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An Online Hypertension Risk Monitoring System

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Abstract—High Blood Pressure is a key risk factor for chronic kidney disease, haemorrhagic stroke, ischaemic stroke, heart failure, myocardial infarction, early death, and cognitive decline. It is still a problem for worldwide public health. The threat of hypertension and related disorders will be significantly reduced with early detection of hypertension and raising awareness. Having a web-based system will bring solution in reducing its devastating effects on health. This study developed a hypertension risk monitoring web-based system which can be accessed by authorized medical practitioners and patients. . The unified modeling language (UML) tools were used to design the system, and Web 2.0 technologies, MySQL, HTML, PHP, XML, Java, and CSS were used in its implementation. The local hosd Web-Apache-MySQL-PHP (WAMP) server was used to host the web-based hypertension risk monitoring system (BP_HRMSystem). Utilizing previously gathered hospital data for testing, the deployed system produced 100% accuracy. In order to offer reliable, fast, and comprehensive information regarding hypertension, it would be crucial to adopt this approach for monitoring hypertension risks. Medical practitioners and patients can use this hypertension risk monitoring system to identify, classify, diagnose, and manage hypertension and associated risk.

Keywords--Risk, Diagnosis, Hypertension, Monitoring, Web-Based System

1. Introduction

Ischemic and hemorrhagic stroke, heart failure, myocardial infarction, cognitive decline, chronic renal disease, and early death are all important risk factors for hypertension [1]. In persons aged 25 and older over the world, the incidence of hypertension was roughly 40% in 2008 [2]. Many nations are dealing with rising amount of heart disease that is the leading cause of illness, sudden death, and high mortality rate in men and women aged fifty-five and above worldwide [2,3]. According to a World Health Organization (WHO) report [4], 17 million individuals worldwide pass away from cardiovascular diseases (CVD) each year. Additionally, 6.2 million people die of strokes each year and 7.3 million die from coronary heart disease [5].

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The chronic medical condition known as hypertension, often known as high blood pressure (HBP), affects the heart [6]. Cardiovascular disease has HBP as its major risk factor, which has remained public health challenge globally [7]. When the average of two or more correct blood pressure readings collected during two or more encounters with medical professionals is $\geq$ 90mmHg for the diastolic blood pressure (DBP) and $\geq$ 140mmHg for the systolic blood pressure (SBP), it is considered to be hypertension [8]. Primary or secondary hypertension are the two categories for the illness. Secondary hypertension is connected to known causes such as endocrine diseases, vascular disorders, or renal problems, while primary hypertension has no known medical etiology [9, 10].

Therefore, it is crucial to control sickness, which entails conducting necessary research, important inquiries into the patient's past, and the physician-assisted delivery of medicine. To maintain the patient's blood pressure within the normal range is the major goal to be achieved [11]. Uncontrolled hypertension increases morbidity, economic burden, and mortality, and especially in older persons, which is a serious public health concern worldwide [12]. Heart disease, retinopathy, stroke, and kidney disease, all have hypertension as their primary and most important modifiable risk factor [13].The absence of suitable evaluative procedures and techniques for cases of hypertension and its management have resulted in upsurge in cardiovascular deaths worldwide [3]. There is need to monitor the risk of diseases. The automation of disease risk assessment is a component of disease risk monitoring, which lowers costs for patients and hospital administration while boosting the effectiveness of specialists [14, 15, 16]. A study by Abrishami and Tabatabaee [17] indicated that medical monitoring systems complement experts in numerous ways for the following reasons: doctors occasionally make mistakes; doctors may not always be available for patients; doctors may not have the required experience; hospitals may not have as many doctors to care for patients; and such systems decrease the cost implications associated with the service and increase the care quality.

The use of information technology (IT) has raised the need to create and establish new methods for delivering effectual healthcare services [18]. The term "e-Health" refers to the employment of communication technologies in the healthcare industry. These technologies include the computer system, internet, wireless, and other portable, devices [19]. In order to implement e-Health, healthcare systems must be completely redesigned to incorporate electronic communications at all levels. Electronically stored medical data about a patient, such as a computerized patient record, can be utilized to make decisions about the patient's health and care. It will assist medical professionals in delivering to patient secure, consistent, adaptable, and timely healthcare.

Clinical decision support system integration may reduce mistakes, improve patients' outcomes, reduce undesirable practice disparities, and enhance patient protection in light of computer-based patient records [20].

For millions of individuals around the world, the quality of healthcare services has improved due to wireless communication technology and computing platform integration in healthcare [21]. Using a web-based technology devices like phones, personal computers (PC), personal digital Assistants (PDAs), laptops, have brought revolution to healthcare services.

Additionally, this has made it possible to rapidly update patient records, which will allow doctors accurately take decisions and deliver higher-quality care for patient. Early information distribution and early patient detection, diagnosis, and management have both benefited from web-based systems. Many health monitoring technologies are being created nowadays to enhance people's health and quality of life [22].

Designing processes that are centered on patient needs is necessary [23], and specialists in the relevant processes should be consulted. This will make it simple for patients to get the knowledge they need to look after their own health.

To identify the risk of hypertension, becomes necessary in order to help the patients know the root of their problems, whether they are primary or secondary hypertension. Early identification of hypertension risk can help people make the necessary dietary and lifestyle changes to prevent the commencement of HBP and/or the associated heart illnesses. Risk of hypertension was categorized by WHO/ISH as Low, Medium, High, and Very High [24].

