Virtual Polyclinic

A Web-based system for medical teleconsultation

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Abstract: East Adriatic coast is characterized by a large number of islands that have always presented a challenging task in implementation of efficient health care in this part of Croatia. One of the most difficult problems is absence of medical specialists because specialist practices on islands are not financially self-sustainable. In particular, successful implementation of health care on the North-Adriatic islands of Cres, Mali Losinj, and neighboring islands has shown to difficult, especially during the high tourist season when the island population becomes much larger then during the out-of-season period. In this paper, we present a web-based system for medical teleconsultation support on islands and other rural areas. The system provides general practitioners on islands with tools to communicate patient information to specialists, typically located in large mainland medical centers. The system supports transport of multimedia medical information. Specialists use the system to transmit medical consultation back to the referring physician. Special attention is paid to security aspects.

1. INTRODUCTION

Providing health care services in rural areas has shown to be a challenging task. Low concentration of population makes health care instutitions not self-sustainable so typically only small ambulances with general practitioners are available in rural areas. In such situation, one of the

biggest problems is lack of medical specialists. Patients requiring specialist opinion must travel to distant medical centers in big towns which is often not feasible due to the patient state or in medical emergencies. Such state of affairs can be dramatically improved by use of electronic means of communication. Rapid Internet development in recent years has made possible new medical applications including telemedicine [1,2]. Telemedicine helps connect rural areas to large medical centers through exchange of medical information between distant locations.

In this paper, we describe a web-based system for medical teleconsultation between small island medical centers and large medical centers located in towns. The system is currently under development. In Section 2, we describe the concept of the system. Details of database implementation are presented in Section 3. User interface and security aspects are discussed in Sections 4 and 5. Conclusion is given in Section 6.

2. VIRTUAL POLYCLINIC SYSTEM CONCEPT

2.1 Motivation

Lack of medical specialists in rural areas such as islands is a motivation for distant consultation of specialists in large medical centers. Croatian coast of Adriatic sea is characterized by a large number of islands many of which have population permanently living there. During the high tourist season there is a large increase of population also requiring medical services. General practitioners and internists require opinion of specialists in order to provide higher quality health care. Conventional procedure requires that the patient travels to a distant medical center. This is often impossible due to a high patient risk, or weather and sea conditions. When transport is possible it represents additional expense that has to be refunded through the health insurance system. If we were able to eliminate need for travel, it would be very beneficial medically and financially.

In this paper we describe Virtual Polyclinic (VP), a web-based system that integrates a multimedia teleconsultation system and an Internet-based health record system. VP helps eliminate the need for travelling between the Croatian islands and large medical centers. VP allows physicians to request and obtain medical consultation from specialists over the WWW.

Security is a very important aspect in many applications of Internet today such as e-commerce and e-medicine. VP employs many techniques for protecting patient privacy. These techniques include data encryption, user authentication, audit procedures, and database integrity protection. The developed system provides a high level of security.

2.2 Virtual Polyclinic System Architecture

VP system consists of a web server and a database server. Web server provides interface to users who access the system over the web. A database is used to store all information in the system. The system is implemented on Linux platform.

The web server is Apache [5], extended with mod_python for dynamic content, and with mod_ssl, which interfaces Apache with OpenSSL library, for secure authentication and data encryption. Webpage formatting is handled by XSLT (XSL Transformations) [6]. Mod_python transforms the output from SQL queries into raw XML trees, which are transformed into XHTML by Sablotron XSLT processor using the stylesheets. This way, web page design is separated from web page content. PostgreSQL [7] is used as a database server. It is interfaced to Python via the built-in python module. The architecture of the VP system is shown in Figure 1.

