HCare WEB APPLICATION FOR EHEALTH MONITORING SYSTEM

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This work presents a design and implementation of an enhanced healthcare monitoring system based on the web application framework and the cloud platform using four vital signs such as blood pressure, SPO2, body temperature, and electrocardiogram ECG. Innovative ECG modules were utilized for automatic diagnose like ECG filtering module and the DCNN-based ECG classification module. The solution provides various functionalities and privileges for the users in order to facilitate the work of doctors or emergency staff to monitor patients in order to provide medical support in a timely manner. Also, it supports patients by providing them with medical assistance through the remote interaction with medical professionals taking into consideration the security and privacy of sensitive medical data.

Keywords: HCare, Security and Privacy, Confidentiality, Alert Processes, Cloud computing

1. Introduction

Different health applications have been developed for mobile devices and vastly utilized by patients and medical personnel [7]. These applications lead to improve communication between doctors and patients thus assist to enhance the quality of treatment in general, therefore the utilization of these applications is quite useful. Generally, people prefer to access their information including medical information, in an effortless and flexible way with the current speedy development of mobile devices, therefore it became necessary to prepare fitting interfaces according to these different devices with use of Responsive Web Design (RWD) to develop a modern web-application [8].

Nowadays, various wearable mini-biosensors have become broadly available where it allows comfortable and non-intrusive monitoring of the activities of patients' lives. With the use of these biosensors that connect to mobile devices, we will be able to collect the medical data from the patients while they do daily life activities which allow us to identify and understand the patient's medical

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conditions. Professionals in the health field attempt to benefit from analyzing and investigating these health data in order to comprehend the diseases and conditions that affect a specific country or community [9], taking into consideration the confidentiality and security of these health data as sensitive data. The medical cases and health data of patients have to be tracked by the doctors when the patients being outside hospitals with the potential to access their recorded data and the ability to record the diagnosis and treatment data to their health profiles.

Building an interactive healthcare environment became an essential need to improve and increase the effectiveness of professionals in the health field, along with the enhancement of security and confidentiality of medical data, and as well as the improvement of quality of healthcare services. This work presents a design and implementation of an enhanced healthcare monitoring system based on the web application framework and the cloud platform using various vital signs such as blood pressure, SPO2, body temperature, and electrocardiogram ECG. This web application system called Hcare where provides the physicians with the ability to monitor the health of their patients as well as provide health and medical consultation to them and allows the patients to observe their health activities. Hcare provides different functionalities for the patients and medical professionals. The basic idea of our solution stated based on a previous survey published in [6].

Information security issues have also been investigated and included in the platform as healthcare information threats in the system, information consent, and information sharing, to obtain better protection of patient information. Also, the techniques and approaches of security and privacy of our Hcare web-app were explained along with the confidentiality of the patient's information. The system provides appointments schedule management between patients and doctors and also provides Alert Mechanism as system notifications or SMS according to the severity of the medical condition of the patient. This system uses enhanced and advanced techniques to filter and classify the vital signs of patients especially the ECG signal where these techniques were previously published in the articles [10] [11].

2. System Requirements

The requirements of users were determined for the healthcare monitoring systems through a survey conducted previously in our published article [6]. This survey was intended to take a comprehensive look at the requirements that are essential for the platform of healthcare monitoring systems from the viewpoint of users. The questionnaire was conducted online by distributing it directly to a set of people who have jobs in the information technology fields or the medical fields and others.

The identified requirements can cover the essential demands for different divisions of users such as regular or elderly patients, in addition, the patients who

suffer from various illnesses. Medical professionals and normal people (non-medical) are agreed that online healthcare monitoring systems will be extremely significant and the demand for it will increase in the market. The survey results are considered necessary to determine the system development priorities for the ultimate product. The product will develop a platform of unified software serving healthcare that saves the users from multiple programs problem and also the websites of specialized healthcare which distract users and doctors. These requirements are: the potential of obtaining medical counsel from a doctor, to get the results of lab, to view and read the medical articles in the web application, to interact the medical staff (doctors and Emergency staff) with patients. The developed solution should offer security, efficiency, reliability, performance, usability and portability.