The goal of this work is to create a web-based Hypertension Risk Monitoring System (BP HRMSystem) that can identify people with hypertension, categorize their condition, and control their risk of developing it. The BP_HRMSystem has achieved that, and it can be accessed by authorized medical practitioners and patients. The use of BP_HRMSystem will greatly create awareness, influence diagnosis, treatment, and management of the hypertension risk.

2. Related Works

Related works on hypertension reviewed that there are several methods applied, with different variables being used in classifying hypertension risk.

A Web-based approach for the control of hypertension was presented by Djam and Kimbi [6]. The Web-based system was implemented using PHP and SQL. Only the individual's age, BMI, and blood pressure were employed in the system's computation. The study's findings demonstrated that the technique may be utilized to estimate the proportion of hypertension risk. However, few variables were used to develop a web-based system.

A health monitoring system for hypertension patients in rural Nigeria was suggested by Bolaji [25]. It was suggested to simulate a real-time mobile health monitoring system utilizing GPRS-capable technology. The monitoring system's data model was created using UML design, and JAVA was utilized to implement the system. The study's findings demonstrated that medical information can be transferred from mobile sensor implants via GPRS to patient records so that doctors could evaluate it. The system cannot categorize the risk of hypertension; it is simply capable of storing and retrieving information.

A real-time blood pressure, measuring temperature, and reporting system for inpatients was created by Egwaile *et al.* [26]. This system's purpose is to wirelessly link to a medical professional or other appropriate care providers and continuously monitor a patient's blood pressure and temperature. The system is centered on the C-programmed STM32F103C8 microcontroller, which controls the system as a whole and interfaces with various peripherals such as DS18B20 and the MPX5050GP. These serve as the system's main sensors for temperature and blood pressure, individually. The health monitoring system was created, built, and put to test. A clinical thermometer and an OMRON blood pressure monitor were used in comparing the findings of the body temperature and blood pressure measurements, respectively. According to WHO/ISH recommendations, the characteristics used were insufficient to make conclusions about the risk of developing hypertension.

Egejuru *et al.* [27] provided an adaptive neuro-fuzzy inference system (ANFIS) model to categorize hypertension risk. The model was emulated using the MATLAB ANFIS Toolbox. According to the study's findings, 33 key variables have been found for assessing the risk of developing hypertension. More than 50% of the patients who were chosen had very high risk of hypertension and 19% of patients had high risk of hypertension. The model aided medical personnel with accurate and early diagnosis, and hypertension management. The model was adopted for the development of the web-based system.

Considering heart failure incidences in Western Nigeria, Idowu et al. [28] created a web-based cardiovascular disease monitoring system that is accessible to both approved healthcare professionals and public health authorities. This was developed utilizing Web 2.0 technologies and unified modeling language (UML) tools. The WAMP server was used to host the locally installed system. Based on the data supplied and extracted by healthcare practitioners and users, the installed system was evaluated for usability and functionality. It was actually created with a variety of factors specifically for heart disease.

A Mobile-Based Hypertension Monitoring System was created by Egejuru et al. [29] to assist patients in understanding their condition, communicating with their doctor, and taking advantage of the doctor's prompt response regarding the impact of hypertension on their health. JAVA and Extensible Mark-Up Language (XML) were used to develop the system's mobile content and style. JavaScript Object Notation (JSON) was used in handling its data store and retrieval method, and was built using the Unified Modeling Language (UML). The system was evaluated using information gathered from a hospital, and the results showed 100% accuracy. This system gave an inspiration in developing the web-based hypertension monitoring system.

3. Methodology

Table 1 and Table 2 in this work list 33 WHO/ISH standard variables for defining hypertension risk that have been independently confirmed by specialists.

According to WHO/ISH guidelines for hypertension risk classification, the most important variables required in determining if a patient has hypertension are the diastolic blood pressure (DBP) and systolic blood pressure (SBP). The DBP and SBP which were monitored from patients and recorded in terms of millimeters of mercury (mmHg) were classified further into different categories which included grade I, grade II and grade III of the hypertension levels (Table 3). Additional variables, also included diabetes mellitus, associated clinical conditions (ACC), target organ damages (TOD), and other risk factors. In other words, after hypertension diagnosis on a patient, the risk will be determined. Each patient's risk of developing hypertension was categorized to be low, medium, high, or very high risk (Table 3). The patient was categorized as no risk or normal for someone whose DBP is less than 90mmHg and SBP is less than 140mmHg (for someone who is not hypertensive, (for someone who is not hypertensive, DBP < 90 mmHg and SBP < 140 mmHg)).

A multi-tiered robust system architecture was designed with Unified Modelling Language (UML). The multi-tiered system architecture consists of client-side (involving patient, medical doctor, hand-held devices), middle-tier (involving application server and system administrator) and server-side (involving database server and hosting services), which is shown on Figure 1.

It is vital to gather and alter the data required for tracking hypertension risk and thereafter apply the system so as to categorize the risk, based on the procedures necessary for hypertension monitoring as discussed in the expert cardiologists' interview. Each user's diary was created by the system, which contained both personal and medical information.

The technology will continuously gather data on people's blood pressure in order to assess each person's risk of developing hypertension. The risk factors with other clinical information included in the system, will be evaluated and the system will immediately classify the risk after three consecutive readings. There is no need to confirm a person's risk since the person has normal blood pressure.

