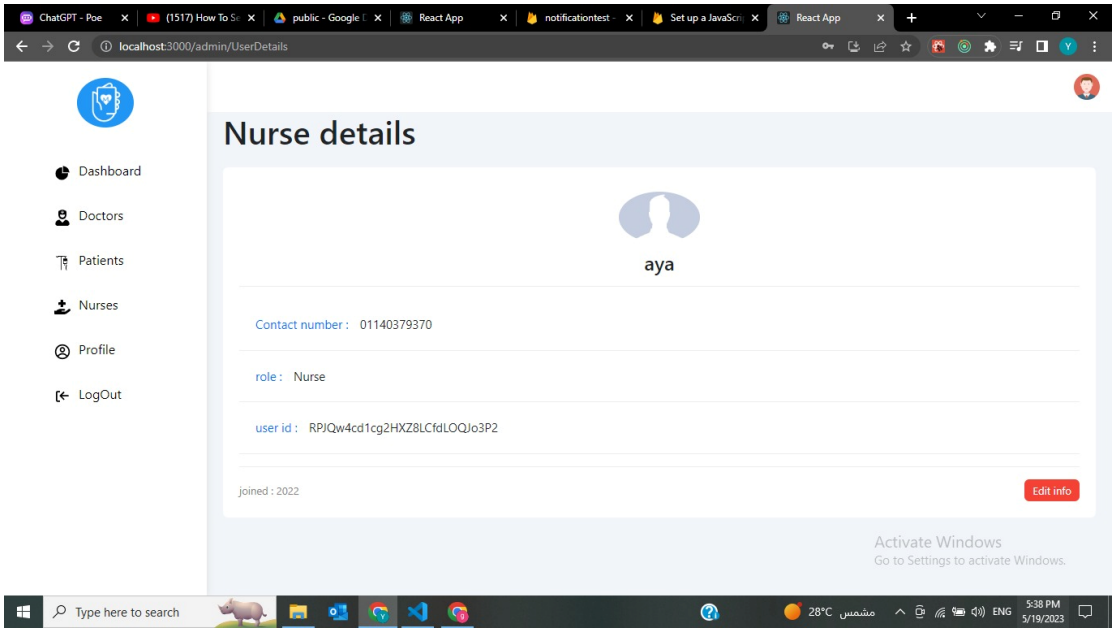

Fig. 4-32 Nurse’s profile

By clicking on ‘edit info’ button it allows users to navigate to a page where we can edit this nurse’s data.

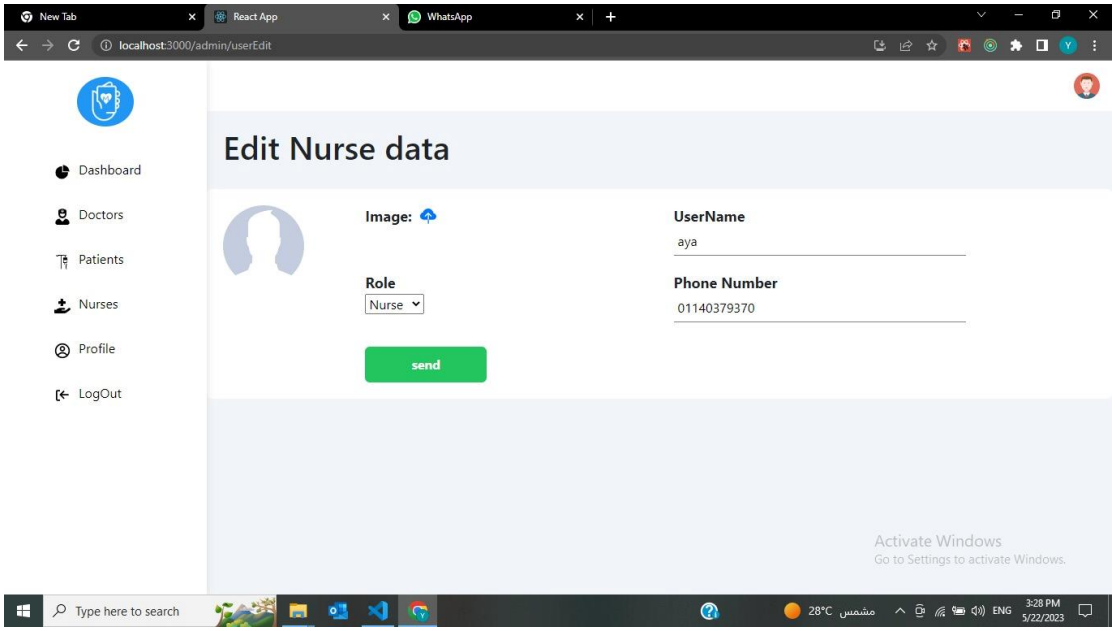

Fig. 4-33 edit nurse's data

The navigation bar also includes a section for the administrator's Profile. This section provides the administrator with access to their personal information and account details, which allows them to view and manage their own account settings within the system. Within the Profile section, the administrator can view and edit their personal details, such as their name, contact information, and other relevant account information. This section also provides the administrator with access to their account

settings, which enables them to manage their login credentials, change their password, or make any other necessary changes to their account settings. By having access to this section of the application, the administrator is able to ensure that their own account is properly maintained and secure, which in turn helps to promote the overall security and stability of the system as a whole.