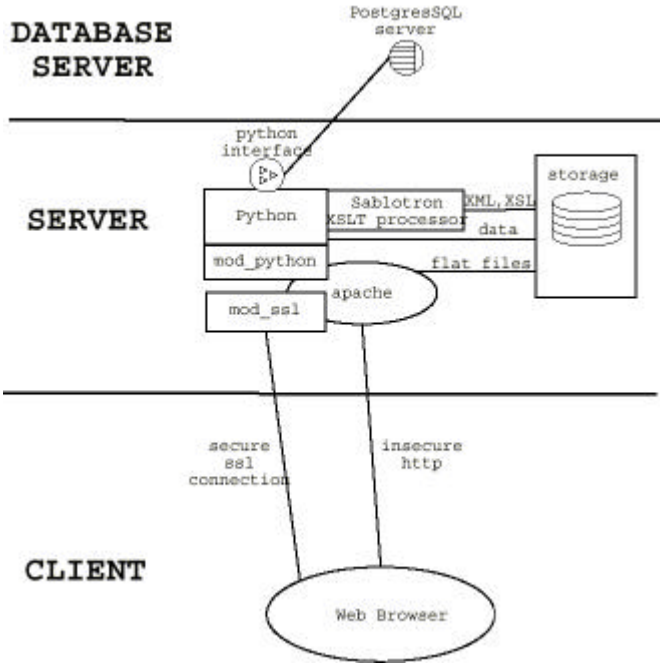

Figure 1. Block diagram of the Virtual Polyclinic system architecture.

3. DATABASE DESCRIPTION

In this section we describe the structure of the database, which is used in VP system. The database can be divided in two main parts. The first part stores teleconsultation data while the second part contains electronic health record data [3]. The database contains:

- User (physician) data, which contains user ID, personal information, medical specialization, login, and password
- Audit information about user access to the system (user identity, actions taken)
- Teleconsultation requests which are being sent by physicians
- Patient records which consist of: personal information, immunizations, medications, allergies, laboratory results (text, images), problem list, and hospital visits

The patient information is recorded through time, so a common attribute of all mentioned data is date and time. Entity-relationship (E-R) model [4] is shown in Figure 2. Note that most of the relationships are binary (only one is reflexive).

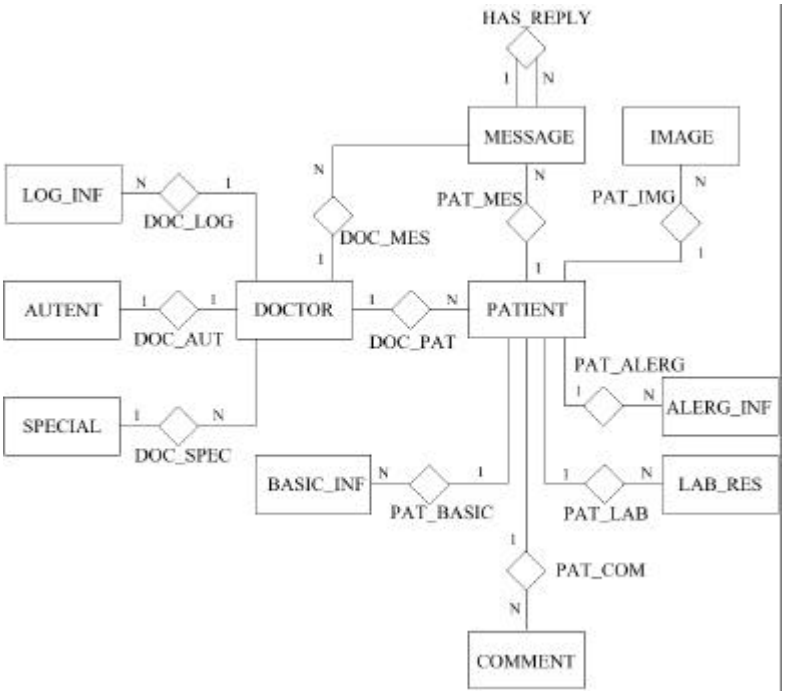

Figure 2. Entity-relationship (E-R) model for VP database.

