Experiences with ARTEMIS - An Internet-Based Telemedicine System

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ABSTRACT

ARTEMIS is one of the first systems to exploit the Internet/Intranet technologies for exchanging patient information among health care providers. The primary project goal was to develop and demonstrate a regional telehealth environment specifically to support real-time consultations among health care providers via a computer network, provide secure access to multi-media patient records and discharge summaries, facilitate authentication/digital sign-off, multi-media mail-based referrals, and network-based dictation/transcription. A prototype is deployed in southern West Virginia in a Community Care Network (CCN). The CCN consists of providers, hospitals, clinics, laboratories. that make up one "Virtual" clinic on the "Intranet". ARTEMIS employs new technologies such as Java and JavaScript for the browser, and CORBA-based "middleware" for interoperability at the server-end. Several experiments were designed for evaluating the impact of ARTEMIS on patient care. In this paper we discuss the challenges we faced and the means by which we plan to meet these challenges. We conclude by outlining new thrust areas in which we are concentrating in our next phase of development of ARTEMIS.

BACKGROUND

Information technology and the Internet have now been identified as key enablers in reducing health care costs without a concomitant reduction in quality of service. This thesis may be justified by the fact that nearly 30% of all health care costs are attributable to some form of information handling, and information technology is the natural answer to meet such a challenge. A team consisting of computer science researchers at the Concurrent Engineering Research Center (CERC) of West Virginia University, practicing physicians and mid level care providers at Valley Health Systems Inc. (VHS) created a telemedicine system known as ARTEMIS in 1993. The team leveraged the Internet-based collaboration technology research that was pioneered at CERC since 1988. This technology was initially applied to the engineering domain before its importance and applications became widespread as we are witnessing today. Because of the open architecture of ARTEMIS, we are able to incorporate new technologies such as World Wide Web (WWW), Java and CORBA into ARTEMIS development with little difficulty. The goal of this research was to (1) reduce health care delivery cost in selected types of service without loss of quality, (2) increase the access to expert-supported health care services based in tertiary care hospitals located in metropolitan areas, (3) facilitate collaboration between rural physicians and hospital based care providers, (4) increase physician acceptance of this new technology by making it less intrusive, and (5) mitigate the isolation of rural physicians by bringing them into regular contact with the physicians in tertiary care hospitals. Our experience with ARTEMIS showed that while Internet technologies are crucial for the success in this area, many challenges remain. In the remainder of this paper we discuss the architecture of the system, the areas of focus, the challenges we faced and the means by which we plan to meet these challenges. We conclude by outlining new thrust areas in which we are concentrating in our next phase of development of ARTEMIS. The new directions in our research focus on the security aspects and a component-based approach to address three specific scenarios: (1) home-based care, (2) clinics managed by mid level care providers, and (3) intensive care patients under the intensivists.

The ARTEMIS SYSTEM

ARTEMIS[1] employs new technologies such as Java and JavaScript for the browser, and CORBA-based "middleware" for interoperability at the server-end. The areas of focus consist of: (1) a distributed multimedia patient record accessible at point of service using a simple client program often referred to as a "thin client", (2) synchronous and asynchronous collaboration between specialist physicians and general practitioners in diagnosis and

treatment planning, (3) support for referral, (4) support systems to increase the amount of care given by mid level care providers supervised by physicians located at a distance, (5) incorporation of robust security measures and (6) evaluation and effectiveness assessment.

ARTEMIS COMPONENTS

The architecture of ARTEMIS is shown in Figure 1. The system is organized as a set of three layers: a) role-based clients, b) middleware to support health care transactions, and c) an information source layer. In this section we briefly describe the various components and services provided by the ARTEMIS system.
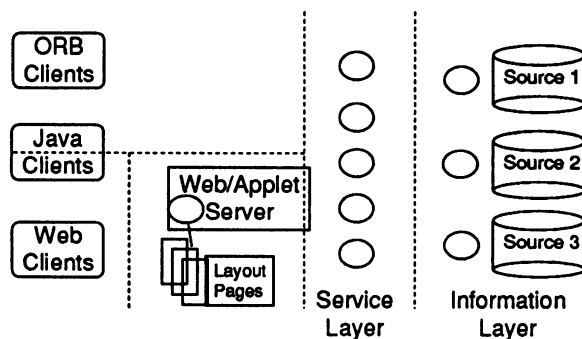

Figure 1: Artemis Architecture

Multimedia Patient Record Service - This provides secure, transparent and unified access to the record. Audio, video and graphics are supported. Master patient index for the same patient provides consistent cross indexing for multiple providers.