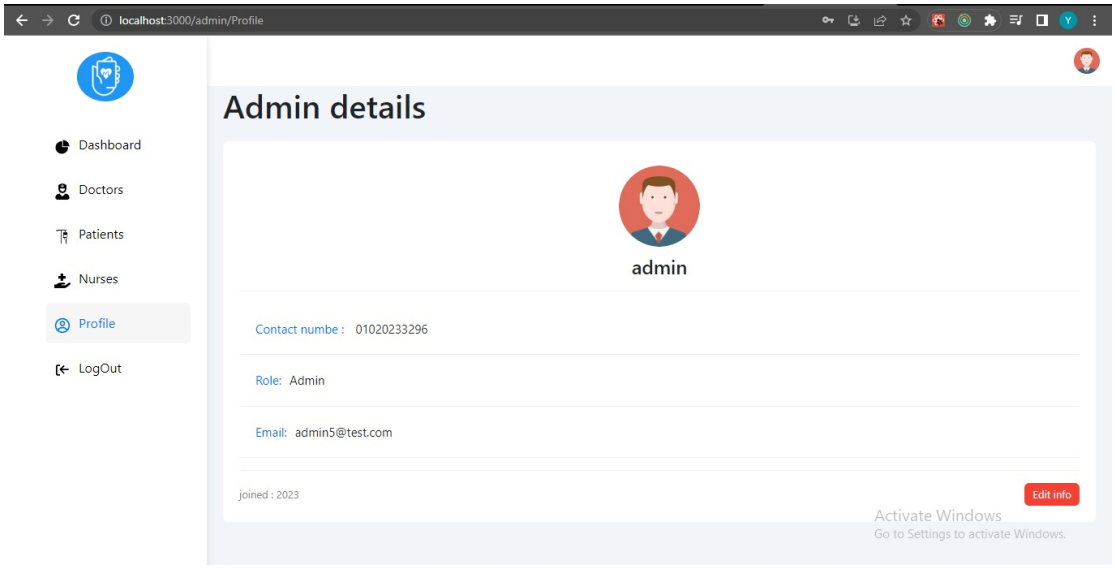

Fig. 4-34 Admin's profile

As a crucial component of any secure web application, the navigation bar also includes an option for the administrator to log out of the system. This option allows the administrator to securely exit the application and to ensure that their login credentials are properly protected. By clicking on the logout button, the administrator's session within the application is terminated, and any temporary data or settings associated with their session are cleared from the system. This helps to ensure that the administrator's account and data are kept secure and that any potential unauthorized access to the system is prevented. The logout option is an essential feature of any web application that deals with sensitive data and plays a crucial role in ensuring the overall security and integrity of the system.

Also by clicking on ‘edit info’ button it allows users to navigate to a page where we can edit this admin’s data.

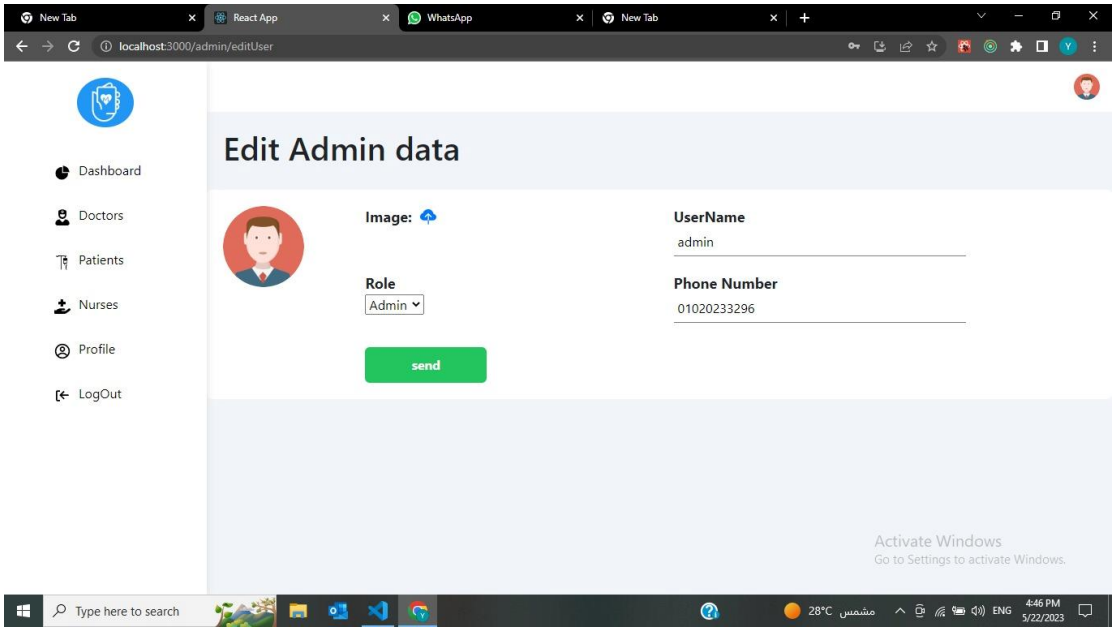

Fig. 4-35 edit admin's data

4.3.2 User's Mobile application

Within the application's initial user interface, the primary page that is presented to the user is an on-boarding page which serves the purpose of introducing the user to the application's various features and functions, as well as providing an overview of the app's overarching vision and mission statement. This initial page is designed to provide the user with a comprehensive understanding of the application's purpose and functionality, allowing them to become better acquainted with the app's interface and ensuring that they are well-equipped to navigate the application with ease and confidence.

