A Cyber Medical Center

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Summary This paper describes the design and implementation of a Cyber Medical Center (CMC) using web technology. The intention is to overcome the inefficiency of the traditional filing system for patients' medical records, which are considered to be time and space consuming. Another objective is to enhance the interaction between the user - the patient in this case - and the medical center personnel - the doctors and staff. This task is achieved by developing a cyber medical center interfaced with the Internet to provide direct public access. The traditional filing system is replaced by a database system for maintaining the electronic medical records of all patients in the medical center. The doctors or staff can either view the medical records or update them through the Intranet/Internet. This system has been successfully developed, implemented and tested on the Intranet platform. It will be available in a university medical center for practical use.

1. Introduction

Developments in web technology have made most of our daily life applications more easy and manageable. The Internet has become a common medium of communication and is found in various places such as offices, homes, and hospitals. The services obtained from the Internet can reduce the gap of communication between any two users, e.g., the users and the health centers. Besides a host of services provided via this scenario, the user can access significant health information. The concept of the web-based health center is not new and there is always some room for modifications, improvements, and adoption of new technologies. The common feature shared among most of these healthcare providers is to establish secure, confidential, and retrievable electronic transactions to the users. It is fundamental in such situations to strengthen the physician-patient relationship by facilitating communication and simplifying transactions to achieve optimum health services.

There are several recent case studies in the area of web-based healthcare systems. A clinic information system (CIS) has been proposed [1]. This system involves a web application for clinics implemented based on fault-tolerant distributed web servers. The fundamental components and packages adopted to develop this system include HTML, Java Servlets, Microsoft Personal Web Manager, and Microsoft Access 2000, all of which have been installed on two Windows NT computers. The prime focus of this study is to make the entire system as a platform and stand alone application. Another approach based on Intranet implementation can also be found [2]. To enumerate the concluding remarks of
In this study, the Internet is considered to be the most inexpensive medium for exchanging health information and accessing online health services. In order to enhance the clinician-provider relationship in employer health clinics another web-based healthcare system was defined in reference [3]. It was found in this study that people of different cultures all over the world would highly prefer to use a web-based screening system instead of filling a paper-based screening or doctor-asked questions at the clinic. The e-health or e-clinic URL is considered as one of the most efficient online systems or services. Several online services such as health advice, appointments, health records, and live chatting on health-related issues are combined in this type of site. A web-based clinical trial expert system (WebCTES) used for the design and implementation of clinical trials was also investigated [4-6]. The prime objective of this system was to better understand the properties of such online expert systems and to determine whether they can actually be adopted in practice or not.

In this paper, a Cyber Medical Center (CMC) is proposed. The CMC is basically a medical center where all users (doctors, nursery staff, patients, and insurance companies) are connected within a single domain network. The users can use a database system locally or via the Internet by browsing the specified medical center’s URL. A scenario for a CMC system is proposed by utilizing other techniques of web development scripting methods and database engines. There is still a belief that the area of medical centers lacks the advantage of utilizing network database facilities in sharing resources and patients’ information. Therefore, the idea involves implementing a database that records medical status of the patients and will be accessible by all doctors of that medical center from anywhere anytime.

The database will be interfaced with the Internet using Active Server Pages (ASP), providing a form-based, easy to use and graphical interface for the user. The ASP scripting methods provide a means for web developers to activate their websites with dynamic live database-driven content. The code that produces this rich content runs on the server directly. The benefit of server-side scripting is that the end result is raw HTML with enhanced security features. Finally, the network that will be implemented will meet the requirements of the medical center in sharing information, resources, hardware and software with centralized administration and support.

2. System model and description

To establish a Cyber Medical Center, a Local Area Network (LAN) has to be set up for 4-5 clients (doctors). The computers can be connected with each other through an active hub to the main server. The server is a Personal Computer with Windows 2000 advanced server or Windows NT operating system. The server and the other clients are connected to the local Internet Service Provider (ISP) through an ADSL line. The LAN terminals can share the database of the main server to access the medical records of the patients, employee’s records, and medicine prescription. For instance, the doctor can access the system to update, send and receive the database files through the network itself or through the Internet. This technique makes things simpler for patients who want to travel and continue their treatment outside the country they live in. In addition, doctors can take the patients’ queries by electronic mail or patients can file their queries before coming to the clinic. This will create virtual waiting rooms as described in the literature [4-7].

