Worldwide Telemedicine Services Based On Distributed Multimedia Electronic Patient Records By Using The Second Generation Web Server Hyperwave

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A distributed multimedia electronic patient record (EPR) is a central component of a medicine-telematics application that supports physicians working in rural areas of South America, and offers medical services to scientists in Antarctica. A Hyperwave server is used to maintain the patient record. As opposed to common web servers -and as a second generation web server- Hyperwave provides the capability of holding documents in a distributed web space without the problem of broken links. This enables physicians to browse through a patient's record by using a standard browser even if the patient's record is distributed over several servers. The patient record is basically implemented on the "Good European Health Record" (GEHR) architecture .

BACKGROUND

In the vast rural areas of southern Latin America specific needs exist for medical doctors in regional hospitals and in the isolated communities -including permanent Antarctic settlements, pacific islands and northern desertic regions at high altitude- to communicate with senior doctors and consultants in healthcare centers of higher complexity, as e.g. university hospitals. Although there are considerable differences in the health systems, Argentina and Chile share the problems that arise from a vast geography: difficult access to health care esp. specialty care, and professional isolation. On the other side, developed countries encounter other questions derived from the ongoing globalization process. There is a need to improve, enlarge, and enrich existing databases on physiological alterations and health problems specific of extreme environmental conditions. Also an improvement of world-wide epidemiological databases is necessary in order to meet the requirements of a global society that seeks standardization of medical services, medical support in catastrophic events, and improvements in travel medicine to provide high standards of medical services to researchers and tourists in remote areas. A project named ARGONAUTA[1] (**A**ust**R**al **O**n-line **N**etwork for **M**edical **A**uditing and **T**ele**A**ssistance) -a cooperative effort among Argentina, Chile, Germany and Italy- offers a reliable approach to meet this broad range of requirements.

EPR & TELEMECINE

General requirements of an EPR

To provide high quality consultation as a telemedicine service, the consultant must be able to access the most complete patient information available. This is the same we demand of modern medical information systems used in hospitals and in physician offices. While early implementations of hospital information systems could manage only patient information regarding visits to a single hospital, expectations of health care professionals on information systems in medicine today are far beyond this limited scope. The information system has to manage patient data in a way that covers all the needs of the authorized participants in the health care process[2]. These include:

1. Accessing the complete medical record of a patient on demand at any access point -provided the user has the necessary authorization.
2. Ensuring the four fundamental security objectives: confidentiality, integrity, authentication, availability.
3. Recording and storing medical data on different systems in different locations.
4. Enabling management of different data types like text, images, movies, sound, and graphics.

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5. Enabling access to information in different languages. The format has to be adapted to the context and the event specific problem.
6. Integrating available coding systems and term sets like ICD, ICPM, SNOMED, GEHR termset, and MeSH.
7. Integrating all kind of medical data through standardized communication interfaces according to national or international standards (e.g. HL7, DICOM, EDIFACT, XML, XDT).
8. Adhering to standards. Apart from communication standards in medicine (e.g. HL7, DICOM) a common data structure for using and sharing electronic healthcare records which is acceptable across clinical domains, countries and computer systems is needed. Such as GEHR (Good European Health Record) architecture which is a standard guide for content and structure of the computer-based patient record.
9. Ensuring a short response time

To fulfil the demands on the information system one has to build up a multilingual multimedia electronic patient record.

Special Requirements of EPR & Telemedicine

Besides the general requirements stated above ARGONAUTA posed special demands on the system:

a) Provision of an infrastructure and telemedicine environment that links users and providers of telemedicine services while ensuring the quality of medical and technical services and standardizing of procedures and protocols. To achieve this goal the demands on an electronic patient record system differ from the demands on the patient record of a hospital information system.