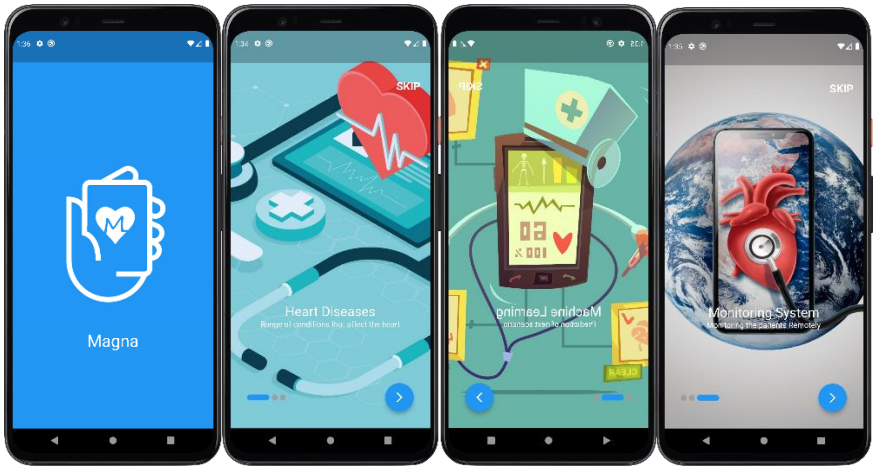

Fig. 4-36 On-boarding page

Once the user has gained access to the main page of the application, the user is presented with two options: they may either log in to their existing account by entering their registered email and password credentials, or alternatively, if they are a new user, they may choose to register for a new account by furnishing their personal details such as their name, password, phone number and the role of the user either

doctor or nurse. This process of registration serves to establish a new user account within the application, allowing the user to gain access to the various features and functionalities that are available within the system. By providing the necessary information during the registration process, the user can create a unique login identity that will enable them to access the application's resources and tools, thereby empowering them to effectively manage their account and oversee the various activities and operations that are associated with their administrative role.

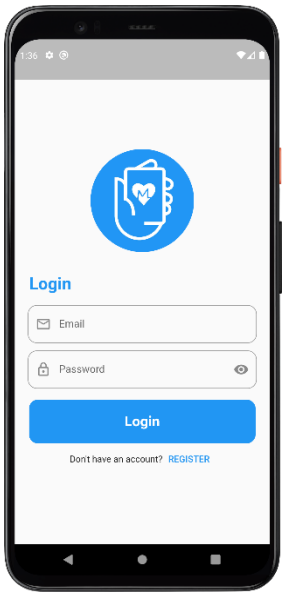

Fig. 4-37 User's login page

In order to ensure the security and validity of the login and registration processes, the application leverages the Firebase authentication mechanism. This serves to authenticate the user's login credentials, as well as to verify that the provided user information and constraints meet the required criteria. If the user happens to provide invalid or incomplete information, or if they enter incorrect login credentials, the authentication process will fail and an error message will be displayed to the user, indicating the nature of the error and providing guidance on how to rectify the issue. Some of the common types of error cases that may arise during the login and registration processes include incorrect login credentials, incomplete user information, or invalid passwords. By implementing this robust authentication mechanism, the application is able to ensure that all user actions are secure and valid, thereby promoting the safe and efficient operation of the system as a whole.

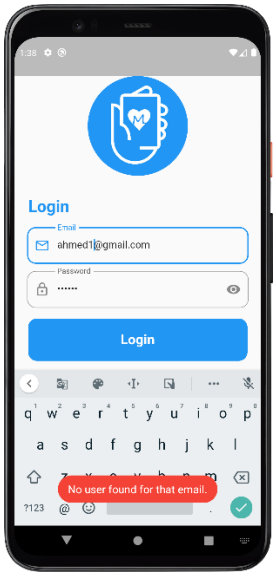

Fig. 4-38 login possible error message

After the user has successfully logged into the application, the system redirects them to the appropriate home page based on their assigned role. For example, if the user is a doctor, they will be directed to a home page that includes a bar with various options. One of these options is the ability to access a patient list, which displays all of the patients that are currently being monitored by the doctor. From this list, the doctor has the ability to remove a patient, edit their information, and add new data or descriptions to aid in diagnosing the patient's case. Additionally, the doctor can write notes or instructions for the nurses to follow up on the treatment plan.