Servers containing files can be located in two different ways and can be accessed frequently for viewing or updating. The first one is by having the main server located at the ISP site and uploading the information to it frequently. The problem with this method is that whenever a doctor wants to update the records of one patient, she/he will have to go to the ISP main offices and fill in a request for updating the information found in the system, and then someone from the ISP must add the information. This method was found to be both time and effort consuming. Another method is by placing a server that contains the data in the clinic itself. The problem with this server is that it should be remain on and secured all the time, that is 24 hours a day, and never be shut down. The advantage this has over the first method is that the data can be updated regularly and locally. Such a scenario was developed and implemented as shown in Fig. 1.

The real system model configuration is illustrated in Fig. 2. The clients can send their requests over the Intranet through the appropriate interfacing form pages. The server receives these requests and processes them in the ASP engine. The web server in this case should be of IIS type (Internet Information Server) to be compatible with the ASP coded web pages.

This system can accommodate multiple users to be connected at the same instant of time. Such accommodation requires particular settings and programming procedures to be carried out on the server’s side. A Firewall Proxy is to be
involved to ensure that there are no instances of duplication. The IIS can also play a role by providing an appropriate setting for maximum users permitted over one single connection at any time. Most of these functions are well classified to be among other jobs of the Network Administrator. The Network Administrator should have the suitable expertise to deal with all of these perspectives. The key components of the system configuration will be described in the following sections.

3. Database

The main objective of the database is to record all required information about patients. Therefore, a query form was prepared based on inputs from the clinic staff and specialists in the area in order to provide the most crucial entities that should be included in the database. Different discussions and presentation sessions were also conducted among users and developers. The prime focus to undertake all these steps is to establish and consolidate the following objectives:
- Database requirements and interface.
- Drawing the E-R diagram.
- Setting up the tables and relational entity diagram.
- Making queries to enable user(s) to access the database efficiently.
- Obtaining the user’s data using forms.
- Viewing the result using reports.

Generally, the database will have two accessible interfaces, one for doctors and one for other users. Each of the interfaces provides the facilities required and needed by the specified user. The doctor interface will provide the ability to check, add and update patient’s records. Also the lab results related to each of the patient can be viewed. On the other hand, the user interface for the patient will provide him/her access to his/her records to register through the site to take appointments and check the doctor’s schedule. The design criteria of the clinic database might be summarized as follows:
- Each doctor, patient, and nurse has a unique identifier to the database system. This may include: full name, contact numbers, email, URL, the gender, the date of birth, the blood type, the specialization, the position, the nurse assistant. In addition, there are two links; one to access the photo of the doctor and nurse and the second one to view the schedule.
- Each medicine has an ID, name, doctor’s ID (who prescribed the medicine), and the medical
category ID that is linked to the look-up table mentioned below. Other information such as the quantity of each medicine in the pharmacy, the exact location of it (row number, column number and shelf number), the origin of this medicine and the expiry date.

- A look-up table is created for administrative use, which contains the medical category and its ID to classify if the medicine is syrup, pills, cream, ointment, etc.

- A look-up table is created for administrative use, which links the X-ray entities to classify which part of the body the X-ray has been taken from.

- A physical examination table represents the first-time examination of the patient in the clinic. This table includes the patient's ID and the ID of the nurse examining the condition of the patient's skin, body marks, scars, skeletal system, joints, Lymphatic System, Head, Eyes, Ears, etc.

- In the clinic, there is a pathology lab. Each lab session will have a unique lab ID, patient ID, and description of the lab results. Some of the tests are Hgb test, HCT test, sugar test, SPGT test, Albumin test, Microscopy: WBC test, Microscopy: RBC test, Microscopy: Casts test, VDRL/RPR tests, HIV 1/II tests, Tuberculin test: reactive/non-reactive.

- Every patient who wants to take an appointment to see a doctor or to visit the lab or the X-ray can register through the website or via the secretary at the information desk. Each appointment will have a unique patient ID, an appointment ID, and a description of the visit, a lab number and an X-ray number.

- When a patient pays the fees to the cashier, a bill will be issued. Each bill will have a unique bill number, the patient ID, doctor ID, first visit date, next visit date, time of bill issued, insurance number, deposit fees, X-ray fees, and pharmacy and lab fees.

A suitable interrelationship structure is to be designed to accommodate all of the aforementioned entities as shown in Fig. 3.

Queries reflect the dynamic nature of specific entities. Append queries are the only ones that are activated by the patients through external connection via the Internet or by clinic internal staff through the database interface. However, only the
clinic staff and specialists using their corresponding forms can do deleting or updating of queries.

Forms are very user-friendly. For example, Fig. 4 depicts a typical form that is accessible to the clinic staff and doctors to enter the patient information and to obtain a printout.