3. System Architecture

The general architecture of the proposed e-health system is illustrated in Fig. 1. Various users are utilizing this system such as patients, doctors, and the emergency staff along with the administrator who control and manage the system. The system architecture is composed of the following components:

- **Sensor-based eHealth wearable devices**: various types of biosensors are measuring significant physiological parameters of a patient like blood pressure, electrocardiogram (ECG), oxygen in the blood (SPO2), and Body temperature. The aggregated data from the biosensors are transferred into the system for preprocessing and decision making.
- **ECG module for automatic diagnose**: The received ECG signals pass through two innovative modules. The first one is the ECG filtering module that uses a hybrid filtering model based on a FIR Chebyshev filter algorithm and Savitzky-Golay filter to remove the noises from the ECG signal. The second one is a DCNN-based ECG classification module that uses Transfer Learning approach in the Deep Learning field using pre-trained Convolutional Neural Network for automatic prediction. Both modules were designed, developed and tested previously, the details being published [10] and [11].
- **Hcare web application**: provides various functionalities and privileges for the users in order to facilitate the work of doctors or emergency staff to monitor patients in order to provide medical support in a timely manner. Also, it supports patients by providing them with medical assistance through the remote interaction with medical professionals taking into consideration the security and privacy of sensitive medical data.
- **Cloud server**: The Hcare web-application runs on Microsoft Azure cloud in the form of Software as a Service (SaaS).

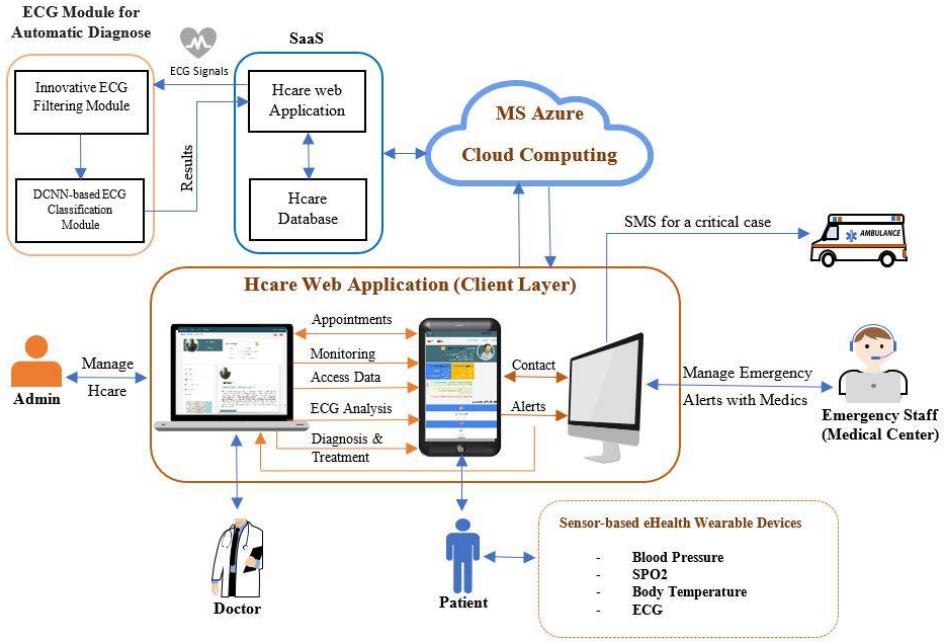

Fig. 1 System General Architecture Diagram

The proposed system consisted of varied components as shown in Fig. 2. The Graphical User Interface (GUI) allows the end-users who are administrator, doctor, patient, ambulance staff, and other to interact with different activities in the system. Identity framework API supports GUI login functionality such as manage usernames, passwords, email confirmation, and others. The users have the possibility to create a login account in which the login details will be stored in identity or they can utilize login information from external providers such as Google, Facebook, etc. [1].

