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Implementation of a Cloud-based Blood Pressure Data Management System

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Abstract. Regular monitoring of blood pressure of a patient can improve hypertension diagnosis and treatment. The objective of this study is to design and implement a cloud computing based blood pressure data management system that allows patients, nurses, physicians, and researchers to access data through the Internet anytime, anywhere and via any device.

Keywords. Blood Pressure, Cloud Computing, Personal Health Record, e-Health

Introduction

High blood pressure increases the risk of heart disease, kidney disease and stroke. It has also been linked to dementia and even Alzheimer's disease. High blood pressure normally has no warning signs or symptoms. Regular monitoring can help ensure that hypertension is diagnosed before it leads to other health problems [1]. If people are already being treated for hypertension, monitoring helps their doctors to make sure that the treatment is effective in maintaining their blood pressure under control.

Take the Pressure Down (TPD) is a joint initiative of the Heart and Stroke Foundation (HSF) and Beacon Community Services in BC, Canada. The program consists of free community clinics providing blood pressure monitoring, risk assessments and education about hypertension. Readings from TPD sessions can help doctors and clinicians to monitor a patient's blood pressure when they are not visiting the doctor's office or clinic. Currently, TPD volunteers use a paper-based form to record patient's blood pressure, demographic, lifestyle and health history data. There are three main drawbacks to using this method: 1). paper-based forms require large physical storage that is difficult to preserve the integrity of the documents; 2). collected data are not available for further review and analysis; and 3). patients/researchers cannot access the data at anytime and from anywhere. For these reasons, the TPD research team decided to develop a web-based database system to manage the data, and let patients to review while physicians monitor blood pressure on-line. The new system requirements include:

- First line nurses/volunteers are able to enter data online, researchers can access data and perform online analysis anytime, anywhere, and via any device;
- Patients and physicians can review blood pressure history through the Internet;
- The system is scalable to contain 34 million records to accommodate the development of a (Canada) national database, and able to export data into an XML/Excel format for further data interoperability with other systems.

1. Methods

1.1. Benefits of Cloud Computing

Cloud computing refers to an on-demand self-service web-based infrastructure that enables the user to access computing resources anytime from anywhere [2, 3]. It is a newer model of delivering computing resources, but it is not a new technology. Compared to conventional computing, such as client-server system, this model provides three new advantages: massive computing resources available on demand; elimination of an up-front commitment by users; and payment for use on a short-term basis as needed [4]. From an IT management's point of view, placing data storage or IT application needs in the hands of a cloud provider essentially shifts the IT management burden to a third-party provider. In that way, the organization can easily get a cost-effective and on-premise IT solution through cloud computing without the need to purchase or evaluate hardware or software, or to recruit internal IT staff to maintain and service in-house database and integration infrastructure. Regarding data security and privacy, compared to locally housed data, cloud providers are able to devote huge resources to solving security issues that many customers cannot afford. Most cloud providers replicate users' data in multiple locations. This increases data redundancy and independence from system failure and provides a level of disaster recovery. In addition, a cloud provider always has the ability to dynamically reallocate IT security resources for filtering, traffic shaping or encryption in order to increase support for defensive measures. Besides providers' commitment to this protection, some organizations, such as the Cloud Security Alliance, have developed a comprehensive guide to deal with security and privacy issues [5]. The Trusted Computing Group [6], a not-for-profit organization, suggests a set of hardware and software technologies to enable the construction of trusted platforms. Governments also play a critical role by fostering widespread agreement regulations.

1.2. System architecture

The proposed system consists of two main components as shown in Figure 1: (1) an Oracle HTTP Server with Application Express (APEX) Listener, and (2) an Oracle Database 11g. The APEX Listener communicates directly with the APEX engine. More specifically, it maps browser requests into database stored procedure calls over an Oracle Net Services connection. The Oracle Database 11g is used to store blood pressure data. Both HTTP Server and database are hosted by a cloud virtual machine.