Modeling the relationship between the actors and system was done using the requirement discovery technique known as Use Case Diagram. A Use Case Diagram, in its most basic form, identifies the actors

Table 1: Risk Factors Identified

S/No	Names
1	Gender
2	Age – Women >= 65 years and Men >= 55 years
3	BMI (Body Mass Index) (Height and Weight)
4	Diabetes
5	Exercise
6	Heart disease Family History
7	Hypertension Family History
8	Alcohol
9	Diastolic BP
10	Systolic BP
11	Marital/Domestic issue
12	Salt intake
13	Sedentary lifestyle
14	Smoking
15	Total cholesterol > 6.5mmo/l (250 mg/dl)
16	Stress at workplace
17	Presence of Plaque (Ultrasound scan) - TOD
18	Hypertensive retinopathy (Fundoscopy) - TOD
19	Left Ventricular Hypertrophy (LVH) (An Electrocardiogram (ECG)) -TOD
20	Protein (Urinalysis) - TOD
21	Cerebral haemorrhage (Cerebrovascular disease)
22	Ischemic stroke (Cerebrovascular disease)
23	Transient Ischaemic attack (Cerebrovascular disease)
24	Angina (Heart diseases)
25	Congestive heart failure (Heart diseases)
26	Coronary revascularization (Heart diseases)
27	Myocardial infarction (Heart diseases)
28	Diabetic nephropathy (Renal Diseases)

29	Dissecting aneurysm (Vascular Disease)
30	Haemorrhages or exudates (Advanced hypertensive retinopathy)
31	Symptomatic arterial disease (Vascular Disease)
32	Papilloedema (Advanced hypertensive retinopathy)
33	Renal failure (plasma creatinine concentration > 2.0 mg/dl) (Renal Diseases)

Table 2: Identified variables and labels for the risk of hypertension

Variable	**Value**	**Crisp Value**	**Linguistic value (Label)**
Systolic Blood Pressure (mmHg)	Below 140 (Normal) 140 – 159 (Grade I) 160 – 179 (Grade II) 180 and Above (Grade III)	1 2 3 4	Normal Mild Hypertension Moderate Hypertension Severe Hypertension
Diastolic Blood Pressure (mmHg)	Below 90 (Normal) 90 – 99 (Grade I) 100 – 109 (Grade II) 90 and Above (Grade III)	1 2 3 4	Normal Mild Hypertension Moderate Hypertension Severe Hypertension
Number of Risk Factor(s)	0 1 – 2 3 and Above	0 0.6667 1	None 1 or 2 3 or more
Target Organ Damage (TOD)	No Yes	0 1	Absent Present
Diabetes	No Yes	0 1	Absent Present
ACC (Associated Clinical Conditions)	No Yes	0 1	Absent Present
Hypertension Intensity/Risk	None Low Medium High Very High	0 0.0833 0.3333 0.5833 1	Normal Low Risk Medium Risk High Risk Very High Risk

Table 3: WHO/ISH Stratification of Hypertension Risk

Risk Factors excluding SBP and DBP	BLOOD PRESSURE (mmHg)		
	Mild Hypertension - Grade 1 DBP: 90 – 99 SBP: 140 – 159	Moderate Hypertension - Grade 2 DBP: 100 – 109 SBP: 160 – 179	Severe Hypertension - Grade 3 DBP: ≥ 110 SBP: ≥ 180
0 risk factor	LOW	MEDIUM	HIGH
1or 2 risk factor(s)	MEDIUM	MEDIUM	VERY HIGH
3 or more risk factor(s), Target Organ Damage (TOD) or Diabetes	HIGH	HIGH	VERY HIGH
ACC (Associated Clinical Conditions)	VERY HIGH	VERY HIGH	VERY HIGH

(Source: - Chalmers *et al.*, 1999.)

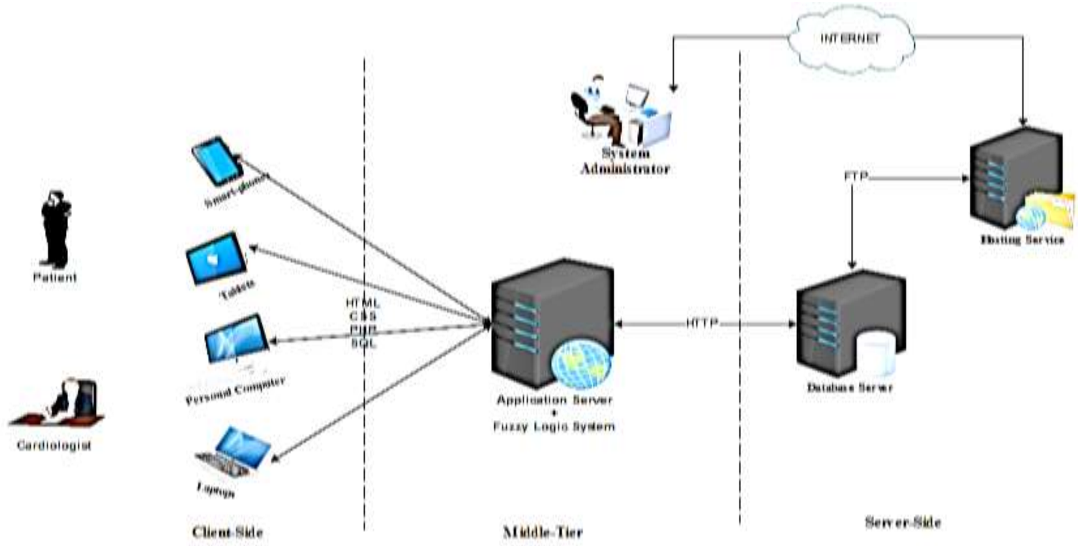

Figure1: BP_HRMSystem System architecture

(users) involved in an interaction, as well as the kinds and names of interactions that are taking place. The system requirements, which would employ the data model required, were presented using these use case scenarios. Utilizing the scenarios allowed for the realistic definition of the system workflow, which was to specifically define the goals and behaviors of the users.