Whilst the entity framework which also called Object Relational Mapper (ORM) is an open-source framework provided by Microsoft that maps the entities with the tables of the database automatically. It allows us as developers to utilize .NET objects for operating with a database [2]. Use Case diagrams were employed to illustrate the functional requirements of the system. Chief components of this diagram are users, the functionalities of system (use cases), and the relationship of them (Fig. 3).

❖ **Functionalities and privileges of doctor:**

✓ He can view his profile information and patients' profile and search for the patient through his ID or name.
✓ Access the patient medical history with the ability to edit and add medical information such as diagnoses and treatments (prescriptions). Also, he can

upload documents or images related to test results, ECG, X-Ray, and so on to be part of the patient medical history.

- ✓ Manage the appointment scheduling with the patients and contact them.
- ✓ Ability to monitor the patient's health activities (ECG, SPO2, Blood Pressure, & Body Temperature) and receive a notification and SMS from the user-end for the abnormal conditions.

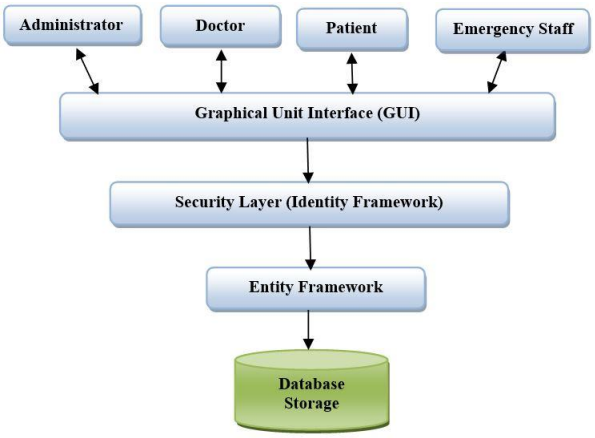

Fig. 2 Database Design Scheme

- ✓ A doctor can perform an electronic diagnosis of an ECG signal that received from his patients through the system to detect whether the patient has Atrial Fibrillation or suffering from other arrhythmias. A hybrid filtering model has applied also in the background of Hcare web-app to remove the noises from the signal before the diagnosing where this model was proposed and published in our previous work [10].
- ✓ Can make reports and print them.

❖ Functionalities and privileges of patient:

- ✓ View his profile and medical history.
- ✓ Search for a doctor according to his specialization, address, and hospital/clinic.
- ✓ The system provides the patients with the ability to manage the appointment time and date with the doctor and confirm\cancel the appointment.
- ✓ View and monitor his medical activities and receive a notification or SMS from the system or doctor for the abnormal conditions.
- ✓ Able to contact doctors and emergency\ambulance staff.

❖ Functionalities and privileges of Emergency Staff:

- ✓ View his profile.
- ✓ View patient profile and his medical history.
- ✓ Receiving calls and emails from the patients.

✓ Receive an auto SMS from the system in case the condition of the patient is critical, and able to detect his location from the GPS.