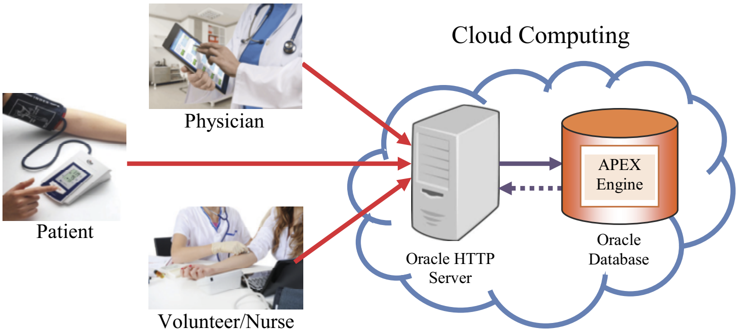

Figure 1. The cloud-based blood pressure data management system architecture

2. Results

2.1. System implementation and functions

The system used Oracle 11g XE as the backend database and Application Express 4.2 (APEX 4.2) that is part of the user interface development tool.

We applied authentication and authorization mechanisms to protect data security and privacy. Authentication is the process of establishing user's identification by providing username and password before the user can access the system. Authorization is for controlling access to resources based on user privileges. There are four types of users in the system: 1). administrator can access all system resources including user accounts and stored data; 2). nurse/volunteer can input patient data and view/modify the data if the person has the patient's permission; 3). physician/researcher can view all patient data; and 4) patient can only review his/her own blood pressure history.

The system functions can be represented by the following four usage scenarios:

Scenario 1: Dave Fisher is a HSF volunteer to take blood pressure reading and provide recommendations for people. Dave uses the system online registration function to create a volunteer account (see Figure 2).

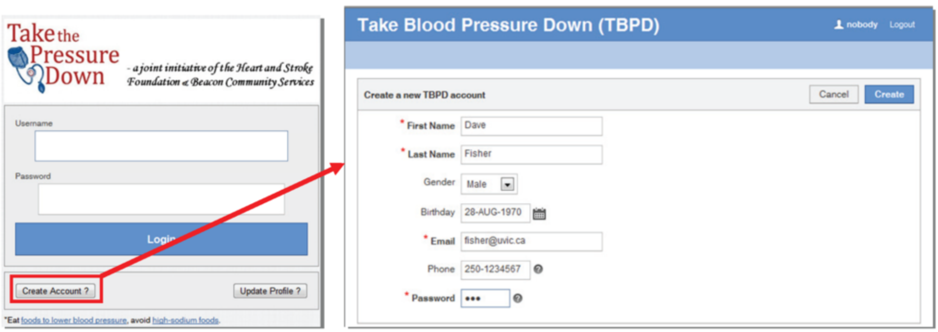

Figure 2. Volunteer user account creation

Scenario 2: Abdul Rauf is a sedentary, middle aged (1970) father of two, who frequently eats takeaways as a result of last minute overtime requests. As a consequence of his fast paced and demanding work environment, he has little time for exercise. As he has recently found that heart disease and stroke are strongly related to high blood pressure. Abdul decides to get blood pressure assessed. After completing his weekly shopping, Abdul notices the HSF mobile kiosk at Bay Centre advertising a free service to help with blood pressure reduction through self monitoring. He speaks to Dave and takes a blood pressure assessment.

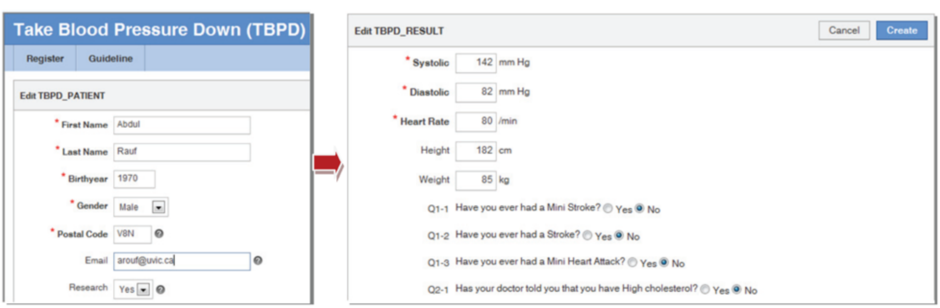

Figure 3. Patient account creation and blood pressure assessment

Dave registers Abdul to the system as a new patient. Then, he records Abdul's blood pressure and related heath information including demographic, lifestyle and health condition (see Figure 3). Since the systolic reading (142) falls in Stage 1 hypertension range, the system prompts alert information to recommend Abdul to see his family doctor (Figure 4).