Table 4 and Table 5 describe data insertion and data query, respectively. There are two namely the system administrator and the principal users, who are the physicians or cardiologists. A dairy is created the moment the user puts in information about the blood pressure. This will record crucial information about the user. The system can work with this data to provide patients the assistance they need, and cardiologists and general practitioners can access it from anywhere to check the patients' information and, if necessary, get in touch with them in the event of an emergency.

Figure 2 shows the Use Case scenarios listed in Table 4 for data insertion and Table 5 for data query. The diagram uses stick figures to represent the users (actors) to represent patient, the cardiologist, and monitoring system that will be interacting with the system. The various actions that users can perform on the system are represented by the oval structures in the diagram. Before taking any action, both cardiologist and patient must log into the system. The cardiologists can examine all of the patient information, but are unable to change the data that patients submit. The locally hosted Web-Apache-MySQL-PHP (WAMP) server was used to host the implemented web-based hypertension risk monitoring system (BP HRMSystem).

Table 4: Use Case - Data Insertion for Users

Use Case Name	**Data Insertion**
Description	Scenarios illustrating Data Insertion
Actors	Cardiologist, Patients, Administrator
Scenario	1. Administrators pre-register the cardiologists by providing hospital-based and personal info 2. Patient registration in the diary 3. Patient Personal info 4. Risk factors provided by Patient 5. Etiological factors provided by Patient 6. Clinical information provided by Patient 7. Login Details (password and user Id)

Table 5: Use Case - Data Query for Users

Use Case Name	Data Query
Description	Scenarios illustrating data query for cardiologists and patients.
Actors	Administrator, Cardiologists
Scenarios	1. User identification checks by system, after providing login detail: • If a user is valid, a menu for actions displays on the system. • If a user is not valid, the system denies access. 2. Cardiologists view patient records' number stored and info provided by patient on the system. 3. Patient able to determine hypertension risk. 4. Patient requires to perform partial activities. 5. Cardiologist can contact patient.

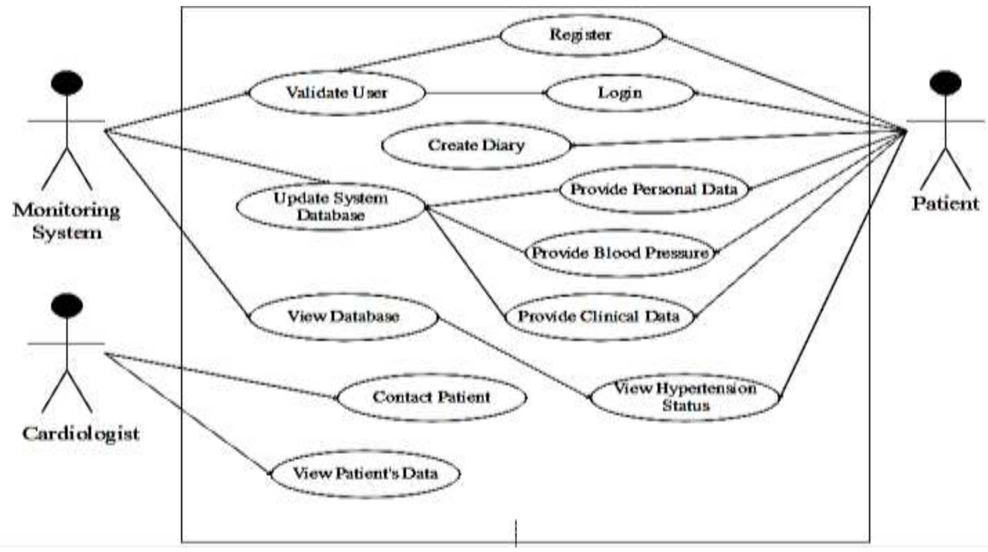

Figure 2: Use case Diagram

The web-based system was developed with JavaScript, Cascading Styling Sheets (CSS), Hypertext Preprocessor (PHP) and Hypertext Mark-Up Language (HTML) for the front-end appearance of the web document to be published for the web-based solution. Following a rapid application development, the layout of the content of the web interface for the system was implemented using HTML version 5, the current method of defining web content. The rapid application development was used since development was focused on a particular unit of the overall code following which the units were integrated into a single system.

The database tables for each entity (class/object) in the system, together with the fields, were constructed for web-based solution using MySQL.

4. Results and Discussion

A. Results

A patient's diary was created by the system, which is being used to store clinical and personal information. The BP-HRMSystem (classification system) correctly classifies patients' blood pressure as Normal, grades I, II and III, where appropriate. The system was able to distinguish accurately the cases of low, medium, high and very high on hypertension risk for patient being hypertensive.

Figure. 3 displays the system main menu (BP_HRMSystem). Figure 4 shows the patient's login menu, and Figure 5 shows the Interface menu, showing the activities of Patient, Doctor and Administrator.