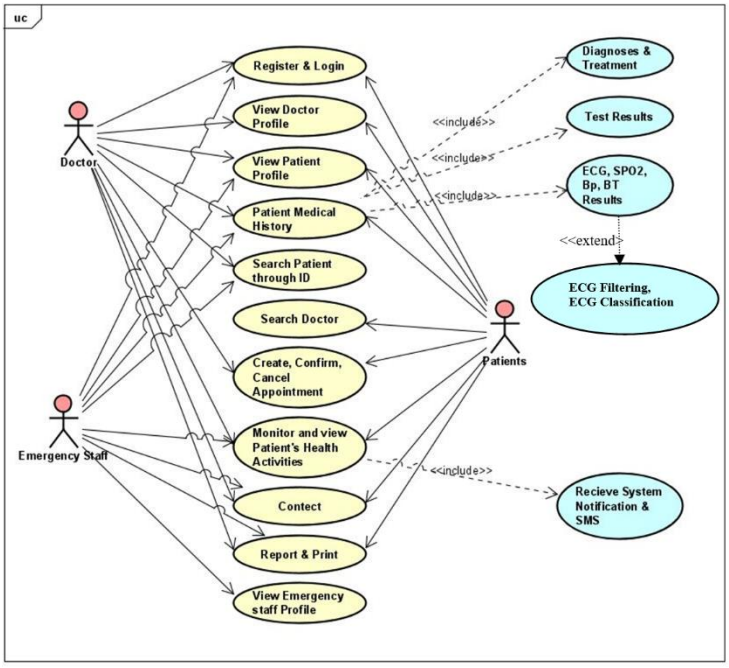

Fig. 3 Use Case Diagram of the Proposed System

4. HCare Alert Processes

The healthcare monitoring system comprises an alerting part. The alerting part either to be a notification through HCare web application or via SMS in order to notify the patients themselves and the medical professionals (Doctors and ambulance staff) about the abnormal and critical health conditions of the patients. Regarding alerting through SMS, it is sent either to the patient's phone, the doctor's phone, or the ambulance phone, according to the level of health condition severity. The alerting SMS contains Patient ID, levels of vital signs, and along with GPS coordinates (sent to ambulance staff).

Fig. 4 a) illustrates the decision making of sending alarming SMS in the system according to the vital signs levels for systolic blood pressures. The diastolic blood pressure case was also considered in a similar way. An SMS will be sent in case the measured data exceed the normal thresholding value.

Fig. 4b) presents the flow chart of ECG diagnosing results where the alert will be sent when the ECG diagnosing result is AFib case or if there is another arrhythmia case. Alerting algorithms for SPO2 level and body temperature level have also been developed and implemented.

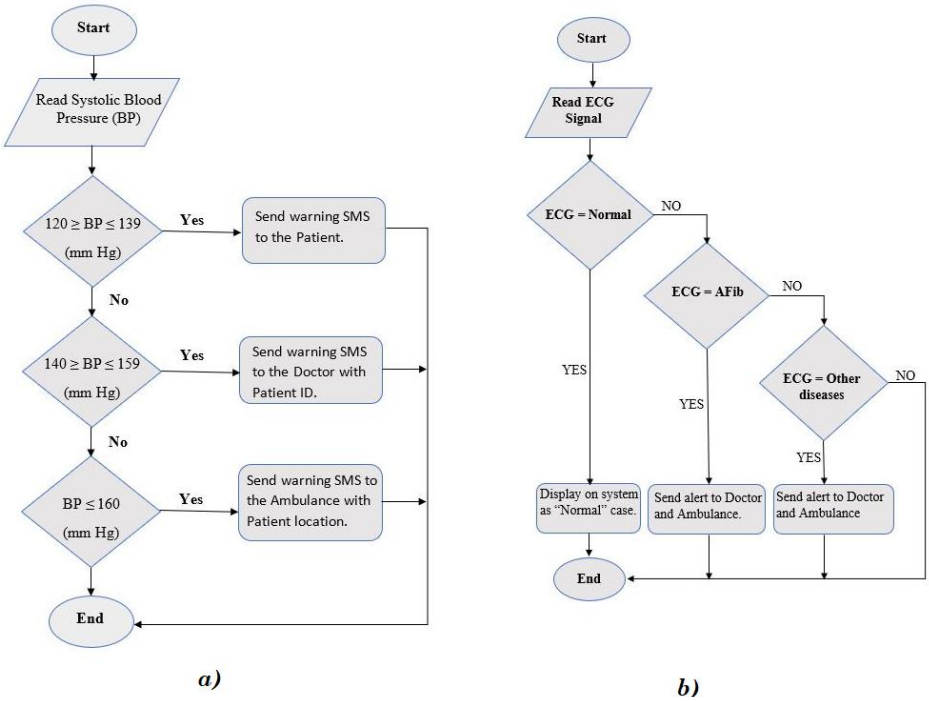

Fig. 4. a) Flow chart of the alerting system based on systolic blood pressure; b) Flow chart of the alerting system based on ECG AFib Disease