MONET (Meeting-On-the-Net) - Developed at CERC, this Desktop conferencing system is now routinely used by the providers at VHS, and between VHS and CERC researchers.

Patient-Record Viewing from Standard Web Browsers (HTML 2.0) - This allows the users to view patient record from a PC or Mac without requiring the ARTEMIS GUI, but maintaining its "look and feel".

Nurses Interface - This role-oriented interface, designed specifically for nurses, allows real time insertion of patients' vital information. The values are verified using JavaScript.

Scanner Interface - This is to be used to insert lab results, images, correspondence, and miscellaneous information.

Dictation-Transcription Service- The health care provider can directly dictate into the computer where the dictation is stored as an audio file. This is

remotely accessed by the transcriptionist. The transcribed information can be digitally signed off after proofreading by the provider. This then becomes part of the patient record.

Automatic Packaging of Referral Information - Using multi-page Web* developed at CERC, the physicians can compose a packet of referral information from patient record and mail it as an attachment using Netscape Mail.

ARTEMIS system has been undergoing deployment in phases in two of the 15 clinics managed by the Valley Health Systems (VHS) and two tertiary care hospitals (St. Mary's Hospital and Cabell Huntington Hospital) located in southern West Virginia. These sites are connected by Frame Relay services provided by Bell Atlantic. The providers can also access the system from their homes using dedicated ISDN lines.

EXPERIENCES WITH ARTEMIS

Patient record is at the heart of all health care transactions as it is the permanent repository for a patient's information. Portions of it are consulted by every person who is directly or indirectly involved in providing health care. This may range from a receptionist who needs access to biographic information to a radiologist who needs access to an X-ray image. Since most of the information in a patient record originates at different points of service, often at widely dispersed locations and over a long period of time, providing a unified access to this information is the most daunting challenge to information technology experts. This is further complicated by extreme demands on accuracy, consistency and confidentiality and rapid response - often in the order of milliseconds.

The ARTEMIS system faced this challenge by adopting the WWW paradigm as the unifying and browsing mechanism and Internet as the delivery mechanism. When the first prototype of ARTEMIS was created in 1993 it found immediate favor with physicians and other health care providers because of its simplicity and intuitive nature of interactions. However, we faced many challenges that need to be met before the system can be deployed for routine use. These are described in the remainder of this section.

Response Time

Health care providers are used to accessing information by merely flipping through the pages of a paper chart. However, we discovered early in our development that the response time of a computer based patient record is significantly longer primarily

due to the shortcomings of the underlying technology, most notably the stateless nature of the World Wide Web paradigm. We have devised two mechanisms to deal with this barrier: (1) pre-fetching information and cacheing locally, (2) devising a state-aware protocol using scripting mechanisms. This resulted in a technology known as Web* which was put in the public domain. These ideas are subsequently adopted by commercial vendors into the off-the-shelf systems. Our current experience shows that this approach will produce satisfactory response times.

Heterogeneity of Information Sources

Since information in a patient record is collected over a long period of time using many proprietary systems uniform access to this information is not easily attainable. To overcome this we have devised a gateway mechanism to connect data sources to the browser using middleware based on the Common Object Request Broker Architecture, popularly known as CORBA. ARTEMIS is perhaps the first health care system to embrace CORBA[2] which contributed to the creation of a standards group known as CORBA-MED. This has paved the way for a scenario where a client software can run on any platform while the data sources can remain on their traditional host systems. We are currently incorporating the new language JAVA which will lead to further flexibility in dealing with this barrier.

