A DBMS-based Medical Teleconference System

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Abstract

This article presents the design of a medical teleconference system that is integrated with a multimedia patient database, and incorporates easy-to-use tools and functions to effectively support collaborative work between physicians in remote locations. The design provides a virtual workspace that allows physicians to collectively view various kinds of patient data. By integrating the teleconferencing function into this workspace, physicians are able to conduct conferences using the same interface and have a real-time access to the database during conference sessions. We have implemented a prototype based upon this design. The prototype uses a high speed network test bed and a manually created substitute for the integrated patient database.

**Keywords:** telemedicine, medical teleconference system, virtual workspace, multimedia medical data
INTRODUCTION

The meaning of telemedicine is growing to encompass a wide range of telecommunications and information technologies. Telemedicine is the interactive audiovisual communication between healthcare providers and their patients or other healthcare providers regardless of geographic distance.\textsuperscript{1-4}

In this article, we describe the design of a medical teleconference system (MTS) to integrate the telemedicine system and patient database to provide a ‘virtual workspace’ to participating physicians. We briefly describe the application modules used in a prototype implementation to manage conference data and perform remote query processes for the synchronization of teleconference data.

BACKGROUND

Although there have been many trials of telemedicine systems, most of them were restricted to simple trials or pilot projects, both overseas and here in Korea. There have been several telemedicine projects connecting a rural clinic with an urban hospital or an island clinic with a community hospital. Unfortunately none of these projects survived the termination of grant funding. The Institute of Medicine (IOM) has reported that, in spite of over 30
years of technological development and demonstration projects, conclusive evidence of the efficiency and cost-effectiveness of telemedicine is only sparsely represented in published literature. The IOM identified several contemporary restrictions on telemedicine development, including high telecommunication costs, awkward and quickly outdated technology, low patient volume, lack of physician interest and limited insurance coverage. In addition to the limitations disclosed by IOM, the authors recognized the time consuming and laborious nature of telemedicine. To prepare for a telemedicine session, usually technical staff and doctors are required to spend several times longer than the session itself. This feature is one of the causes of low physician interest in telemedicine projects.

Most conventional telemedicine systems work in a so called ‘copy-and-synchronize’ mode, which requires that conference material be prepared prior to the session and copied onto local disks at every site involved. It requires enormous time and work to convert patient data into a format suitable for the telemedicine system. Also in such a setup, data is not directly retrieved from the database at the time of the teleconference session. Any potential discussions concerning data that is not prepared in the conference material cannot be effectively supported.

Customization for a smooth telemedicine process and ease of handling of presenting material is one of the most important features for effective communication. During the telemedicine session large quantities of materials and data need to be discussed within a limited time. Sometimes presenters are requested to skip or make a short brief of the
patient’s illness. So tools for better presentation and rearranging of patient data are the key components for successful implementation of the telemedicine system. Unfortunately most conventional telemedicine software packages fail to provide versatile tools for the easy management of the telemedicine session.

We propose an MTS which can be used for teleconference sessions among physicians in different hospitals with institutional links. MTS connects two hospitals for case-conference and delivers textual data as well as multimedia data such as x-ray images and angiographic cinema images. The easy-to-use tools which handle the data and edit whole sequences of presentation materials are the key elements. Our current prototype implementation is based on a central server model where all contents of the patient database have been manually integrated.
DESIGN OBJECTIVES

The common goal of a telemedicine system is to provide and improve medical decision making among participating physicians. To achieve this goal, distributed and fragmented patient records should be rearranged into an easy-to-find structure in the telemedicine system. Another important criterion for a successful telemedicine system is that time saving tools be taken into consideration in order to present brief yet meaningful clinical information during a teleconference.

The following objectives were established for MTS design.

- It must be directly integrated with the existing clinical database, to allow any information needed during the conference to be retrieved quickly and easily.
- It must provide a single uniform interface so that the medical professionals can view patient data in a coherent and consistent manner.
- It must be more than merely an interconnection of different applications. The system must provide a virtual shared workspace, that allows participants to organize the various forms of conference related data, and allows the presentation of such materials systematically for more effective conferencing.