b) The amount of patients and patient data entered into the electronic record is much lower for a telemedicine system like ARGONAUTA than for a common hospital information system. For a telemedicine consultation in an emergency case e.g. the amount and the completeness of administrative data are less important than access to results of disease related examinations. This includes text, image, and sound. For several specialties (e.g. pediatry, cardiology) different pathways must be available for data entry. Common browsers like the Netscape navigator or the Internet Explorer offer only very limited functionality for data entry, online error correction and intelligent user interaction.

c) Multiple languages: Much information in a patient record is built on short terms or text phrases which can be translated automatically into different languages.

d) Confidentiality and data security: For sensitive material confidentiality and data security are of utmost importance. This is particularly the case in building a database containing the records of patients, hospitals and physicians spanning countries and continents. In order to ensure confidentiality in this environment the system must employ the most sophisticated methods available in regulating storage, communication and access to data. This requires the use of strong encryption.

e) Online consultation services: In addition to patient data in the electronic patient record for offline telemedicine consultation often an online video consultation is useful.

IMPLEMENTATION

Electronic Patient Record:

An electronic patient record was developed by the staff of the German Aerospace Center (DLR) according to the GEHR standard-guide. It includes the following transactions[3]:

1. *Administration:* to record information which assists the management of the patients but is not specifically related to their health status.
2. *Contact:* to record information related to the care provided by clinical staff in contact with a patient (e.g. encounter record, progress note).
3. *Summary:* to record information that is deemed to relate to care that had been provided to the patient or patient's relatives in the past and which has a relevance beyond any single transaction.
4. *Report:* to record information which has a legal status outside the electronic patient record. Thus report transactions involve communication from one responsible person to another.

Server:

In the last years we observed new developments away from systems using proprietary standards for the storage of data and the user interface to systems using databases with a standardized query language and HTML capable browsers. Functions which are not directly supported by the HTML language can be achieved by the JAVA capabilities of common browsers like the MS-Explorer and the Netscape Navigator. A problem which still lies before us involves the reliable storage of related documents using

a common web server like Apache. To meet these requirements the second generation web server from Hyperwave[4] was introduced. Hyperwave technology allows one to administrate documents stored in servers located anywhere in the world, without having the problem of broken links and lost documents. Hyperwave's design is modular. This makes the server flexible and allows the user to add or replace modules as desired. A control process called "hwservercontrol" can be configured by the user to start any process along with the server.
The server is based on the following three different layers:

1. the protocol conversion layer
2. the session layer
3. the database layer

The protocol conversion layer offers several different protocols to fulfill different user needs. We use the WWW gateway (WaveMaster) which transforms HTTP to Hyperwave's internal client-server protocol (HG-CSP). The session layer communicates with the database layer. This is the layer where documents, links and metainformation are stored. The database layer consists of three modules, the object server (wavestore or Oracle) which maintains objects (including users), their relationships, indexes and access permission. This makes it possible to replace Hyperwave's internal database with an Oracle database without changing objects or applications. The full text server (ftserver) maintains an inverted index of all text documents for searching while the document cache server (dcserver) stores local documents of the server as well as cached documents from remote servers. Hyperwave offers for communication between clients and the server encryption using the Secure Socket Layer (SSL) technique. Strong encryption can be achieved by using the US-domestic version of a browser with strong encryption enabled or the international version of Netscape Navigator after applying a patch from fortify (http://www.fortify.net/README.html).

Network

Several nodes were built in Argentina (Comisión Nacional de Actividades Espaciales and Universidad Nacional de Córdoba), Chile (Instituto Antártico Chileno and Universidad de Chile), Germany (DLR and University of Bonn) and Italy (Consiglio Nazionale delle Ricerche and Ospedale San Camillo in Rome). Physicians from hospitals in rural areas next to the nodes in South America communicate with local nodes by using internet protocol via telephone lines. Facilities in Antarctica primarily use the nodes in South America. On demand physicians in Germany and Italy can become involved in the process of health care delivery.
For the presentation of data standard mime-types are widely used. If the browser's capabilities of graphic representation of the data common plug-ins are used. Therefore nearly any type of graphical information can be displayed by using a standard browser on a common PC system or workstation.