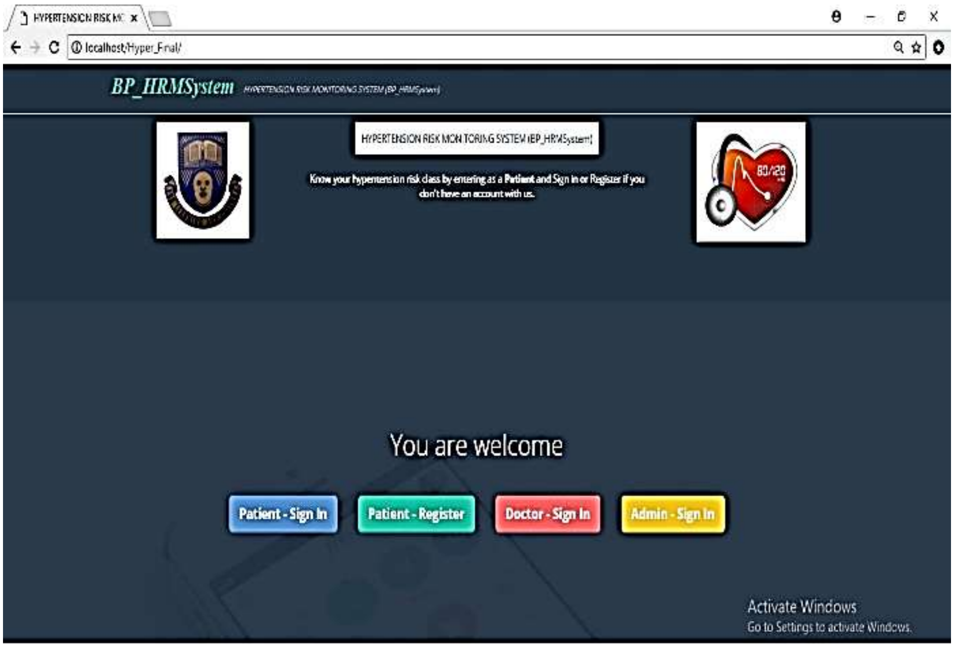

Figure 3: BP_HRMSytem main menu

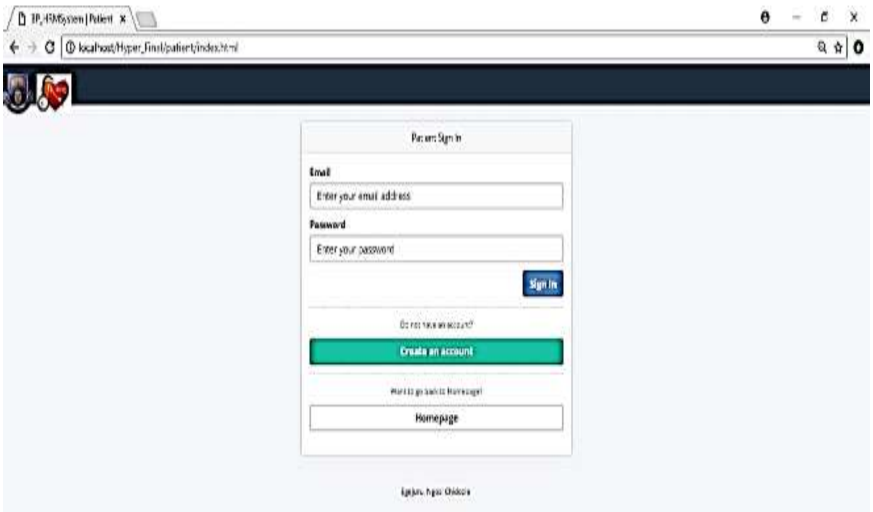

Figure 4: BP_HRMSystem Login Menu

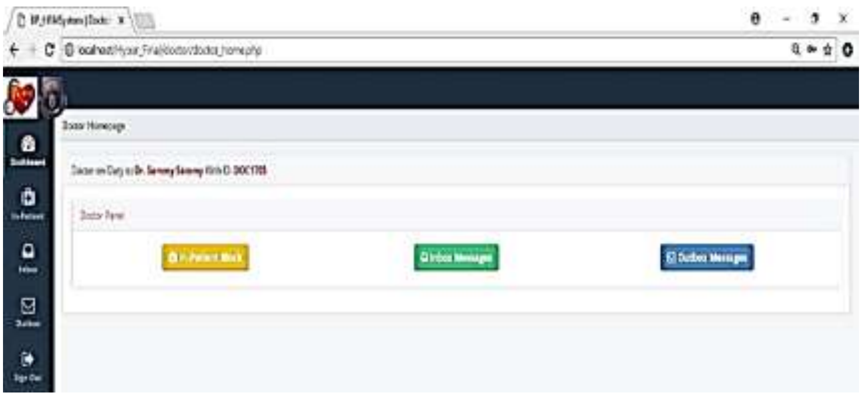

Figure 5: BP_HRMSytem Interface showing various Activities

Figure 6, Figure 7 and Figure 8 show the interface screenshot that is for the patients in providing information regarding their state of health, which includes all the information stated in the questionnaires used to collect information from the patients selected for this study and in accordance with WHO standard to classify the risk. All section must be provided with necessary information to enable user proceed in determining the state of patient's health.

Figure 9 shows the screenshot of the interface used to present the result of the analysis of the patients provided information. The Figure shows the previous reading provided by a user in graph presentation of the patients' increase and decrease of diastolic and systolic blood pressure levels.