Each object within a particular form should perfectly match the format of the corresponding field’s attribute as set in the database tables, otherwise some unintentional errors could be generated. For instance, if a particular field has been configured to have a non-zero length entry, and if the nurse or the doctor forgets to enter any data into that specific location it will force the database engine to generate an automatic error message requesting the user to enter the relevant data. Furthermore, if the data type for any particular field has been specified differently than that being entered by the operator then this will also result in the generation of an error message. In addition, some special masking techniques can be implemented to force the operator to use certain formats and any violation of this rule will not be processed by the database. These procedural steps are necessary while operating the database directly via the network. On the other hand, additional scripting commands have to be properly inserted into the web page of this form to avoid an unpleasant situation. If scripting was not provided for the user to ask him/her favorably not to leave any important field to fill in, a “bad connectivity to the database” message will show up in the browser. Such situations are very critical regarding the reliability of services provided by the clinic and should be handled with extreme care.

Furthermore, reports have to be very clear and can be generated with one single record or a list of records. Several methods are used to generate such reports. One is by using the report generator of the database itself, and the second method is by using the crystal report. The crystal report is an optional component that can be added to a database developed using Microsoft Access. This generates highly efficient and professional reports. Figure 5 depicts a typical report of one patient.

Some reports can be generated for particular users by simply defining their IDs in especially dedicated forms. In such cases, certain VBA commands (Visual Basic for Access) are to be properly manipulated while designing that particular report.

A similar procedure can also be implemented for situations when a particular entity is to be retrieved and reported. It is worth emphasizing that all of these methods are important if the database is manipulated directly without the web interface. Otherwise all of these events will not be executed since most of these commands can be very well customized using the ASP language, which is highly similar to, and compatible with, Visual Basic. Another aspect worth mentioning is that patients should not access reports through the Internet.

When the entire database is built successfully, a startup switchboard might be configured and implemented to present only the required entities for the user. This reduces damage caused by mistakes. The main database file is then to be saved on the main server and multiple shortcuts are to be created and placed on the desktop of each user.

This database is then to be interfaced to the web developing tools by utilizing the ODBC (Open
4. Web development

The design criteria for the Web development of the proposed clinic home site are based on the aforementioned points. Among other objectives, the design should be simple, straightforward, professional, and user friendly. There should be no ambiguity while the user navigates using any link in the clinic web page and the navigation style should lead him/her directly to the desired location without difficulties.

The proposed design was implemented by providing the essential elements required for hosting the entire web site and then creating a path through which the completed forms can be submitted to the database. It is quite common in such practices to protect the user credentials from being exposed to other unintentional operators or hackers. As far as the Internet communication is concerned, these twofold criteria could be achieved in two different ways. First, is to ensure that there is a secure location for the host server. Second, is to improve the transmission flow between the user and the host machine. The database has to be saved in a proper folder and certain access privileges should be exercised by applying scripting techniques such as the Active Server Pages (ASP) by Microsoft to prevent any electronic hackers [8-11]. This kind of scripting language is mainly devoted to providing a higher level of immunity against tapping while transmission takes place between the host and clients’ machines on the Internet. The key power of this scripting technique lies in its compilation and the execution style. Both compilation and execution are conducted on the server side to prevent any unintended third client from tapping the procedure.

To accommodate such requirements an Internet Information Server (IIS) was adopted. This server is fully compatible to the ASP coding environment and is highly flexible in order to manipulate different tasks as related to Microsoft components. Later, the ODBC method was implemented to interface the database to our developing tools, such as MS FrontPage 2002 edition. This program has a fully featured wizard to help developers in generating ASP scripting to the database in an efficient and straightforward manner through the ODBC intermediate stage. Figure 6 illustrates the system software structure.

It can be seen from Fig. 6 that the data flow occurs in either direction to communicate useful information as requested by the user or to provide data to any program executed on the server side. The only connection to the relational database is through the ODBC and hence information can be admitted or retrieved via the IIS operating system.
Fig. 6. System software structure.

The IIS operating system should belong to the same family as of the ODBC. The Windows operating system as a matter of fact will be playing the major role in identifying each and every component and drive and to perform data management in the best possible and efficient manner. The operating system with the support of this powerful drive will be capable of handling and executing any sophisticated operation related to the database and this operating system handles the flow of execution among all other applications that could be running on the same machine using other interfacing drives. Using the ODBC makes development procedures much easier than before it was invented in the early 1980s.