Services

Offline Consultation: To perform an offline consultation the requesting physician has to identify himself to the system. After selecting a patient from his local patient list he can add for the patient contacts with different specialists or select the insert button to add results to the patients record. The opening screen allows the physician to add nearly any kind of data to the electronic patient record. The list of supported data types includes text, graphic of several different mime types, video (e.g. mpeg1, mpeg2, avi), sound and so on. The browser allows one to search the local file systems for the appropriate file which can be added to the patients record by pointing at the add button. After adding all important data to the patients electronic record the consultant can browse through the complete patients file and add his suggestions to the record.
Online consultation: For online consultation internet video conferencing systems like NetMeeting are used. NetMeeting is based on standards like H 320 and H 323 for video conferencing and T 120 for the exchange of data. Using this standard providing consultation services via video conferencing between a physician on an remote node and a physician in a facility in a rural area or health care professionals on a base in Antarctica can be performed via an internet connection. Online consultation via internet between facilities in Germany and Italy with bases in Antarctica were tested with success. The position of the Antarctic bases near to the South Pole render communication between them and European locations via geo-stationary satellites difficult. The maximum available bandwidth is limited to 64 kbit. In addition to video conferencing, file transfer and the white board capability are used. Since the NetMeeting shared application function uses raw data image transmission with only 256 colors without compression this facility should be used only for small images
Languages: For this feature the system uses a built in thesaurus. Depending on the selected language (e.g. German) not only the name or description of a field on the screen but also the content of a field which accepts only a limited number of different terms like sex (e.g. "male" or "female") will be shown to the end-user as "männlich" or "weiblich" which is the German equivalent. In addition to German, English,

Spanish, Italian and Russian languages are supported in parts.

