Doctors-OnLine

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Abstract

This paper describes the design and development of a Java web application that implements the facilities of an online clinic. Emulation of face-to-face consultation and co-diagnosis with other doctors are accomplished via multipoint video and audio conferencing. Patient record and appointment data management is achieved through JDBC 2.0 API with a relational database. A hardware measurement kit enables vital patient health data to be measured and transmitted to the patient's PC via Bluetooth Interface. The data is then forwarded to the doctor during a consultation. Prescriptions are sent via email to the patient as well as to the selected pharmacy so that they can be ready for collection by the patient or be delivered to the patient. Web-based user interfaces are generated with Java Servlet 2.2 API and security is accomplished with Java Secure Socket Extension 1.0.2 over the Secure Socket Layer.

Keywords: remote diagnosis, BlueTooth interface, wireless communication, audio, video conferencing

1. Introduction

The increased mobility of rising population of cosmopolitans and tourists have heralded the need for vital and personal information, especially financial and medical, to be available conveniently and quickly. With the advent and prevalence of the Internet worldwide, it seems logical that Internet offers a highly suitable conduit and this led to the fruition and development of this project, online medical diagnosis system.

The online medical diagnosis system is literally an online clinic. It allows patients to request for appointments and doctors to meet up with them via video conferencing. Thus, it is possible for doctors and patients to interact visually and audibly. Moreover, the system also provides a kit to the patient that will measure and transmit the patient's health signs such as body temperature via the Internet to the doctor. This will aid in the doctor's assessment or diagnosis.

As with any clinic, patient medical records are stored in the system and is available online to both doctors and patients.
However, only doctors have the permission and the professional knowledge to update such records. The patient, on the other hand, benefits from the ability to peruse his or her medical records whenever necessary.

Enhydra Java Application Server 3.01 is used to deploy and manage this system. The back-end relational database employed is Inprise Interbase 6.01. Both Enhydra and Interbase are Open Source projects. Video conferencing capability is achieved with Microsoft Netmeeting 3.01.

2. System Architecture

The online clinic system is designed to:

- Allow doctors and patients to interact from any place and at any time
- Provide video, audio and text communications to fully emulate physical consultation
- Accept patients’ vital health signs such as body temperature which are sent over the Internet to the doctor for diagnosis without patient intervention
- Manage patient medical records including diagnosis, prescription, image and document attachments
- Allow prescriptions to be emailed to patients upon request
- Keep track of both doctors and patients appointments
- Include encryption technology to protect sensitive and confidential medical information

This is designed as a Java web application and is based on a three-tier architecture [1]. The architecture comprises three separate logical layers, namely, the presentation layer, business layer and the data layer. This is illustrated in Figure 1.

![Figure 1 Doctors-Online Application Framework](image-url)
2.1 Presentation Layer

The presentation layer contains presentation objects. These objects are loaded and executed by the Enhydra Presentation Manager.

When a patient browser sends an HTTP request to the server, the Presentation Manager passes the request to the corresponding presentation object that will be instantiated and called. The presentation object may further pass the data to and receive data from the business layer. It then formats the data for display and generates the HTTP response back to the patient browser. Java Servlet API 2.2 is used for the generation of HTML pages.

2.2 Business Layer

The business layer contains business objects. Business objects define the application’s business logic, including algorithms and specialised functions, but not data access or display functions. It serves to evaluate information sent by the presentation layer and also transform the data from the data layer into the appropriate form required for display by the presentation layer.

The Enhydra Session Manager creates a unique session object whenever a patient logs on. Patient-specific information will be placed in the session object by the application object. Both the presentation objects and business objects will make use of the session information.

2.3 Data Layer

Data layer contains data objects that will interface with the persistent data source. In this case, the data source is a relational database.

The Enhydra Database Manager [2] is responsible for the state of a database connection, the current SQL statement being executed by the data object and the result to be passed to the data layer. Java Database Connectivity (JDBC) 2.0 API is employed to communicate with the database servers.

The separation of business logic and user interface add flexibility to the design of this web application. Multiple user interfaces can be built and deployed without changing the business layer. Similarly, a change in the data source used may only affect the data layer and leaves both the business and presentation layers untouched, thereby improving maintainability and increasing performance.

3. Patient Health Measurement Kit

The Patient Health Measurement Kit is a wireless hardware device designed to capture the vital health data of the patient. Figure 2 shows its block diagram. It comprises a temperature sensor, an analogue to digital converter (ADC) to convert the sensor voltage into digital values for input into the PC. The entire kit is controlled by an 8-bit microcontroller, the AT89C51, a flash memory version of the MCS-51 family [3]. The microcontroller uses serial interface to connect to the bluetooth development kit [4] for data transfer. Vital signs of a human include body temperature, pulse rate and blood pressure. However, for this system, only the temperature measurement is implemented. The recordings of pulse rate and blood pressure have been planned for future implementation. The setup and operation of the system is shown in Figure 3.
Figure 2 Overview of Health Measurement Kit

At the time of appointment, the patient launches the Visual Basic program. The program automatically directs the browser to access the patient login page for the patient to login. The patient will then be prompted to measure his vital signs. The controller transmits the measured value to the patient’s computer through the Bluetooth interface [5][6]. This reading is captured by the Visual Basic program through the RS232 serial port which is interfaced to the Stonestreet Bluetooth receiver. Once the readings have stabilised, the program will be sent via the Internet to the Doctors-Online server. The server will then capture these data and presents them to the doctor for diagnosis.