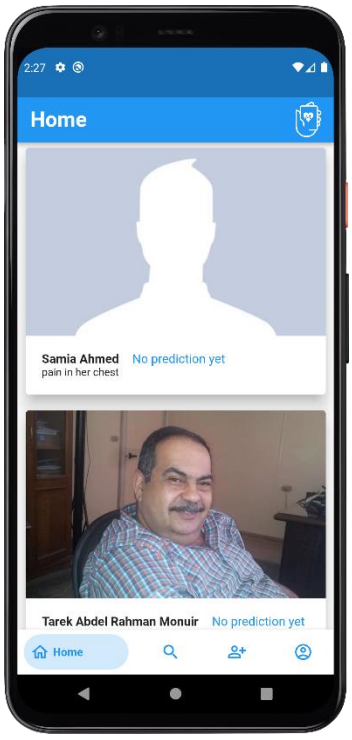

Fig. 4-39 doctor's patient list

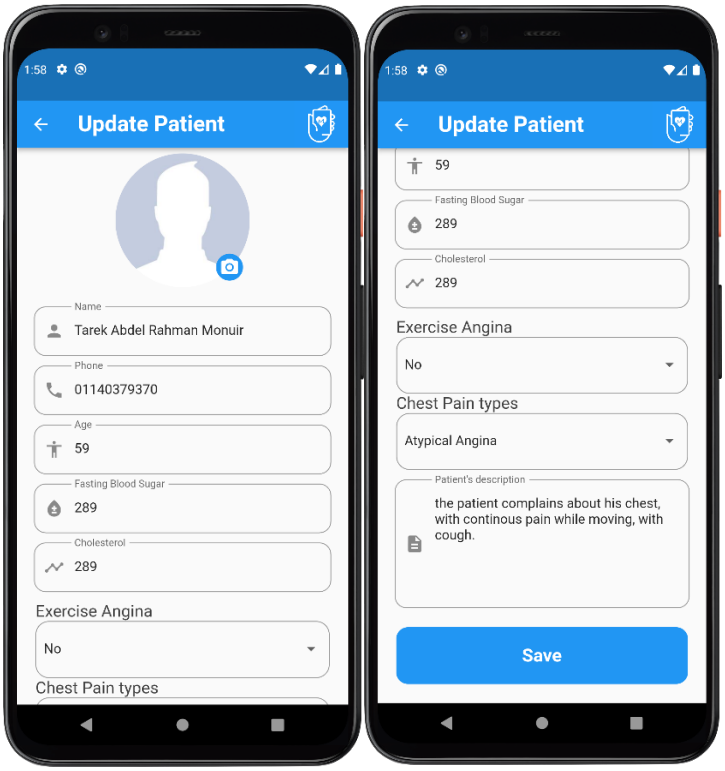

Fig. 4-40 doctor views one patient

In addition to the aforementioned options on the doctor's home page, there is also a search function available within the patient list. This feature allows the doctor to easily locate a specific patient within the list by entering search criteria such as the patient's name or identification number. By utilizing this search function, the doctor can quickly access the patient's information and make updates or changes as necessary.

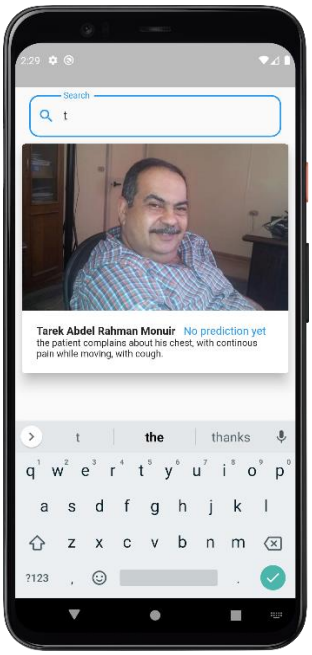

Fig. 4-41 search in patient list

Furthermore, the doctor also has the option of adding a new patient to the patient list by utilizing the "Add Patient" feature on the app. This feature enables the doctor to input various patient details such as the patient's name, photo, phone number, age, gender, fasting blood sugar levels, cholesterol levels, exercise habits, angina status, and chest pain type. Additionally, the doctor can provide a detailed description of the patient's medical history and current condition in order to facilitate effective diagnosis and treatment planning. By utilizing this feature, the doctor can ensure that all patient information is accurately and efficiently recorded within the application.

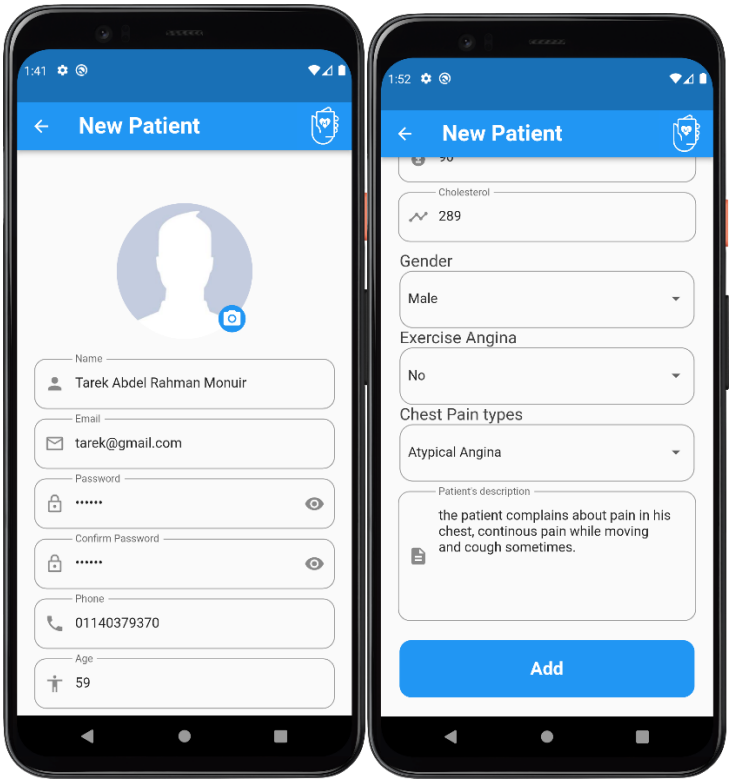

Fig. 4-42 Adding new patient

The doctor also has the ability to edit in patient’s account and activate or deactivate home service.