E-R diagram shows entities and how entities are mutually related, e.g. entity *SPECIAL* and entity *DOCTOR* (stands for specialization) are related through relationship *DOC_SPEC*; mapping between entities is 1:*N*, which means that a physician is specialist in only one area, but several physicians can specialize in a single area. In the same manner we can describe most of the other relations between entities.

One special relation mentioned above is reflexive relationship, in our E-R diagram reflexive relationship is *HAS_REPLY*, and it is connected with entity *MESSAGE*. In this case reflexive relationship is used to show that entity *MESSAGE* can have replies, replies have same attributes as *MESSAGE* so entity *MESSAGE* have two roles, the first as message and the second as reply.

4. WEB-BASED USER INTERFACE

User interface for VP modules is based on WWW technology. In this way, user only requires Internet browser to use the system. This approach provides platform independence of the developed system.

The system is accessed by opening the initial web page where user authentication is performed. This page is accessed using SSL protocol to ensure secrecy of exchanged information. The user provides his/her username and password to access the following pages. The initial web page is shown in Figure 3.

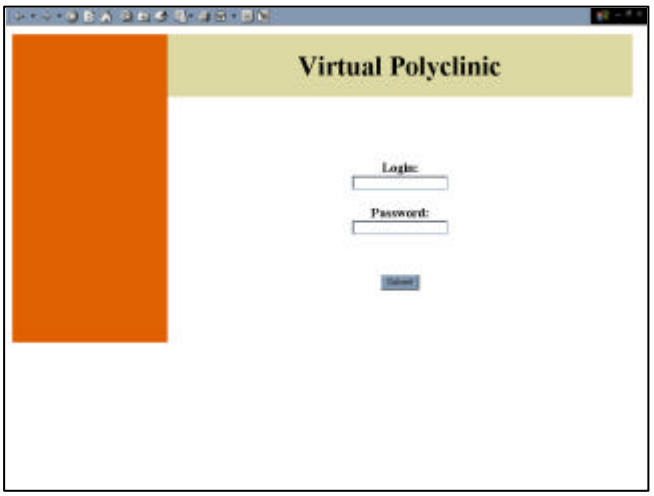

Figure 3. The authentication web page.

4.1 Teleconsultation Module

Teleconsultation module provides users with functionality required to conduct remote teleconsultations. A teleconsultation request contains information about the patient which is located in electronic patient health record and a note from referring physician describing the request.

To achieve minimal response time the physician is also notified of a pending consultation request by means of GSM SMS (short message service). In this way, the physician receives notification about the request on his mobile phone.

User interface of the teleconsultation module consists of a set of web pages visited by the user. The initial page is shown in Figure 4.

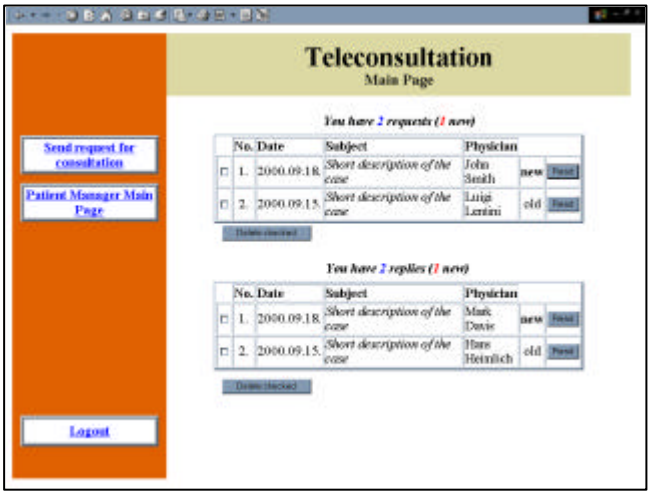

Figure 4. Teleconsultation module main page.

4.2 Electronic Health Record Module

Patient record as a data structure that helps to describe important facts considering patient's health has been used since the fifth century B.C. when Hippocrates proposed purpose of the patient record. His observations were noted in chronological order, so this type of record is called time-oriented medical record. Improvement of the medical record organization lead to source-oriented and problem-oriented medical record (for details see [3]), where data within sections are in chronological order.