The critical nature of the patient information requires high-quality display technology and support for a comprehensive multimedia capability.
SYSTEM ARCHITECTURE AND COMPONENTS

Overview of Medical Teleconference System

We designed an MTS which is composed of a database server and client teleconferencing applications. The main role of the database server, in addition to hosting patient data, is to generate and store conference files. Users who will give presentation at the teleconference prepare presentation sequences before the teleconference and store relevant information into conference files. They can review the presentation materials, edit the presentation sequence, and store the presentation sequence information into conference files.

The client teleconferencing application is a set of modules for conference material preparing, remote query processing, and conference control. For preparing teleconference material, it is designed to get patient data from HIS and to store the information into conference files of MTS database server. Also it performs special queries. As the MTS database server has the highest access priority for the client application, the client application first searches the patient information stored in the conference files. If the client application fails to find the data in the conference file, it performs special queries to find data in HIS database.

MTS Database server module

The database server is directly connected with the client systems so that the entire contents
of the database are available as a conference resource. Figure 1 shows the overall architecture of MTS in which three clients communicate with the database server via a high-speed network. The client application is designed to be run on each participant’s system.

The MTS database primarily stores patient records in a simple structured format, as well as storing a variety of multimedia data and information for controlling the conference sequence. The system provides attendees with a conference file which contains reference information for the conference. The logical structure of the conference file is shown in Figure 2.

Conference Content (CC) includes the patient profile, name of physician in charge, doctor's notes, patient history, physical examination results, and laboratory test results. Rather than making copies of patient data, the CC maintains a list of pointers to the associated data contained in the database. The data are classified into six different types according to their characteristics:

- The Memo consists of textual data including chief complaints, systemic reviews, notes, past medical history, and examination notes.
- The Grid table is a table of records describing multimedia information generated from CT, MRI, and X-ray examinations.
- The Spreadsheet displays the numeric results of each examination. Rows within the spreadsheet contain various examination values such as CBC and other hematologic data.
The *Image* is used for scanned images from X-ray, CT, MRI, and SPECT examinations. The *Audio* consists of sound records encoded in WAVE format. The *Video* features animated images generated from angiography, ultrasonography, and others.

Conference Metadata (CM) contains data items needed for the control of the conference process. CM is composed of four parts: profile, sequence information, derived data information and annotation information. The profile summarizes pertinent introductory information about a specific conference session including author, title, theme, time of the conference, and remarks. The sequence information is a step-by-step procedural definition of a conference session and contains pointers to the conference contents. It is generated by marking leaf nodes on a patient record tree. It can be modified at any time by using the sequence editor. (Figure 3) The derived data information includes ‘group view’ and ‘transition graph view’, which are special views synthesized with different basic data views. During early design stages, users of MTS requested a virtual work space to integrate patient text based data and graphic information. To meet this requirement, window-like models were developed to present images in a grouped ‘group view’ form, and to present data graphically versus time in a ‘transition graph view’. The ‘group view’ is a thumb nail viewer which provides an integrated view, from a group of CT, MRI, or X-ray images and angiography videos as a single episode. The transition graph view is used to analyze the trends over time of various values selected from the spreadsheet data, as can be seen in Figure 4. The annotation information is a set of textual and geometric objects (i.e., circles,
rectangles, arrows, etc) that are annotated on images.

**MTS client application module**

The client module is subdivided into a database module and a conference management module, as shown in Figure 5. When the user requests the next view at a conference, the conference management module invokes the remote query module to retrieve the necessary data. User actions captured by the user interface are converted into the motion parameters required for the remote database query module, which generates a query according to the submitted criteria, and passes it to the database server and then delivers the retrieved result to the appropriate data viewer module.

Modules in the client program function as follows.

**Data Navigator** is closely related with the patient record tree of Figure 3. It enables users to quickly navigate any part of the patient records and gives participants an integrated view of many types of patient data. Basically, patient record tree is automatically expandable during a conference while interpreting the sequence information of the conference and showing its corresponding conference contents. In order to achieve such a data navigation facility, each leaf node of patient tree has database query information that includes SQL parameters. Thus, when clicking on a node, related conference contents are retrieved from the database, and then their appropriate view instances are dynamically generated.