The alerting messages will not be sent to all the users (patients, doctors, and ambulance staff) for any abnormal case but it will send the alert message according to the severity level of vital signs if the severity level is medium the message will be sent to the patient only, and if severity level is high then the message will emergency send to patient and doctor, and in case severity level is reached to a critical level then the alert message will be sent to all the users patients, doctors, and ambulance staff. The purpose of this distribution is to avoid inconveniences for doctors and emergency personnel due to the large number of alert messages that perhaps unnecessary to them. Except for ECG, the alerts will be sent to the doctor and staff for any kind of arrhythmias because arrhythmia could be considered critical in all cases from the medical perspective.

5. System Security Measures

Information security of the healthcare field is extremely significant due to high health security threats. Healthcare systems face many hazards to the security of health information arising from ransomware, IoT devices that were insufficiently secured, and human elements as well [3]. The entire communication stages that perform by users in a healthcare system in a sequence to achieve a certain targeted mission must be secured and protected [4]. In order to obtain

better protection of patient information, information security obligated to have the ability for further classify patient information confidentiality and broaden the scope of safety measures respectively in the same system [5]. Measures like healthcare information threats in the system, information consent and information sharing have been considered. Different protection steps were applied to patient-sensitive data through the safe points of web application to ensure integrity and privacy [14].

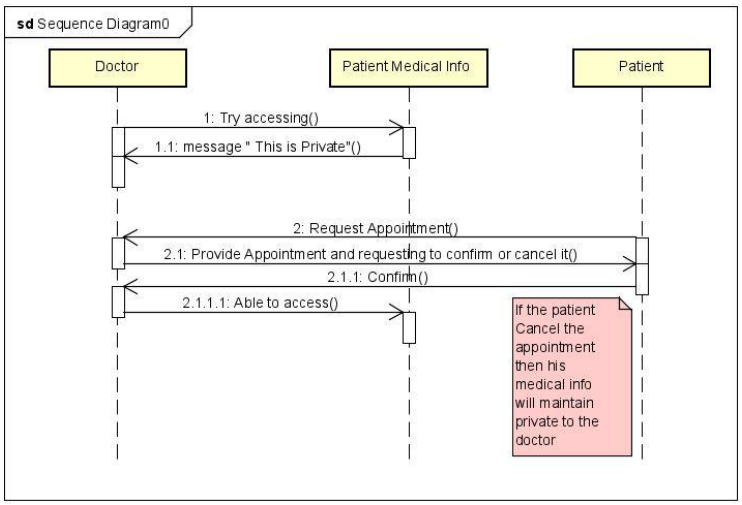

Fig. 5 Privacy Scenario of Patient's Medical Info through Appointment

Confidentiality is quite comparable to privacy. Confidentiality can be defined as an individual's right to retain his personal medical information as private info. Measures must be taken to prevent sensitive data of the patients to be reached by the wrong persons and restrict the access to authorized users only. The sharing of medical information is subject to the decision of the patient himself. The patient decides for whom will share his medical information with the medical staff and as necessary need. Medical professionals have the responsibility to protect the patient's health information when received it from them. In our proposed system, the doctor will not be able to access the patient medical information until the patient requests an appointment with this doctor and the appointment must be confirmed by the patient, in this case only, the medical information of this patient will be reachable by the doctor otherwise the information will maintain on its private status, Fig. 5 illustrates this scenario.

Two-factor authentication (2FA) method was applied to improve the security layer in order to protect the users accounts. Data Encryption technique of the identity framework has been used to ensure the confidentiality by encrypting user’s ID and the information of the user.