Inflexible Input Mechanisms

While the WWW paradigm provided an easy to use point and click mechanism for browsing, getting information into the system remains inflexible as keyboard is the primary input mechanism. Health care providers, particularly physicians find the keyboard both intrusive and awkward. This has become a major obstacle for deployment of ARTEMIS. We believe a combination of dictation/transcription mechanisms and a tablet based input mechanism will partially mitigate this obstacle. These coupled with handwriting recognition and flexible form-filling may finally pave the way for full adoption of the electronic patient record.

Consultation

Bringing the benefits of the expertise of hospital based specialists to the rural populations has long been the goal of telemedicine systems. Based on our long experience with developing a network based conference system known as MONET we developed a real-time consultation capability into ARTEMIS. However, we discovered this capability was not fully utilizable not because of any technical shortcomings but because of the busy schedules of physicians which make it nearly impossible to arrange impromptu consultations. A store-and-forward approach seems to be the most viable mechanism for consultations. During our initial deployment of ARTEMIS in VHS we discovered that real-time consultation capability can in fact be useful in promoting social interactions between providers which can ultimately lead to a more collaborative environment. This can also contribute to reduction of rural physician isolation.

Referral

Referring a patient to another physician or a health care organization is one of the most common transactions in health care. When a patient is referred, a subset of the patient record that is pertinent to the referral is also transmitted. In the ARTEMIS system we provided a facility where a referring physician can create a multimedia packet and send it using e-mail. However because of the wide diversity of e-mail systems, it will be difficult to deploy it effectively until a fully interoperable e-mail system become available.

Mid Level Provider Supervision

Mid-level providers such as nurse practitioners and physician's assistants are responsible for providing a variety of health care services, especially in rural areas. They generally work under the supervision of physicians who monitor and approve the decisions made by the mid-level providers. Physical site visits, faxes and telephone are the present means by which this supervision is carried out. We found the physicians at VHS to be quite enthusiastic about using e-mail and the real-time consultation system for providing supervision. We are currently in the process of incorporating this into the normal work-flow of physicians and mid-level providers. A detailed evaluation to ascertain the value of this facility will be carried-out over the next two years.

Security and Confidentiality

While information technology can lead to improvements in health care, it can also severely compromise the integrity of service unless the information is made secure. Even though no information system can be completely secure we can build effective barriers to prevent malicious intrusion. The initial prototypes of ARTEMIS depended on the use of fire-walls to prevent unauthorized intrusion from outside. This does not however protect the system from internal compromises. We have found that excessive security mechanisms can inhibit the acceptance as it can lead to cumbersome login-logout protocols. We plan to

experiment with the use of smart cards and point of service protections based on biometric technologies. Our initial evaluation of these techniques seem to be promising. A public/private key based encryption mechanism is technically feasible but it cannot be widely used until reliable certification authorities are ubiquitous. This area forms a major thrust of our work over the next two years.

ARTEMIS Evaluation

We are studying the impact of ARTEMIS on the reduction of medical providers' time and effort and on their level of satisfaction with the system - especially usefulness of the new features provided by ARTEMIS. Several statistical studies[3] were designed, mostly to compare the data collected before and after deployment of the ARTEMIS system. In some cases data will be collected several times after deployment so that the effects of the adjusting period can also be studied. Separate experiments were designed for medical care providers (MCPs which include physicians, physicians' assistants, nurse practitioners, nurse-midwives), and nursing care providers (NCPs) since their responsibilities are different. Collected data were of qualitative as well as quantitative type, and appropriate techniques were employed accordingly[4]. The biggest challenge in conducting the analyses was a very small sample size - quite understandable in rural settings with only a few providers working. The statistical experiments for ARTEMIS evaluation are briefly described below.