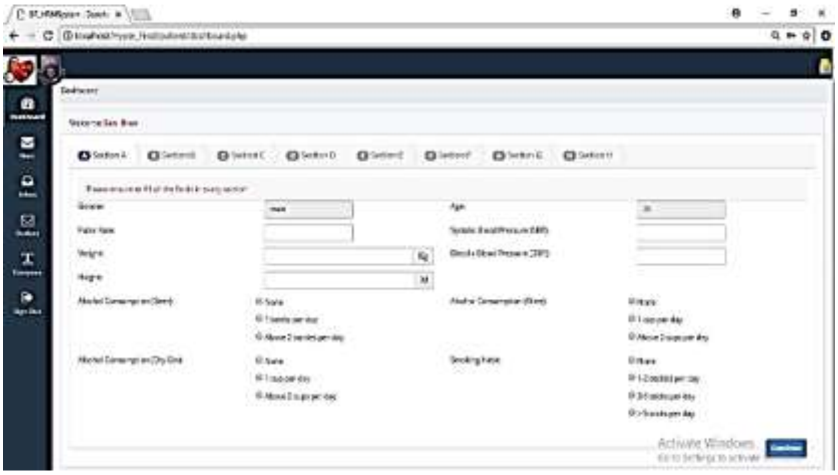

Figure 6: Dashboard for Patient Information on Hypertension

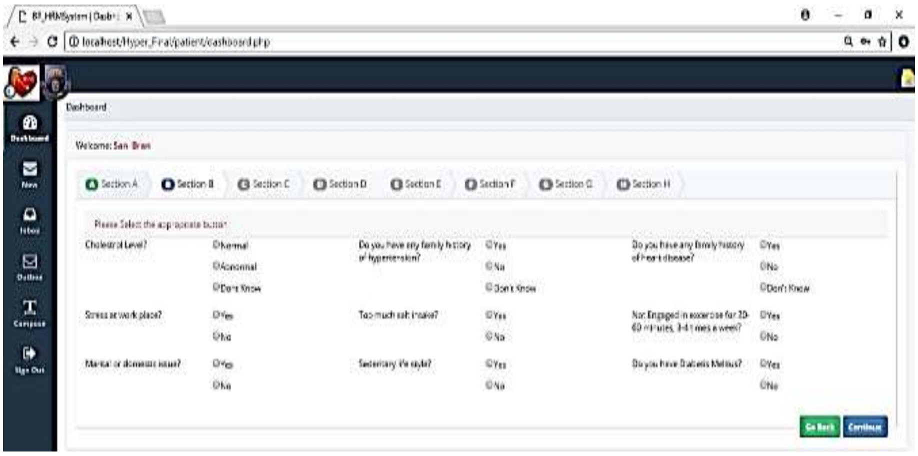

Figure. 7: Dashboard for Patient Providing Information on Hypertension

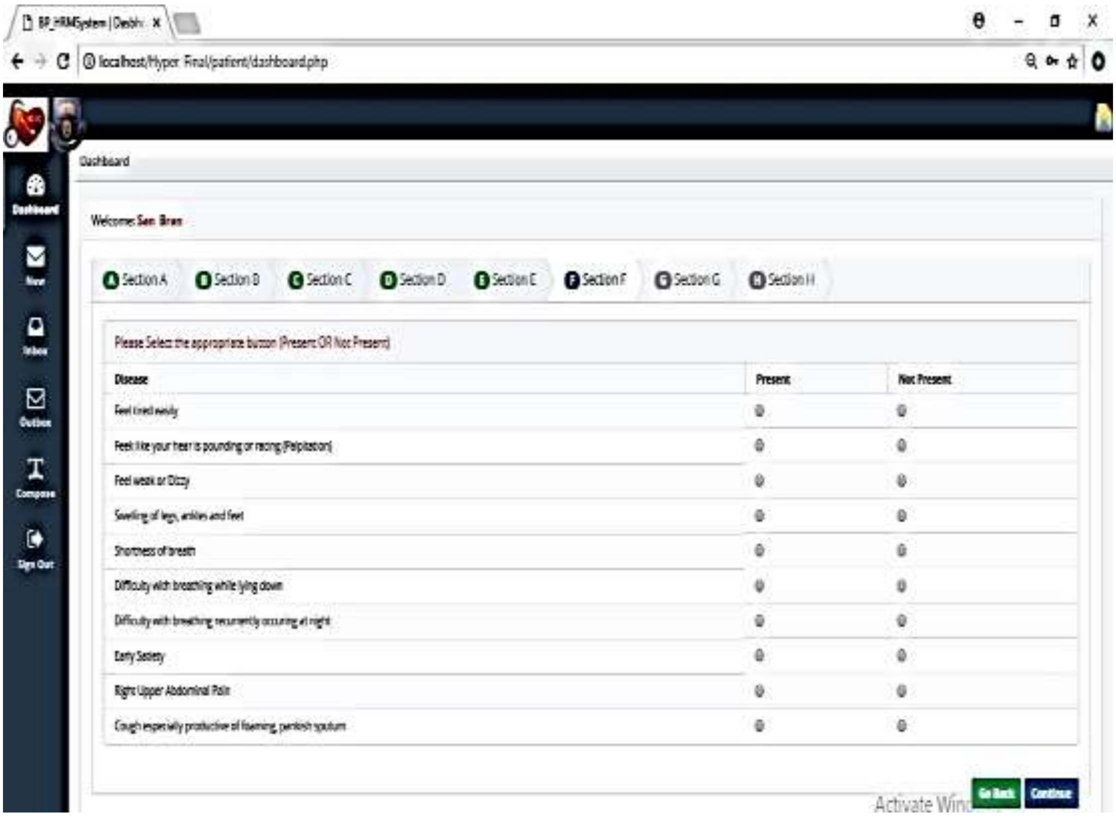
Figure 8: Patient Dashboard Continued

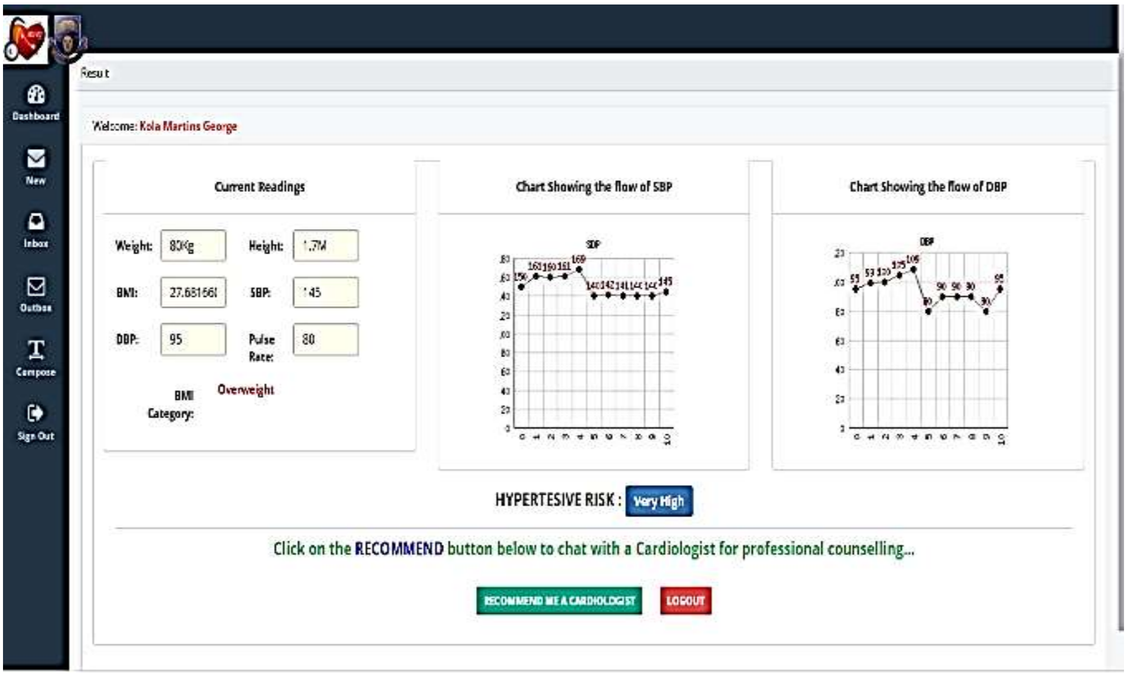
Figure 9: Patient Viewing Results

Figure 10 presents the dashboard of the administrator, displaying different types of activities that can be performed by the administrator which were classified into three: managing administrator, managing requests, and doctors. Hospital that is registered has an administrator that in turn registers doctor that works in their hospital and want to have access to the record of the patient.

Figure 11 displays the administrator accessing the incoming alert and forwarding it to any accessible doctor so they can treat the patient.

Figure. 12 displays the dashboard accessible by doctor on the assigned patient's facts for prompt medical consideration.