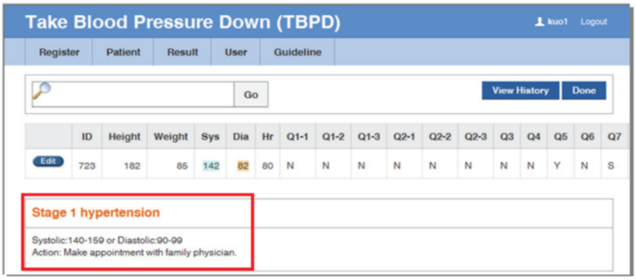

Figure 4. The system's decision support function

Scenario 3: Abdul uses his iPhone to review his blood pressure history (Figure 5).

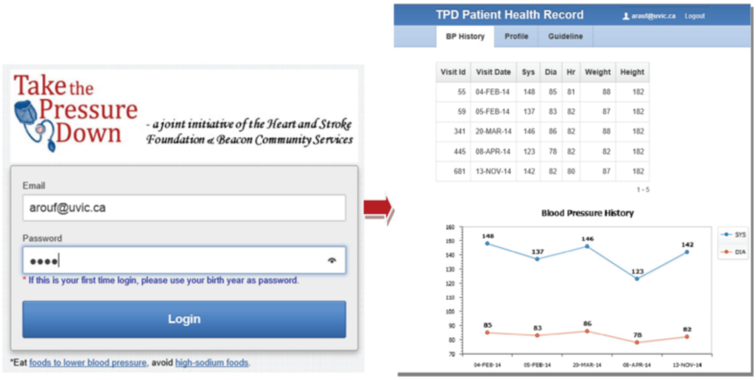

Figure 5. Personal blood pressure monitoring function

Scenario 4: Dr. Jeff Li, the manager of HSF BC, who provides regular reports which will be used to assess both the success of engagement with the public as well as providing blood pressure status for the local population. Jeff starts and interacts with the TPD application by selecting appropriate parameters to generate statistical charts that would assist in identifying trends that would enable & gauge the success of the intervention/project (Figure 6a). The data can be exported into an Excel format for advanced data analysis (Figure 6b).

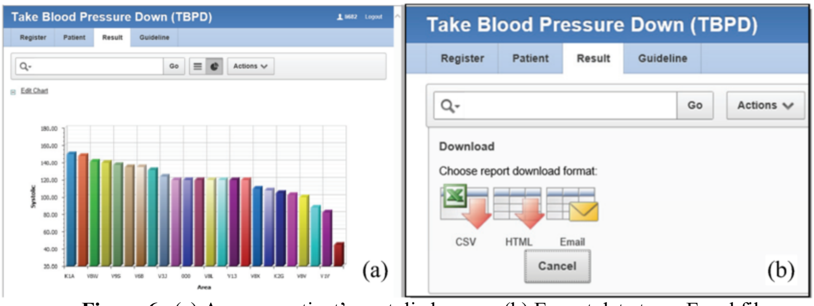

Figure 6. (a) Average patient's systolic by area, (b) Export data to an Excel file

2.2. Usability evaluation

We conducted a usability test to evaluate the system. Twenty five volunteers including 9 males and 16 females, ages 15 to 65, were recruited to test the system. An online questionnaire tool [7] was used to collect and record the participants' responses toward the experience of the system and human-computer interactions (HCIs). The questionnaire includes two parts [8]. The first part of questions collected the participant's personal information such as gender, age and computer experiences. The second part was ten usability questions. Each question has 5-point system usability score from 1 (strongly disagree) to 5 (strongly agree).

The evaluation results reveal that 56% would use the system frequently and 72% found the system is easy to use. There were 84% of the participants that believed that a new user knows how to use the system right away. Only 8% of the participants indicated that they need help to use the system. Overall, these favorable percentages indicated that the majority of respondents found the system to be useful, effective, and efficient. The evaluation questions, corresponding mean scores, and standard deviations are listed in [8].

3. Conclusion

In this study, we designed and implemented a cloud computing-based blood pressure data management system that allowed users to access, update and modify data through web interface browser anytime, anywhere, and on any device, which provides an e-Health operational platform. The main benefit of using cloud services model for this application is that it provided reliable massive computing resources on demand while it eliminated up-front hardware with reduced software commitment (free for use) and maintenance.

User can login to the system at http://db3.his.uvic.ca:8080/apex/f?p=500 as a volunteer (Username: Fisher544, Password: 123) to enter patient data, or as an internal researcher (Username: Li682, Ppassword: 123) to query database. Also, the user can login to the system at http://db3.his.uvic.ca:8080/apex/f?p=501 as a patient (Email: arauf@uvic.ca, Password: 1970) to review his blood pressure history.

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