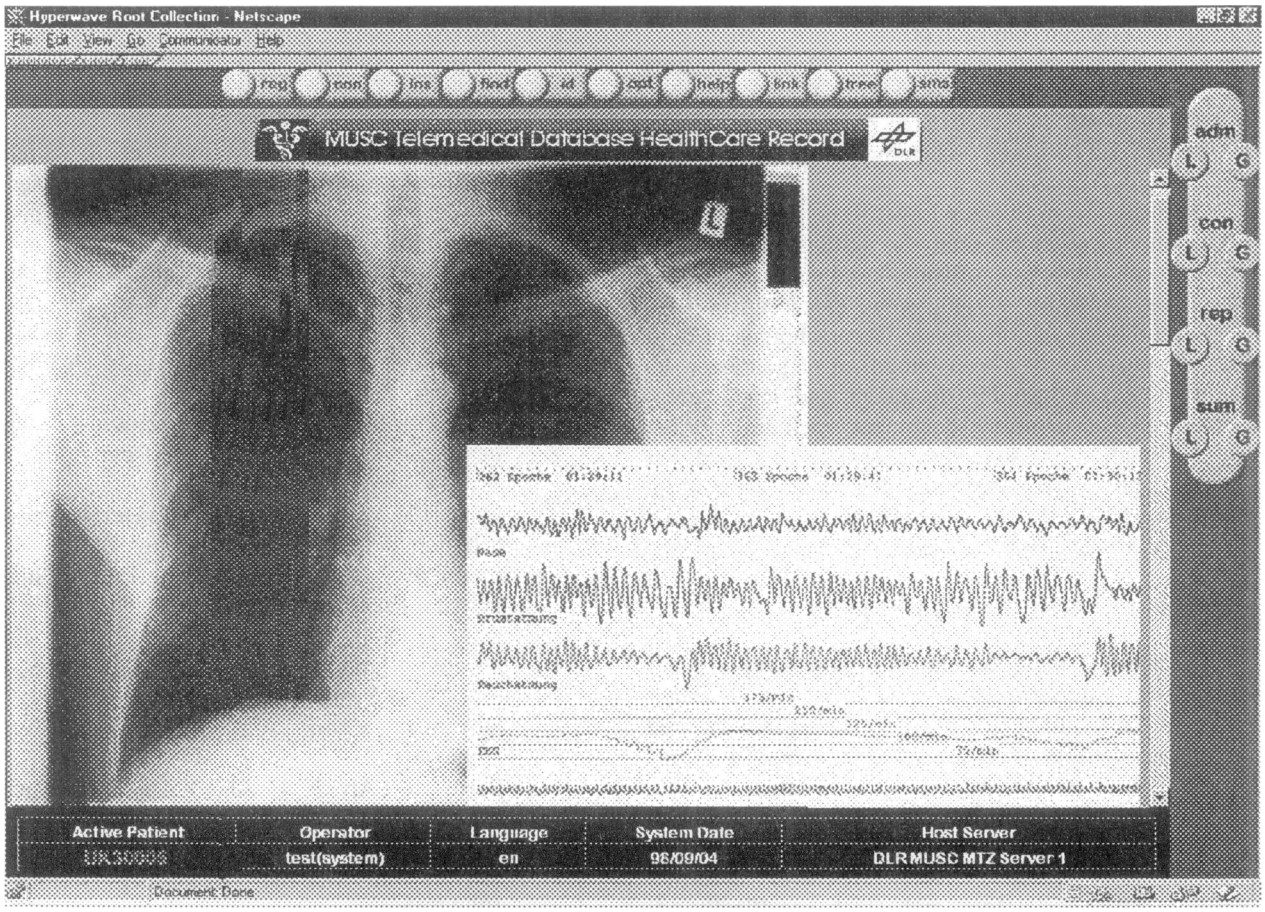

Figure 1: Screen shot from the electronic health care record

DEVELOPMENT AND OUTLOOK

DLR's implementation of the electronic patient record used for the ARGONAUTA project allows one to add additional services to the patient record. Under construction is a module which creates links between information in the patient record and documents from external information sources e.g. medical guidelines for physicians and patients (e.g. CancerNet[5]) or literature.

To further enhance the interactions between the electronic patient system and the user a pure Java prototype of the user interface, running in a Java virtual machine, is under development. This prototype does not even need a browser for working. While the average response time is less than two seconds some functions need several seconds including the time for loading the applet via the network. A compiler like IBM's High Performance Compiler for Java (HPJ), translating Java classes into native code, can be used to speed up performance-critical tasks.

XML: To exchange information in medicine between different systems well known communication standards like HL7 are used. These standards have limitations. They don't offer all the formats necessary for communication of all kinds of documents including the context of the documents. A solution of this problem may be the Extensible Markup language (XML)[6] which is a subset of the Standard Generalized Markup Language (ISO 8879). XML was developed by the XML Working Group (originally known as the SGML Editorial) formed under the auspices of the World Wide Web Consortium (W3C) in 1996. XML does not only describe a class of data objects; it also describes the platform independent protocol for the exchange of

documents and the automatic processing of documents after receipt. In addition to layout information they provide metadata that will help people find information and help producers and consumers of information find each other.
The separation of a document into data, structure and presentation is conform to the GEHR model of an electronic patient record. The electronic patient record can be stored on heterogeneous databases.

Security: Secure Socket Layer technology is used in communication between the system and the end-user. In addition to software based encryption smart cards containing cryptographic chips can be used with the requisite hardware. The technique of digital signatures has been integrated to guarantee secure access, genuine document and legal acceptance. The complete document, including further information like style sheets, have to be signed. For the signature of distributed documents the concept "Dsig-1.0 Digital Signature Labels" proposed by the W3-Consortium is used.

CONCLUSIONS

A system is being developed that not only satisfies general requirements of an EPR but also takes account of requirements posed by an application used across continents: these are esp. related to confidentiality and security, use of a variety of languages, and online interconsultations. The implementation currently being tested builds upon the experience gained by using HyperWave information server technology and which specifically addresses the needs for systems that support cooperation across the borders of organizations, regions and nations in a heterogeneous environment[7]

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