**Data Viewer** provides ‘view templates’ for six basic types of patient data. The image
viewer supports image-processing functions such as zooming, panning and annotation. The video viewer, for example, has a repeating function that can be used to observe a critical portion of a video repeatedly.

**Session Manager** provides functions to manage the conference session. It enables the participants to start, find, join and leave a conference session. It automatically constructs a virtual workspace when a new session is initiated and also stores conference conclusions and recommendations.

**Sequence Manager** manages the conference sequence and prefetches sequentially referenced conference content. For managing the conference program, a sequence editor is implemented, in which the view sequence can be defined according to the predetermined conference scenario. For prefetching, a method called ‘informed prefetching’ was adopted.

**Synchronization Manager** synchronizes client actions and is achieved through the following steps. The client PC, as an initiator, requests patient data from the database using the conference metadata in its local memory. At the same time, it sends a message to the other client PC to synchronize the request action. As soon as the other client receives the synchronization message, it requests the same patient data from the database, which simultaneously processes the identical requests from both client PCs and then forwards the resultant data to each client. (Figure 6)
STATUS REPORT

We have developed a prototype that implements our design presented in this manuscript. We were fortunate enough to test our system over a high-speed network testbed where the central database server and the client systems for remote participants were all connected to an ATM-based B-ISDN network via 155Mbps optical fiber links. There were virtually no problems due to communication delays. However, because native ATM networks cannot support TCP/IP directly, communications were carried out on top of an ‘IP-over-ATM’ intermediate layer. The test environment is summarized in Table 1.

To start a conference, the conference initiator must ask for participants to log-on to the conference by executing their own client program and accessing a conference session. When a conference session is established, a workspace is automatically created and the conference proceeds in the order predetermined by the conference file. However, if any of the conference participants ask for data not included in the file, the data can be retrieved dynamically from the database by navigating through a tree-like navigation menu. This also means that a conference session can proceed without any preparation. Two (or more) users can simply log-on from remote locations and start discussing certain issues while looking at the synchronized database interfaces. All the activities that may occur during the conference, such as adding annotation to the existing image or writing a concluding note
for the conference, can be appended as a part of the conference file and maintained permanently for later use.

Figure 7 shows a typical view of the MTS user interface. In order to view an image, the user must actuate the image viewer by clicking the appropriate item in the grid table. The image viewer provides annotation tools that allow users to add necessary annotations to the images. If an image item selected from the thumbnail table is linked to MPEG data, the video viewer is then automatically executed. A toggle switch is provided that allows the user to view the desired recording by setting the start and end points using the slide bar provided. Both the image viewer and the video viewer display data on a separate monitor in order to satisfy the physician’s need to see various types of data simultaneously. A white board with full annotation capability is also provided.

MTS has been tested at medical settings in order to verify the practical effectiveness of the system. Specifically, it has been tested in two different types of set up; case consultation and case review. The first is where a physician at a local clinic would consult a specialist in a general hospital about a serious case (for example, a 60 year old man who suffers from breathing difficulties). The physicians were quite impressed, in part, by the speed at which high quality medical images were provided, but mostly by the convenience that the integrated workspace view provided along with our synchronization feature. The second setup is where MTS has been used as an aid to case conferences where resident physicians at a hospital review the cases at hand. The physicians who used the system to present their
materials have expressed satisfaction that MTS provides a user interface that could be used to easily view and share patient information without having to compile physical files and prepare slides for overhead projection. They feel that MTS supports their clinical activities more effectively than the more conventional conference tools. However, there were some delays and awkwardness in the synchronization for video data control because the video viewer requires considerable CPU and memory resources.

The patient data integration challenge was much too big an issue to be included in the prototype project scope because the hospital’s information system is composed of several independent distributed and heterogeneous systems. Instead we have built the MTS database from these disparate systems relying heavily on skilled operators who would write database queries to retrieve relevant data from a source and write programs that would transform, clean the data, and then populate our database. The majority of multimedia data were collected from scratch; image data were digitized using high-resolution scanner and digital camera, and analog video data were collected using a video capture board equipped with an MPEG encoder.
DISCUSSION

The current project has achieved its goal of demonstrating that the integration of the teleconference functionality to clinical database retrieving is a promising approach to physician-to-physician teleconferencing. In terms of overall system performance, we concluded that database retrieval and network bandwidth were the two major determining factors of system performance.\textsuperscript{12} This was particularly the case in situations requiring real time database access, where rapid and accurate data delivery was critical for conference continuity.