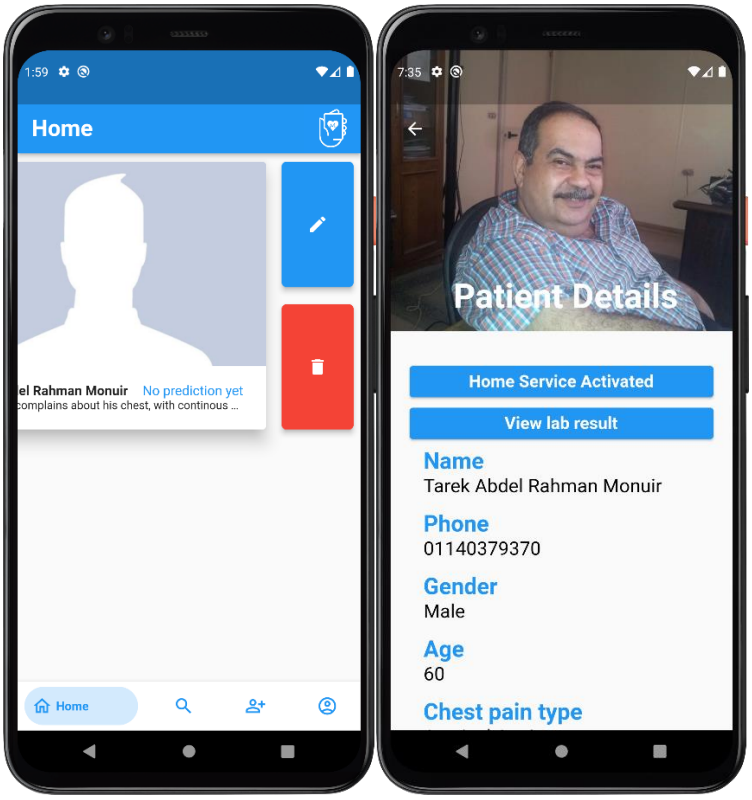

Fig. 4-43 doctor edits patient's account

The doctor also has the ability to view lab results and add comment to the patient.

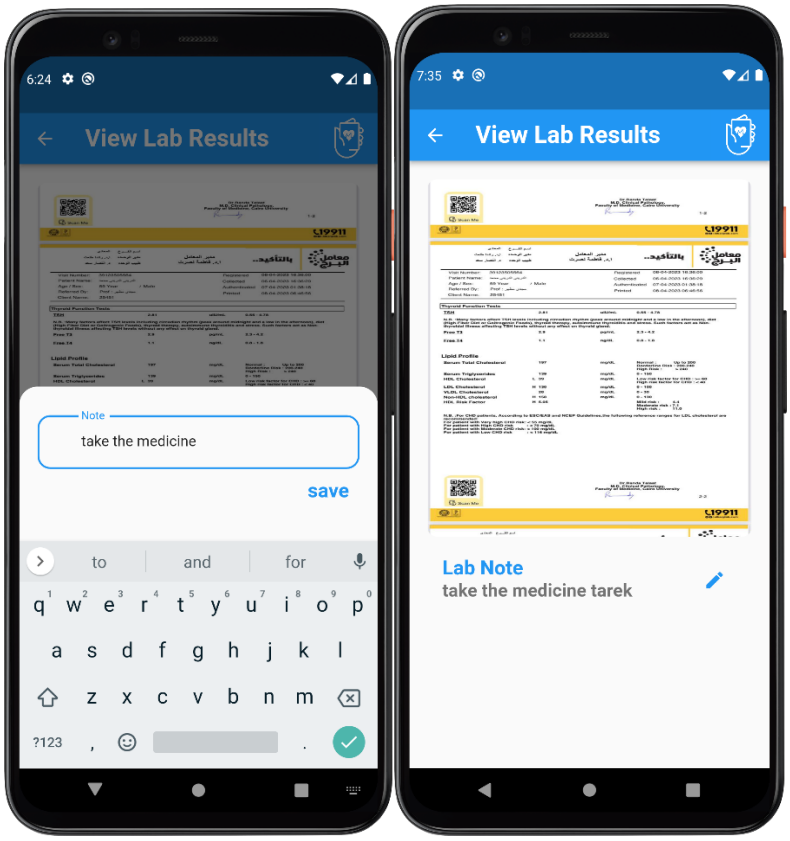

Fig. 4-44 lab results

The doctor also has the ability to edit their own account information within the application. Specifically, the doctor can make changes to their name, photo, and phone number as needed. By having the ability to edit their own account information, the doctor can ensure that their profile is up-to-date and accurately reflects their current contact information and professional status. This can be especially important for maintaining effective communication with other medical professionals and ensuring that patients are able to reach their doctor when necessary.