Our implementation of an electronic patient record is based on the source-oriented concept. According to that concept the record content is structured according to the method by which it was acquired, e.g. laboratory results, allergy information, etc. Data within each source is organized in chronological order.

VP electronic health record module provides functionality for maintaining patient records. It enables users to add, edit, and delete patient record. For security reasons it is not allowed to edit certain fields in the patient record containing medical information.

User interface of electronic health record module is realized as a set of web pages. The initial page is shown in Figure 5. The user can access pages for adding, editing, and deleting record by visiting the appropriate link on the page.

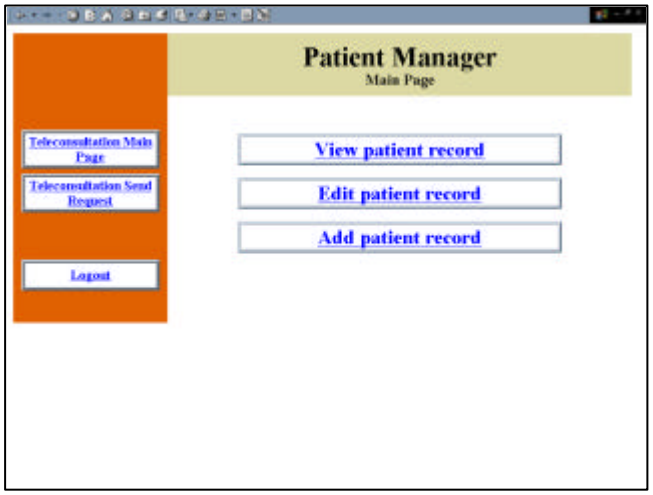

Figure 5. Electronic health record main page.

5. SECURITY CONSIDERATIONS

5.1 Secrecy issues

Authentication is handled via simple login prompt. The security of this phase is ensured using SSL (Secure Socket Layer) encryption. Passwords are not saved on the client (via cookies) to prevent password stealing.

In the current system, the authority space is 'flat' - in other words, each user has the same level of access. This may change, depending on the

requirements. Database itself controls the privileges. System administrator is required to have physical access to the database server.

Accountability aspect is handeled in the following way. Database uses stored procedures to log all the transactions (and all the database access goes via stored procedures). The webserver does not allow access that does not get logged (still, gaining root access on the webserver may allow the cracker to attack the database itself).

Database has integrity checks implemented, up to the limitations of SQL. This includes referential integrity checks. SSL protects data integrity in transit (including man-in-the-middle attacks).

To protect confidentiality the data is only served to authorised users, using the authorization scheme described above. SSL is used to encrypt the server responses in transit.

To ensure database protection we have used the following methods. Database is on a separate machine, which does not have direct network access (it is firewalled and limitted to the access from the webserver itself). Gaining the root access on the server may still allow the attacker to compromise the database, however, this is up to the webserver security policy.

5.2 Availability

In the current implementation, availability of the server depends on the stability of the individual components (specifically, apache, mod_python and python). There webserver will restart itself on crash.

Database availability is also entrusted to the database implementation, with watchdog for restarting. Due to 3-phase commits, in case of database failure, at worst a small number of transactions may be lost.

Database integrity is ensured by updating using strict transactional approach. The database can not end up in non-consistent state (this includes failure of access logs to update), except on storage hardware failure. Regular backup schedule is handled by the database server.

6. CONCLUSION

In this paper we have presented a web-based system for medical teleconsultation and Internet-based health record that was developed for medical teleconsultation support on Croatian islands. The VP system is currently under development. The system is not limited to island-to-mainland teleconsultations but can also be used in other rural areas where specialist consultation is required. The VP system reduces risk to patients who cannot be transported due to medical problems. For patients who can be transported

it reduces discomfort due to travel. VP also reduces health care costs since it eliminates the need for travel.

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