For effective database retrieval, we constructed an index system using object identifiers (OIDs) as primary keys for each object type.\textsuperscript{11} To resolve the network delay problem, possibly caused by the transmission of multimedia data, a prefetching algorithm was employed. Multimedia data is prefetched at the beginning of the conference thus leaving adequate network bandwidth for the transmission of other data. Specifically, we adapted a data caching mechanism called ‘informed prefetching’, which aggressively utilizes knowledge of future access to conference contents. As a result, the system can significantly reduce network latency time during a conference session, and take full advantage of its limited repository. Furthermore, in order to reduce the volume of message exchange resulting from the synchronization of mouse movement, our system provides movement support only when a partner’s action has some significance.
Although the size of the prototype database was relatively small (100 patients) and the process of building it was laborious, the effort has successfully demonstrated the utility of a truly integrated patient database.

One of the most important features of the system is that it offers participants the ability to retrieve data directly from databases while a conference is in progress. This was possible by building a multimedia database user interface that allows the user to view medical records in an integrated manner, and adding a conferencing facility to this workspace. Users are able to discuss cases while using a database interface with which they are familiar. The reduction of response time and the mimicking of the access patterns of doctors promise to give a teleconferencing system which is tightly coupled with clinical database and which provides practical advice from remote sites.
REFERENCES

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Table 1. Test Environment.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client PC</td>
<td>HW Intel Pentium Pro with 64MB main memory with 2GB disk.</td>
</tr>
<tr>
<td></td>
<td>Dual monitor driven by dual analog PCI VGA card</td>
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<tr>
<td></td>
<td>SW Windows 95 operating system</td>
</tr>
<tr>
<td></td>
<td>Network 155Mbps ATM PCI card</td>
</tr>
<tr>
<td>Central Server</td>
<td>HW SGI Origin200 server with 512MB main memory with 12GB disk</td>
</tr>
<tr>
<td></td>
<td>SW IRIX operating system</td>
</tr>
<tr>
<td></td>
<td>UniSQL DBMS</td>
</tr>
<tr>
<td></td>
<td>Network 155Mbps ATM PCI card</td>
</tr>
<tr>
<td>Network</td>
<td>Backbone Dedicated ATM switch with guaranteed 155Mbps</td>
</tr>
<tr>
<td></td>
<td>LAN Distance less than 1km</td>
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<tr>
<td></td>
<td>WAN Distance about 100km linked through dedicated ATM switches with</td>
</tr>
<tr>
<td></td>
<td>guaranteed 155Mbps</td>
</tr>
<tr>
<td>Scenarios</td>
<td>Case Between two physicians in remote locations (WAN).</td>
</tr>
<tr>
<td></td>
<td>Consultation The server sits on one side.</td>
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<tr>
<td></td>
<td>Case Conference Resident physicians gathered in one room. The system is</td>
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<tr>
<td></td>
<td>Review used as a presentation tool accessing the server locally (LAN).</td>
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<tr>
<td></td>
<td>Presentation could be seen at a remote location using teleconference</td>
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<tr>
<td></td>
<td>features.</td>
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<tr>
<td>Database</td>
<td>Size 10GB / 100 patients</td>
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<tr>
<td></td>
<td>Tables Queries and programs written for each data source. Some degree of</td>
</tr>
<tr>
<td></td>
<td>manual editing involved.</td>
</tr>
<tr>
<td></td>
<td>Multimedia data Most images and video data existed in analog forms.</td>
</tr>
<tr>
<td></td>
<td>They were digitized for this purpose.</td>
</tr>
</tbody>
</table>
Figure 1. Architecture of DBMS-based Medical Teleconferencing System
Figure 2. Logical structure of conference file
Figure 3. Patient record tree and sequence editor
Figure 4. Transition graph for the cumulative display of clinical test results
Figure 5. The module architecture of a client application
Figure 6. Synchronization process for client retrievals
Figure 7. Typical view of the MTS user interface