Work-Sampling Study[5] to measure the proportion of providers' time spent on each of the pre-determined type of activities: reviewing charts, caring for patients, documenting visits, and other. After analyzing the results of work sampling, we realized that the time spent on documenting visit was seriously underestimated in the study. The reason for that became clear after interviewing the providers. We found that they often document visits during the lunch time and/or after normal working hours. Therefore we asked the providers to record the "extra" time they spent each week on documenting visits. Based on the additional data we adjusted the percentage of time spent on each type of activities. It should also be noted that some part of the time spent in "other" activities is actually patient-care related. Due to the nature of such activities (for example, telephone calls or other conversations related to patient's problems), this could not be captured.

Missing Information Study to determine the frequency of information missing from the patient record. Often, information is missing from a patient record due to the shortcomings of the paper-based record system (pages get lost, lab results are not entered or are late, part or the whole of the patient record is at another clinic etc.). By "missing" information we mean results of tests that were ordered but have not been entered in the chart or parts of the patient record that were misplaced, lost, or not sent with the patient. The missing information were classified under three categories: laboratory results, radiology reports, and other. The physicians themselves recorded the instances of missing information. We expect that the use of ARTEMIS system will considerably reduce the average number of such instances.

Dictation/Transcription Turn Around Time Study to determine how much time is saved when the MCP's notes dictated to the computer are accessed, processed and returned by the transcriptionist electronically. This experiment was added later in the project as this became a prioritized feature of ARTEMIS. The collected data showed that while the time for the transcriptionist working on site was 1 or 2 days, the time for the transcriptionist located elsewhere was 6 or 7 days. We found that during the period we collected this data, the time was even longer (5 more days) when there was a major holiday such as Thanksgiving. Using the ARTEMIS system, this turn around time can be drastically reduced. The audio file in which the provider's dictation is archived can be retrieved and corresponding transcribed notes can be returned by the transcriptionist electronically. This also eliminates the instances of missing tapes. This type of events, while not very likely, happens once or twice a year. It actually happened during the time we collected data, and the dictation for some 20 patients visits was lost which was difficult to reconstruct. The new feature will make such situations more unlikely.

Survey of Medical Care Providers and Nursing Care Providers to determine general satisfaction level, degree of providers' effort (usability), confidence in security and accuracy, frequency of unnecessary testing due to failings in the paper record system, availability of information from another organization or after normal working hours, and support for referral and consulting. We also included a question on providers' familiarity with computers. When asked about their overall satisfaction with the paper-based patient record system, MCPs' opinions were almost equally split between low, moderate and high satisfaction levels while the nurses were much more satisfied. For the

questions dealing with referral and consulting situations: if an easier information packaging method were available, 70% of MCPs would send more information when they refer patients to another provider. In an informal consulting situation, 80% would at least sometimes share more information when asking for advice, and 96% would like "sometimes" to see the actual data before giving advice.

Patient Satisfaction Survey to elicit patients' viewpoints on patient record system, and identify any concerns the patients may have regarding the use of computers for medical records and in the examination room. From the results of the patient survey, one observes immediately that there is remarkably little variation in the answers to at least four of the questions. Patients seem to report few problems with the present system, but are nonetheless willing to embrace the new one. For example, asked whether they would like computers to keep their medical records, overwhelming majority (88%) of the patients answered "Yes". When asked whether they approved of computers in the examination room, an 88% answered "Yes".

FUTURE WORK AND CONCLUSION

Based on our experiences with the first prototype of ARTEMIS, we are currently focusing on the development of a fully deployable system emphasizing the areas of: (1) home-based health care, (2) delivery of health care using mid level care providers and (3) providing support for intensivists to care for intensive care patients. Statistical experiments will be repeated as the system is routinely used, and the comparison study will be performed. The usefulness of the new features of ARTEMIS system (for example, packaging/sending referrals and dictation electronically, plotting lab results, looking at remote X-rays and ultrasound images) will be determined from the frequency with which these features are used. The study will be expanded to include other clinics as they join the "Intranet". We will also follow the guidelines recommended by the Institute of Medicine[6] on our evaluation effort.

Our study will hopefully show the effects of the computerized system on improvement in the process of health care delivery by facilitating better and timely information to the providers for better decision making, better communication between the providers, and between providers and their patients. In the end, a medical information system is a tool for practicing medicine--the science and art of healing.

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