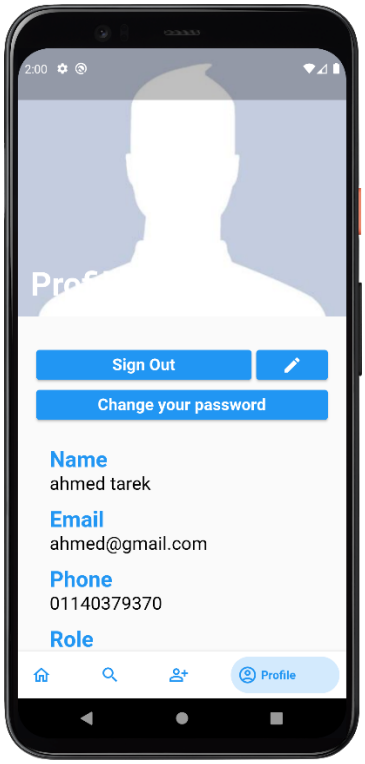

Fig. 4-45 Edit account's info

Finally, the doctor also has the option to sign out of the application when they have completed their work or need to step away from the system. By selecting the "Sign Out" option, the doctor can securely log out of the application and ensure that patient information remains confidential and protected. This feature is important for maintaining the security and privacy of patient data, and helps to ensure that only authorized personnel have access to sensitive medical information.

If the user is assigned the role of a nurse, they will be directed to a different home page within the application. This home page will include a patient list that the nurse can access to view details about each patient that they are responsible for monitoring. However, unlike the doctor's role, the nurse will not have access to edit or make changes to the patient's information.

Instead, the nurse will be able to view the patient's details which are on the hospital and follow up on the treatment plan and instructions provided by the doctor. This may include monitoring the patient's vital signs, providing medications, or assisting with other aspects of patient care. By utilizing the patient list and accessing the patient's details as needed, the nurse can ensure that they are providing high-quality care and following the doctor's instructions accurately and effectively.

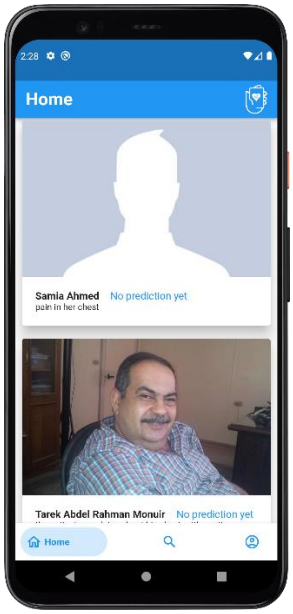

Fig. 4-46 Nurse's patient list

The nurse can also view only one patient without editing in his info.

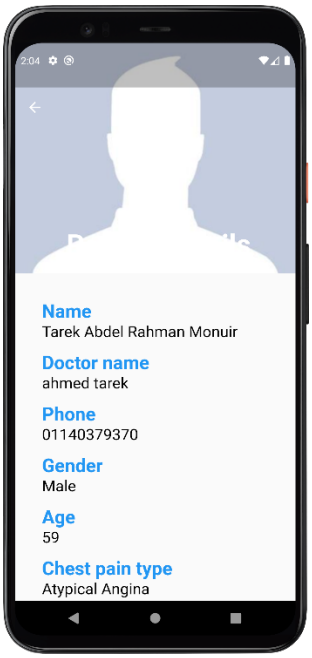

Fig. 4-47 Nurse views one patient

In case the doctor activated home service for a patient, account will be created for the patient to have this service as monitoring his case and follow up online with the

doctor, he also can add his clinical lab results and the doctor can add a note or comment for him.

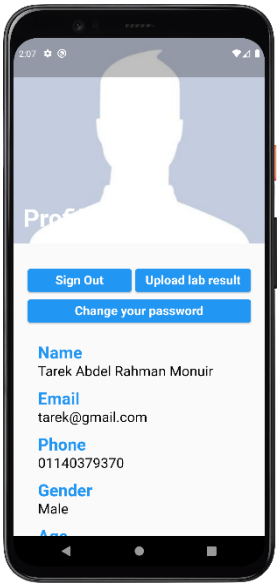

Fig. 4-48 patient's profile after login

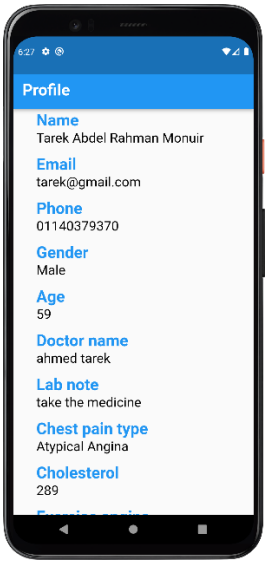

Fig. 4-49 view doctor's comment

Chapter 5 : Testing and results

5.1 Introduction

The process of testing is an integral and highly important aspect of software development that involves a rigorous and systematic approach to verifying and validating software to ensure that it meets its intended requirements and performs as expected. The primary objective of testing is to identify any defects, bugs, or errors that may be present in the software, which can then be addressed and fixed before the software is released to end-users.