6. Design and Implementation

Different design environments and tools have been used for the web application development: C# Programming Language, ASP.Net MVC, JQuery, Bootstrap, Identity Framework, Entity Framework and SQL Server. The cloud component of the system was developed based on SaaS concept [12-13]. Cloud computing allows us to carry out the computation by offering various types of services and the method of exchanging data through the Internet. The services of healthcare system are offered to users (health professionals or patients) over an internet network. Microsoft Visual Studio v.2016 has been used to deploy Hcare web-app on the MS Azure cloud. The MATLAB algorithms of the innovative ECG filtering and automatic diagnosis modules have been integrated with Hcare web application through assembly libraries called Dynamic Link Library (DLL) and the header files generated by means of MATLAB Compiler™ SDK approach. The web pages are designed to cover the requirements of health services, and this design is included with different sub-web pages also. Fig. 6 shows the home page of Hcare web application. From the home page the user can scroll down and read the latest three health news, the system display the most three interested news and if the users want to read more health new then they can click on the button (See more) or Health New option from the top bar of the page to view all the recent health news.

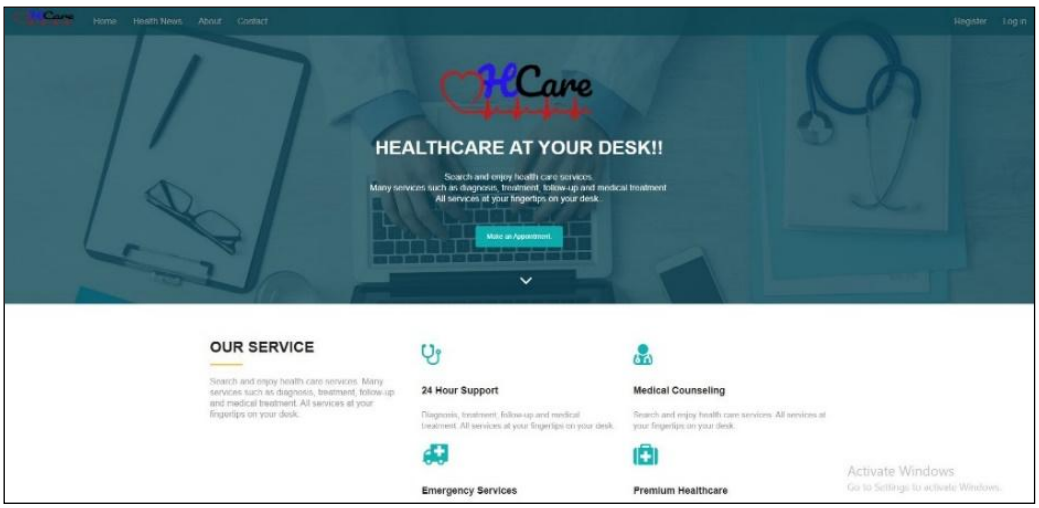

Fig. 6 Home Page of Hcare Web App

The administrator has privileges to manage all the users in general and control their roles by keeping the user as a patient or convert him to be a doctor or paramedic. The doctor can manage the appointment schedules with patients,

access the profile of their patients along with their medical history. In addition, a doctor can monitor medical activities (SPO2, blood pressure, body temperature, and ECG) of a patient and receive alerts for the abnormal statuses where the doctor can diagnose the patient and suggest prescriptions by adding treatment and medicines according to that. The system provides additional services to doctors such as correspondence with the patients by messages and chat, and they can make reports and print them. The patient will be provided with various functionalities in this section of the system such as view his profile, medical history, health information. He can read digital diagnoses and prescriptions that are given by a doctor. Also, he can monitor the levels of his medical activities and receive alerts as notifications or SMS from the system or doctor for irregular conditions where the alerts notifications will be on three levels as *medium*, *high* and *critical*. Presenting the activity chart for each of SPO2, Blood Pressure, and Body temperature of a patient is significant for an accurate diagnosis.