The other design efforts involve focusing on coming up with a professional look. Such a task would require the involvement of different graphic design programs as required. To add to our objective of keeping the entire site looking simple yet providing the required guidance during navigation, the design layout illustrated in Fig. 7 was developed. This design satisfies all the requirements of the clinic.

Obviously, it has a new logo that was primarily designed for the clinic, which stands for "Cyber Medical Center". As the patient connects to the
site, she/he will face a nice, friendly photo along with an introductory word, which will indicate to the patient the kind of friendly and supportive treatment she/he will receive from the clinic. To the left side there is the navigation structure, which will repeat itself in each web page. The "What CMC" bar will tell the user what exactly is the Cyber Medical Center. The "Why CMC" bar will tell the user why this clinic was established, its goals and its benefits. The "User Guide" bar will help the user through the website and will help him/her to know more about the registration forms and how to use the website to get information. Each navigation bar is linked to the page that it refers to, for example, the "New Patients Login" bar will link the user to a page that has a form that the new user should fill out. The "Old User Login", "Staff Login" and the "Doctors Login" bars will link the user to the pages that will ask the user for the user ID for each page. The "Calendar of Events" bar will tell the user the kind of events that will take place in the clinic with their timings. The user can contact the clinic through the "Contact us" bar and can check the frequently asked questions through the "FAQ's" bar. Therefore, the user should find the navigation links quite flexible.

It is evident that this index web page was downloaded to the browser after writing the IP address of the host server. This IP address is considered as a fixed identity assigned by the local network server. In addition to this, a meaningful name could be configured through the Domain Name Server (DNS) as only the IT people of our campus can manipulate this IP address. However, this would result in undesirable conflicts and unstable situations, which may interrupt other current services over the local network. So much so, this service was avoided and instead the CMC was tested using a small network consisting of a small number of machines. Therefore, the IP address as indicated in Fig. 7 is a virtual one and can be facilitated either by using the Windows NT or Windows 2000 technologies. However, this small network structure was fully operational and received compliments from different people especially the clinic staff. For example, assume that the user chooses the New Patients Login. Once the link is activated the web page as illustrated in Fig. 8 will be displayed. Each text box in the above form is directly connected to the database that is hosted on the IIS machine. Once the form is filled out with the appropriate data, it will provide confirmation to the user, as depicted in Fig. 9.

In the event of an error, there should be a mechanism to allow the user to re-enter his data once an error message has been displayed after the data has been checked by the ASP codes. An example is when a previously registered patient accesses the Old Patients Login web page and by mistake enters a wrong identification number.

FrontPage automatically generates this confirmation page - using ASP scripting method - when
it finds that the data received is correct. Any change or modification of the ASP of this page would seriously damage the sequenced procedures as governed by FrontPage. It has also been verified that the information submitted by the user directly flows into its proper place in the database.

5. Findings and results

The CMC was the result of our research, design and implementation. It successfully achieved the objective that it was designed for, that is, designing and implementing a Cyber Medical Center using web technology. This will result in more flexibility in real-life clinical applications by providing the ability to transfer, update, and view patients’ records at any time from anywhere. This ultimate goal can be very well accomplished using the services provided by the Internet interface and replace the traditional filing system by an electronic-web-based database system for patients’ medical records, which are considered to be time and space consuming.

Our final product was a webpage with different links to the database designed using Microsoft FrontPage2000 and Microsoft Access in accordance to the requirements of the clients, which were in this case the doctors. Any visitor to the CMC home page can explore it by going through several links.

The structure of the homepage is summarized in the flowchart shown in Fig. 10.

6. Conclusions and recommendations

A Cyber Medical Center (CMC) has been proposed and developed in this paper. The prime intention was to utilize the recent advances in technology to offer efficient services to the users. Patients could preview the clinical services that could be provided to them or other related information by simply navigating the CMC home site before coming or registering to the clinic. They could also keep track of their medication history and could eventually observe their progress or anticipate any future impact that requires direct involvement of the clinic staff. The technology behind this service scheme relies highly on using a dedicated web server, such as IIS, to implement ASP codes to ensure immunity against any information tapping over the Internet. An MS Access type database was implemented to store the clients’ credentials in a secure location on the web server and to be flexibly manipulated by the clinic staff, as required, in an on-line fashion. This system was constructed using a small network on campus, and the general performance of the system was found to be completely satisfying to all participants, especially the clinic staff. As the data in the
database will grow owing to increasing clients’ records, it is recommended to transfer the Access database content to large-size databases using highly dedicated and sophisticated developing environments such as Oracle.

References