In this chapter, a comprehensive set of test cases have been developed to ensure that the system is both functionally valid and free of errors. These test cases have been designed to systematically evaluate the various features and functionalities of the system, and to identify any potential issues or errors that may be present. The tests are executed under a wide range of conditions and scenarios, with the aim of uncovering any problems that may arise in real-world usage.

By implementing a robust and thorough testing process, the system can be ensured to be of high quality and reliability, minimizing the risk of any issues or errors that may negatively impact end-users. The test cases outlined in this chapter serve as a critical component of the software development process, and play an essential role in ensuring the overall success of the system.

5.2 Test cases for mobile app

Table 4.Test cases for mobile app

Test case ID	Test case scenario	Test case	Pre-condition	Test steps	Expected results	Post condition	Actual results	Pass/Fail
001	Verify log in	Enter valid username and valid password	Need valid email & already user	1.enter valid account 2.enter password 3.click “login” button	Login success		Successful login	PASS
001	Verify log in	Enter valid username and invalid password	Need valid email & already user	1.enter valid account 2.enter password 3.click “login” button	Error message “wrong password provided for the user”	Enter valid mail and password	Error message	PASS
001	Verify log in	Enter invalid username and valid password	Need valid email & already user	1.enter valid account 2.enter password 3.click “login” button	Error message “email address invalid”	Enter valid mail and password	Error message	PASS
002	Verify register	Enter valid email and required info	Need valid email not signed in	1.enter Username 2.enter phone	Register success	Login with email and password	Successful registration	PASS

				3.enter email 4.enter password 5.select role				
002	Verify register	Enter invalid email or not fill required info	Need valid email not signed in	1.enter valid username 2.enter invalid email 3.not fill all required inputs	Error message “please enter valid email” or “please fill all the required data”	Enter valid data	Error message	PASS
003	Verify adding new patient	Add new patient, enter required info	New patient	1.click “add patient” button 2.enter name, phone, age, fasting blood sugar, cholesterol 3. Choose gender, exercise angina, chest pain types. 4. you might add description 5. click “add”	Added successfully	New patient added to patients list	Added successfully	PASS
003	Verify adding new patient	Add new patient, not enter required info	New patient	1.click “add patient” button 2.enter name 3.not enter all required info 4. click “save” button	Error message “please fill all the required data	Enter required info	Error message “please fill all the required data	PASS
004	Verify removing existing patient	Remove patient	Existing patient	1. Click “remove patient” button.	removed successfully	patient removed from patients list	removed successfully	PASS
005	Verify editing account	User edits his info	Has account	1.click “edit” button 2.edit info 3. click “save” button	Edited successfully	New info appeared in account	Edited successfully	PASS
006	Verify phone credentials	Enter phone number equals to 11 digits		1.regiester for first time or editing in account 2.enter phone number in text field	No errors		No errors	PASS
006	Verify phone credentials	Enter phone number less or		1.regiester for first time or	Can’t processed		Can’t processed	

		more than 11 digits		editing in account 2.enter phone number in text field	and note to edit it		and note to edit it	
007	Upload lab results	Patient uploads lab results	Login	1.click "upload lab results" button. 2.upload photo.	Uploaded successfully	View uploaded photo	Uploaded successfully	PASS
007	Upload lab results	Patient didn't upload lab results	Login	1.click save	Message "there's no lab results uploaded"		Message "there's no lab results uploaded"	PASS

5.3 Test cases for website

Table 5.Test cases for website

Test case ID	Test case scenario	Test case	Pre-condition	Test steps	Expected results	Post condition	Actual results	Pass/Fail
001	Verify log in	Enter valid username and valid password	Need valid email & already user	1.enter valid account 2.enter password 3.click "login" button	Login success		Successful login	PASS
001	Verify log in	Enter valid username and invalid password	Need valid email & already user	1.enter valid account 2.enter password 3.click "login" button	Error message "wrong password provided for the user"	Enter valid mail and password	Error message	PASS
001	Verify log in	Enter invalid username and valid password	Need valid email & already user	1.enter valid account 2.enter password 3.click "login" button	Error message "email address invalid"	Enter valid mail and password	Error message	PASS
002	Verify adding new patient	Add new patient, enter required info	New patient	1.click "add patient" button 2.enter name, phone, age, fasting blood sugar, cholesterol 3. Choose gender, exercise angina, chest pain types. 4. add description 5. click "add"	Added successfully	New patient added to patients list	Added successfully	PASS