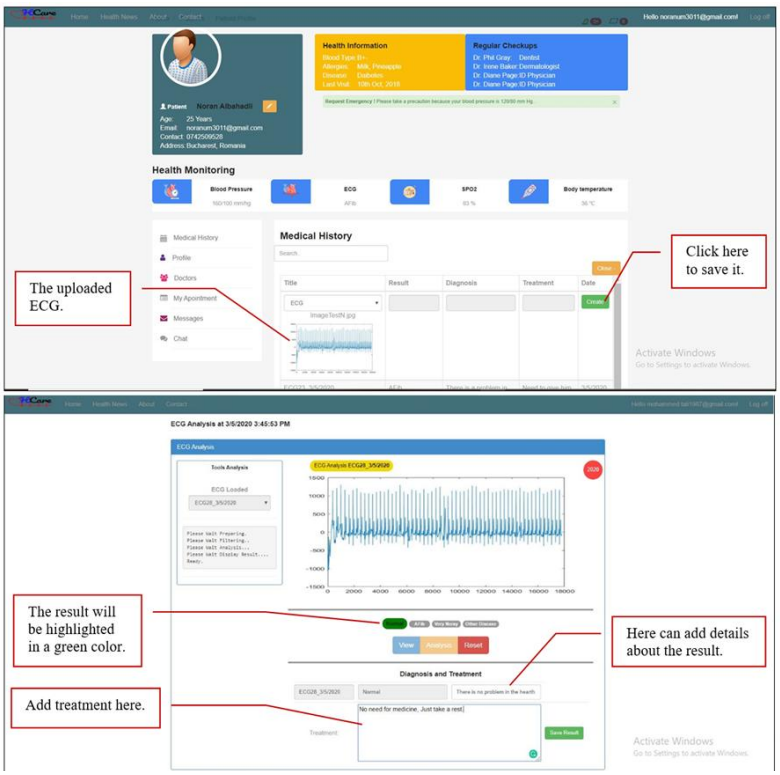

Fig. 5 ECG Analysis Process

The ***emergency section*** deals with the critical statuses of the patients and it manages by an emergency center where all the critical conditions will be received including patient information like (patient name, blood type, gender, address, the coordinates of location, and health status) and listed it according to severity level

then send it to the mobile of ambulance staff to take the necessary action. Patients can reach the emergency center via various means of communication provided by the system like emails, chats, and phone calls.

The ECG analysis section designed to support the doctor in diagnosing the electrocardiogram (ECG) of patients for an AFib disease by uploading the signal manually or receive an ECG signal from the patient side through the system. The system provides a doctor with the ability to view the ECG signal and analyze it to predict the result in case it is Normal, AFib, another disease, or very noisy can't be classified even after the filtering processes (Fig. 7). The proposed Hcare Web Application was intensively tested from several aspects with the use of various browsers such as Google Chrome, Brave, and Internet Explorer and in different devices like laptops, smartphones, and tablets. Hcare was tested by numerous doctors and patients, and they were satisfied with the use of Hcare and its services. The functionality of the proposed system has been tested, and we have confirmed that everything is working successfully.

Hcare is a scalable and easy extendable system. The number of vital signals of the patient can be increased for better medical observation. Moreover, the classes of the ECG signal can be increased to detect more heart diseases.

7. Conclusion

This work presents a design and implementation of Hcare web application framework for healthcare monitoring based on various vital signs such as blood pressure, SPO2, body temperature, and electrocardiogram ECG. The design was based on different requirements that are determined based on a previous survey. This project includes a cloud computing, the mechanisms of security and confidentiality, and the use of the Responsive Web Design (RWD) pattern. The main tools that used to design and develop the Hcare are C#, ASP.net MVC, Jave Script (JQuery), Entity Framework, Bootstrap, and SQL Server technologies due to good operability and compatibility. This system supports patients by providing them with medical assistance and saves time and mobility. The system provides several services for the patients and medical professionals such as monitoring the medical activities of the patients by the patients themselves and their doctors, and they will receive warning alarms as system notifications or SMS according to the severity of the medical condition of the patient.

The main purpose of this system is to provide the doctor with the ability to analyze the ECG signal of a patient to determine the AFib disease or if there is any other disease, also he can add electronic diagnosis notes and treatment for the patient and save the results in the record of medical history of the patient. Intensively system testing proved that all the system functionalities work properly. Finally, the outcomes of the system will assist doctors or emergency staff to observe patients in order to provide medical support in a timely manner.

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