The login procedure is required in order to confirm the identity of the patient in concern and ensure that the data is sent over a secured Internet communication channel.

4. Video Conferencing and Diagnosis

At the same time the Visual Basic program is been executed, the NetMeeting software is also activated. Once the patient has successfully logged in, the application object determines and stores the IP address of the patient’s computer. This address is used in the generation of a NetMeeting link that will be presented to the doctor in his appointment page.

On the appointment page of the doctor, a list of appointments will be displayed in chronological order. Besides this, the doctor will be able to see whether a patient has logged in as well as the generated NetMeeting link and a hypertext link to the examination page of the patient containing the vital health data that was transmitted from the Patient Health Measurement Kit. The doctor will also be able to access the corresponding patient’s medical records. Such medical records can be retrieved by the doctor as shown in Figure 3 for discussion with the patient.

When the doctor is ready to interact with the patient, he will click on the NetMeeting link bringing up the NetMeeting software. The NetMeeting software on the doctor’s computer shall ‘call’ the NetMeeting software on the patient’s computer as determined by the IP address. If the call is successful, video conferencing will be established between the doctor and the patient via ILS servers. The flow of information is shown in Figure 3. The doctor can, in addition, establish a new video link to another doctor to co-diagnose the patient's condition.

Based on the health information and the interaction, the doctor can proceed to diagnose the patient. The diagnosis shall be stored as part of the patient medical record into the database. In order to fully implement the features of a patient’s medical records, the doctor can choose to upload files to the database. In other words, the Doctor-Online system will also act as a virtual hard disk. This allows X-ray scans (shown in Figure 4),
detail medical history and other vital information to be uploaded. The patient will be able to download these files for perusal. However, a patient is not allowed to upload. The doctor has read, write and delete access to the attachments. The upload is done via a POST request to the Doctors-Online server over Secure Sockets Layer.

Prescriptions are made and sent via email to the patient as well as to the pharmacy selected by the patient. The patient can either collect the prescription personally or have the prescription be delivered.

5. Security

Due to the sensitive nature of medical information, security is a vital aspect of this system. Communication channels between the patient and server and that between the doctor and the server will be secured. Strong encryption is employed with the use of Secure Sockets Layer. This is accomplished through the provision of the export version of Java Secure Socket Extension 1.0.2. Through the relaxing of US export laws, cryptically strong algorithms are made available [7].

Figure 3 Flow of Information between Patient and Doctor
6. **System Evaluation**

6.1 **Commercial Potential**

The commercial potential of this system are summarised as follows:

- Allows patients, wherever and whenever they may be, to seek medical attention from their very own doctors.
- Allows doctors and specialists who are geographically distributed to co-diagnose a patient's conditions.
- Allows physical bio-medical measurements to be taken and transmitted direct to doctors.
- The online medical records allow vital medical information of any patient to be available to doctors, wherever they may be, to aid in their diagnosis.
- Invaluable to business travellers, tourists, elderly, patients who are physically immobile.
- Overcomes the problem of travelling in adverse weather conditions and over vast distances to seek consultation.
- Allows prompt round-the-clock healthcare services.
- Reduces queues in clinics for trivial ailments.

Figure 4 Web-based User Interface of Doctors Online
6.2 Comparison with Related Systems

LifeShirt [8] is a comfortable, washable garment that can be worn at home, work or play. Sensors embedded in the LifeShirt continuously monitor 40 psychological signs and record the data in a small recorder that clips on the patient's belt. Patients can upload data stored in the LifeShirt to an Internet-connected PC via a handheld computer. These readings go to the LifeShirt Data centre, a high-security website where staff physicians can analyse the data and make it available for online viewing by the doctor and his patient.

Micropaq [9] is an ambulatory patient monitor from Welch Allyn Protocl Inc. It is a patient worn telemetry monitor with the display, alarms and parameters of a standalone portable vital signs monitor. The Micropaq monitor is principally designed for use in cardiac care with ambulatory patients connected wirelessly to Protocol's network and a central nursing workstation. It can be used as a portable or spot-check monitor on hospital medical-surgical floors or as a basic transport monitor when critical patients are moved from one hospital department to another.

Although the patient health measurement toolkit proposed pales in features and complexity when compared to LifeShirt and Micropaq, the Doctors-Online system as a whole has the following advantages in addition to the commercial potential mentioned above:

- **Ease of Use.** The use of wireless technology renders the health measurement kit less cumbersome to be used. Moreover, it also allows data to be transmitted automatically to the patient's PC as well as to the doctor, without the need for patient's intervention unlike LifeShirt where manual uploading is required. This seamless integration through the Internet together with the use of video conferencing can thus fully emulate a face-to-face consultation.

7. Conclusion

The feasibility of implementing an online clinic is demonstrated with the Doctors Online system. The system is designed as a Java web application with a modular three-tier architecture to increase flexibility, facilitate maintenance and improve overall performance. Doctors-Online has been designed to facilitate patient to remotely consult his family doctor at any time from any place. Consultation is effected via audio and video conferencing to fully emulate physical consultation. Discussion with doctors other than the family doctor is accomplished via multipoint audio/video communications. Physical examination is facilitated by providing patients with a kit to measure health signs such as body temperature as well as through video. Measured data is transmitted directly to the doctor via Internet. Security is maintained with the use of Secure Socket Layer (SSL).

There is room for improvement in the system. For instance, code reusability can be improved by the use of Enterprise Java Beans (EJB) and reduce video conferencing dependence on platform and browser by offering more diverse conferencing choices other than NetMeeting.
REFERENCES