002	Verify adding new patient	Add new patient, not enter required info	New patient	1.click “add patient” button 2.enter name 3.not enter all required info 4. click “save” button	Error message “please fill all the required data	Enter required info	Error message “please fill all the required data	PASS
003	Verify removing existing patient	Remove patient	Existing patient	1. Click “remove patient” button.	removed successfully	patient removed from patients list	removed successfully	PASS
004	Verify adding new doctor	Add new doctor, enter required info	New doctor	1.click “add doctor” button 2.enter name, phone, email. 3. click “add”	Added successfully	New doctor added to doctors list	Added successfully	PASS
004	Verify adding new doctor	Add new doctor, not enter required info	New doctor	1.click “add doctor” button 2.enter name 3.not enter all required info 4. click “save” button	Error message “please fill all the required data	Enter required info	Error message “please fill all the required data	PASS
005	Verify adding new nurse	Add new nurse, enter required info	New doctor	1.click “add nurse” button 2.enter name, phone, email. 3. click “add”	Added successfully	New nurse added to nurses list	Added successfully	PASS
005	Verify adding new nurse	Add new nurse, not enter required info	New nurse	1.click “add nurse” button 2.enter name 3.not enter all required info 4. click “save” button	Error message “please fill all the required data	Enter required info	Error message “please fill all the required data	PASS
006	Verify adding new admin	Add new admin, enter required info	New admin	1.click “add admin” button 2.enter name, phone, email. 3. click “add”	Added successfully	New admin added to admin list	Added successfully	PASS
006	Verify adding new admin	Add new admin, not enter required info	New admin	1.click “add admin” button 2.enter name.	Error message “please fill all the required data	Enter required info	Error message “please fill all the required data	PASS

				3.not enter all required info 4. click “add”				
006	Verify editing account	User edits his info	Has account	1.click “edit” button 2.edit info 3. click “save” button	Edited successfully	New info appeared in account	Edited successfully	PASS
007	Verify phone credentials	Enter phone number equals to 11 digits		1.regiester for first time or editing in account 2.enter phone number in text field	No errors		No errors	PASS
007	Verify phone credentials	Enter phone number less or more than 11 digits		1.regiester for first time or editing in account 2.enter phone number in text field	Can’t processed and note to edit it		Can’t processed and note to edit it	

5.4 Results

The various test cases conducted have successfully demonstrated the system's capability in terms of its functionality and its ability to handle a multitude of potential errors in a manner that is easily comprehensible and user-friendly.

The system is successfully able to sense patient’s vital measurements and process it to give an accrue prediction, with successful connection to the network between device, mobile application and website portal.

Chapter 6 : Conclusion

Our Wireless Patient Monitoring System for Cardiovascular Diseases is a comprehensive and innovative solution that aims to improve the diagnosis and management of cardiovascular disease. Our project represents a significant advancement in healthcare technology by integrating software, hardware, and machine learning to provide a scalable, efficient, and user-friendly system for healthcare providers and patients.

The software component of our system includes a mobile app for doctors and nurses to remotely monitor patients' health through ECG sensors. This feature facilitates timely medical intervention and reduces the risk of complications, resulting in better patient outcomes. The website for administrators provides a centralized platform to control the system and manage patient data, enhancing collaboration and communication within the healthcare team.

Our machine learning algorithm is a key component of the system, as it predicts the risk of heart disease based on patient data. The algorithm takes into account various factors, such as age, gender, and medical history, to provide accurate and reliable predictions. This feature enables healthcare providers to take proactive measures to prevent the onset of heart disease and provide personalized care for patients.

We have utilized the latest technological advancements, such as Firebase integration and ECG sensors, to develop a scalable and efficient system that makes it easier for healthcare providers to manage cardiovascular disease patients. The home service feature provides patients with greater access to their health information, allowing them to track their progress and upload lab tests for doctors' review.

Overall, our project has the potential to make a significant impact in the healthcare industry by improving patient outcomes, enhancing communication and collaboration within healthcare teams, and promoting the safe and efficient operation of the healthcare system. Our Wireless Patient Monitoring System for Cardiovascular Diseases represents a major step forward in the field of healthcare technology, providing a comprehensive and innovative solution to cardiovascular disease management. We are proud of the hard work and dedication that went into this project and are excited about the potential impact it can have on patient care. By leveraging the latest advancements in technology and continuing to innovate, we believe our system can continue to make a positive impact on the healthcare industry, improving patient outcomes and enhancing the quality of care healthcare providers are able to provide.

Chapter 7 : Future work

- Our project has the potential to improve even further with future developments in various areas. One key area of development is the implementation of chat functionality between doctors and nurses, as well as between doctors and patients. This communication system could improve collaboration within healthcare teams and enable personalized and efficient communication with patients.
- Another important area of development is the integration of a chatbot system for patients. This system could provide 24/7 support and assistance for common health inquiries and help patients who may not have immediate access to medical professionals.
- A screen on the device to display the reading of the ECG sensor could provide real-time feedback and insights to healthcare providers. Moreover, the implementation of text recognition for uploaded files from patients could enable machine learning predictions to be generated from uploaded files alone.
- Expanding the system to work for other diseases and conditions is also an important future development. We plan to use larger datasets and train models to work with a variety of medical conditions, thereby increasing the reach and impact of our project.
- Additionally, we plan to add doctors from other specialties to work with cardiovascular disease patients, as these patients require specialized care and attention.
- Additionally, we plan to allow patient to add files of clinical labs, radiographs, CT, and MRI.
- On the hardware side, we plan to use Raspberry Pi due to its compact size, low power consumption, and cost-effectiveness. This could enable us to develop a more portable and accessible system for healthcare providers.
- Overall, we believe that these future developments have the potential to significantly enhance the capabilities and impact of our project. By implementing these features, we aim to provide a comprehensive and effective healthcare solution that meets the needs of patients and healthcare providers alike.

Appendix:

This is the GitHub link to get the access to the mobile application.

This is the GitHub link to get the access to the website.

Or you can download the app directly by scanning this QR code.

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