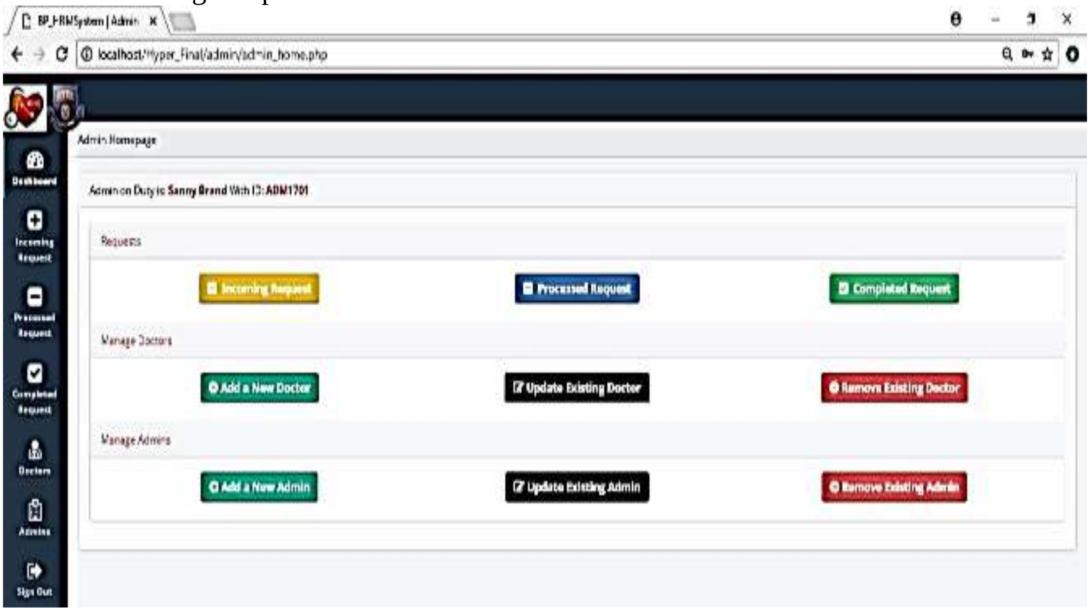

Figure. 10: Dashboard showing Activities to be carried out by Administrator

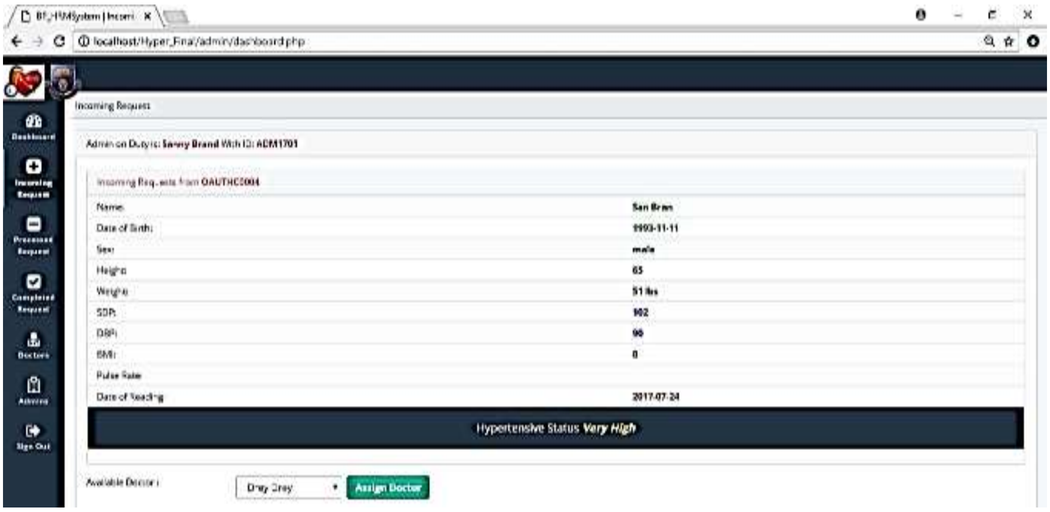

Figure. 11: Dashboard for Administrator to Assign Doctor to Patient

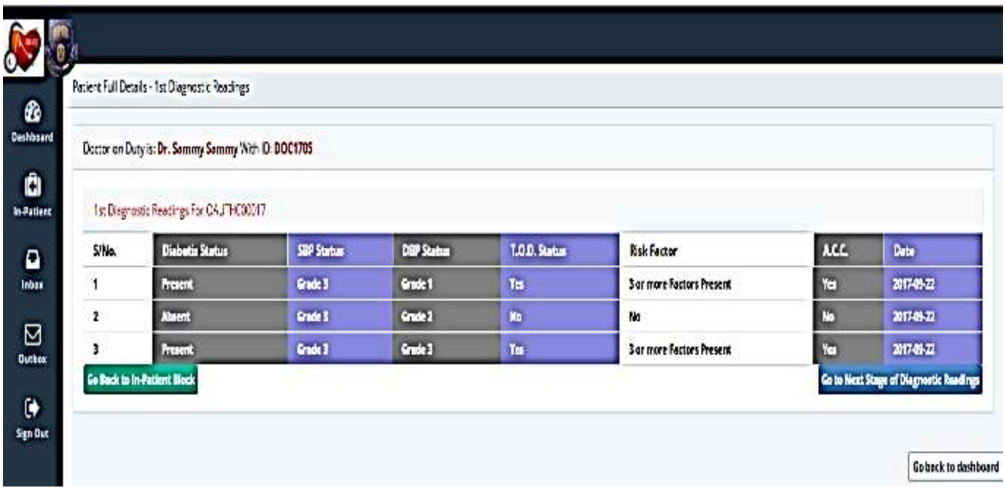

Figure. 12: Dashboard for Doctor to View Assigned Patients

B. Discussion

The system for hypertension risk was created for web-based system users, in order to make the system without problems available to users from every remote location. Figure. 6, Figure. 7 and Figure. 8 were used to put in values for the variables required for the monitoring system development. The 33 variables confirmed and identified by specialists provided rightful information used to classify and monitor hypertension, and its risk. All the sections in figure 5 being completed by a user, needed to provide necessary information before the users can proceed in determining the state of health regarding hypertension.

The variables under ACC, were identified using the symptoms of the diseases suffered by the patients. After the variables have been input into the system, the monitoring system calculates the BMI and plots the BP of the patient (Fig. 9). The system also classifies the hypertension risk of the patient.

Figure 10 shows the Administrator's menu, which handles management of the Doctor, user and message. This gives the Doctor the opportunity to connect with the patient, interact and do recommendation. The Doctor views patient's record but will not be able to modify the record. The Doctor's response, comes as alert to the administrator, then to the patient.

Fig. 11 handles the incoming alert from patient's record and the system classification, which the administrator will assign to a Doctor for review. The figure 8 gives a summerised information of a patient.

Fig. 12 gives a detailed information on the patient, being viewed by the Doctor that the patient was assigned to, by the administrator. Thereby assisting the Doctor in making decisions.

When the variables are input into the system, the system identifies the patients that are hypertensive, classify the hypertension and hypertension risk, and through the Administrator, sends information to the Doctor (in a registered hospital), who cross-checks the patient's information and send message to the patient through the Administrator. The moment a link has been established by the Doctor, the system and the Doctor monitors the patient based on the records supplied by the patients.

6. Conclusion

A developed web-based application enables patient check the hypertension status in any location and at any point in time and also assisting physician in patient's monitoring and classification of hypertension risk easily. The identified results are saved online in the record of the patient, which is shared with physicians through SMS and web. All these are monitored by an Administrator. The historical data gathered from hospital was tested on the implemented system and yielded accuracy of 100%. The BP_HRMSystem developed can classify any hypertension dataset it will come across. The results from BP_HRMSystem corresponded with the result stated by the experts, showing very high prediction accuracy.

This study has provided a system to be used for classifying hypertension risk, thereby enabling healthcare professionals having correct diagnosis and appropriate management of hypertension. This study provided a healthcare system that maintains diary that plots the patient's blood pressure flow, explicitly classify human blood pressure, and it is applicable both in developing and developed countries. This helps in giving early warning and educate the patient.

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