Implementing a Web-based Clinical Information System Using EMR Middle Layer Services

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The Clinical Summary is a Web-based application for accessing the clinical database at the Massachusetts General Hospital. The application has been developed to give physicians in our health care community access to clinical information for patients they refer to our hospital. "Middle layer" services, written previously for the hospital's clinical workstation, supply much of the application's functionality. Employment of reusable services together with a Web-based front end has afforded a rapid and inexpensive means for developing a new clinical information system. This paper discusses the system's design, function, and methods of implementation.

INTRODUCTION

We have developed a Web-based information system to provide clinical information to referring physicians in our health care community. The system is designed to give authorized physicians quick, convenient access to clinical information on patients they have referred to our hospital.[1] Using a Web browser, these physicians will be able to view their patients' discharge summaries, laboratory results and diagnostic reports residing in the clinical database at Massachusetts General Hospital (MGH).

The usefulness of Web technology for prototyping and deploying integrated clinical information systems has been well documented by efforts at Boston Children's Hospital,[2] Columbia Presbyterian Medical Center,[3,4] the University of Minnesota,[5] and elsewhere. Our experience during design, implementation and preliminary user testing supports these findings. We believe our approach is significant from a different standpoint, specifically the modesty of effort and expense required to realize our goal by reusing pre-existing services to access the hospital's clinical repository.

Our design priorities were 1) to provide a stable, user-friendly front end, 2) to limit the training and installation needed at deployment, 3) to protect data using password protection and data encryption, 4) to limit the programming and development tasks required to interface the new front end with the existing clinical information repository.

We addressed these goals by utilizing Web technology to create the user interface and by reusing electronic medical record (EMR) services already written for the hospital's clinical workstation to provide the interface to the clinical repository.[6] Together, these approaches greatly reduced the time and resources required for prototyping and implementing our product.

We believe the economy realized by this approach is important for two reasons: 1) The pace of change in the health care environment has been intensified by both market-place and technological forces. Heavy investment of time or material resources for a system that may be obsolete within years or even months of deployment is no longer acceptable. Solutions to information needs, therefore, must be nimble enough to adapt to unpredictable new requirements, or must be inexpensive enough that they can be discarded and replaced as needed. 2) Integration of information resources is a primary concern for the development of clinical information systems. The ease with which this system was constructed using pre-existing services to the back end database suggests that planned integration with other hospital resources can be efficiently achieved using the same methodology.

DESCRIPTION

The clinical information resides in a legacy relational database, known as the Patient Care Information System (PCIS), deployed in June, 1990. The database environment is Tandem "Nonstop SQL," with COBOL85 Pathway services. The database currently contains clinical information for over 500,000 patients, with more than 9 million specimens and reports (see Table 1). The PCIS also contains a Master Patient Index (MPI) which provides patient identification and demographics. The central database has real time interfaces to more

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than a dozen hospital department systems from which it downloads information.

PCIS Information Type	Patients	Reports
Lab (Chem, Heme, Imm)	411,000	7,073,000
Microbiology	160,000	879,000
Radiology	239,000	1,154,000
Pathology	106,000	228,000
Cardiology	45,000	114,000
Discharge Summaries	69,000	118,000
Operative Notes	67,000	107,000
Total		9,673,000

Table 1: Clinical reports available in the Patient Care Information System (PCIS).

Identifying information about providers is stored in a "practitioner" table. Information about which patients a referring provider can view are stored in an "enrollment" table. These "practitioner" and "enrollment" tables reside in an Oracle database managed by the EMR.

Function and Behavior

Providers accessing the Web server's home page are presented with a login form on which they enter username and password. After being authenticated, the referring provider is presented with a list of patients to whom (s)he has been granted access (see figure 1). MGH providers are presented with a search form where they enter a patient name or MGH unit number; the results of the search are then displayed as a list of patients matching the search criteria. The patient list includes information for patient selection, as well as an "inpatient location" value for currently hospitalized patients.

Clicking on a patient in the list generates a list of report titles for laboratory and diagnostic studies. By clicking on a title in this list the clinician can see the full report contents (see figure 2). Laboratory studies are displayed as a "last known values" list.

The key interface design goals have been to provide useful information with every screen and to minimize the need for navigating among different screens. These goals have been addressed by using "frames," a widely used Hypertext Markup Language (HTML) extension. The screen is divided into functional regions: a title area, the patient header, the report titles listing area and the results area. The title area displays the clinician's identifying information. It also contains a button that allows the

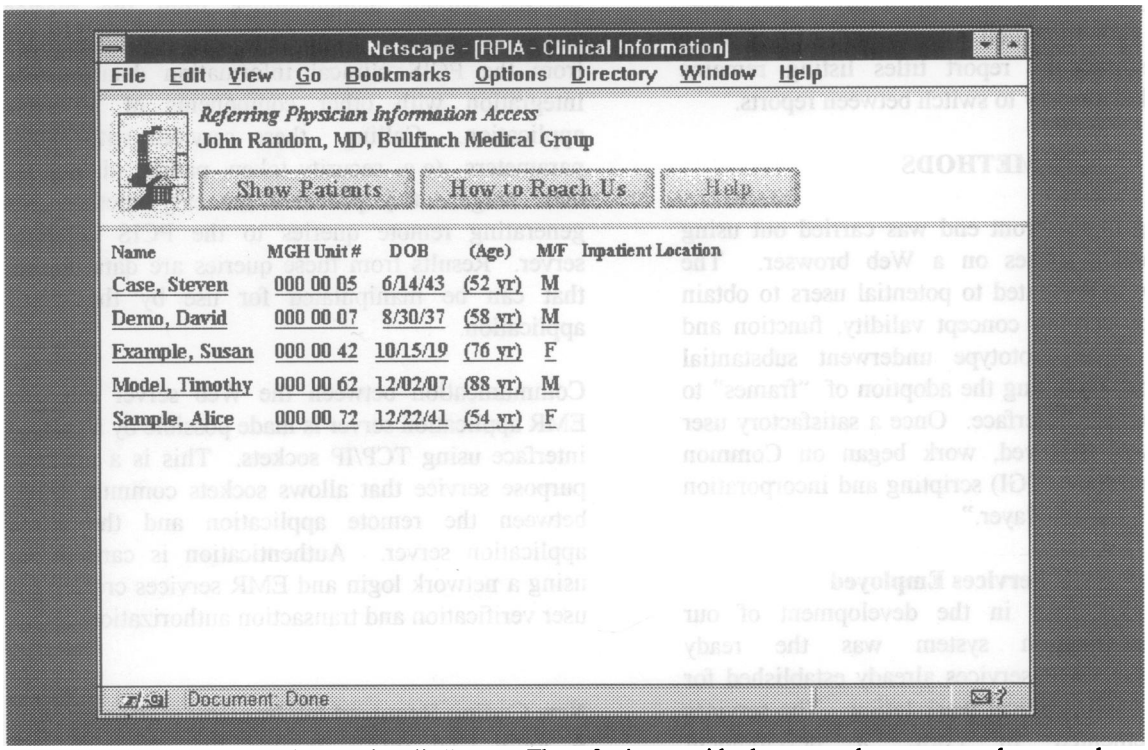

Figure 1: Screen capture showing "patient list" page. The referring provider has entered username and password on a login screen and submitted it. The next screen, shown here, displays the provider's patient list. Each patient in the list is a hypertext link. Inpatient location is also displayed for current inpatients (though it does not apply to this group of patients).

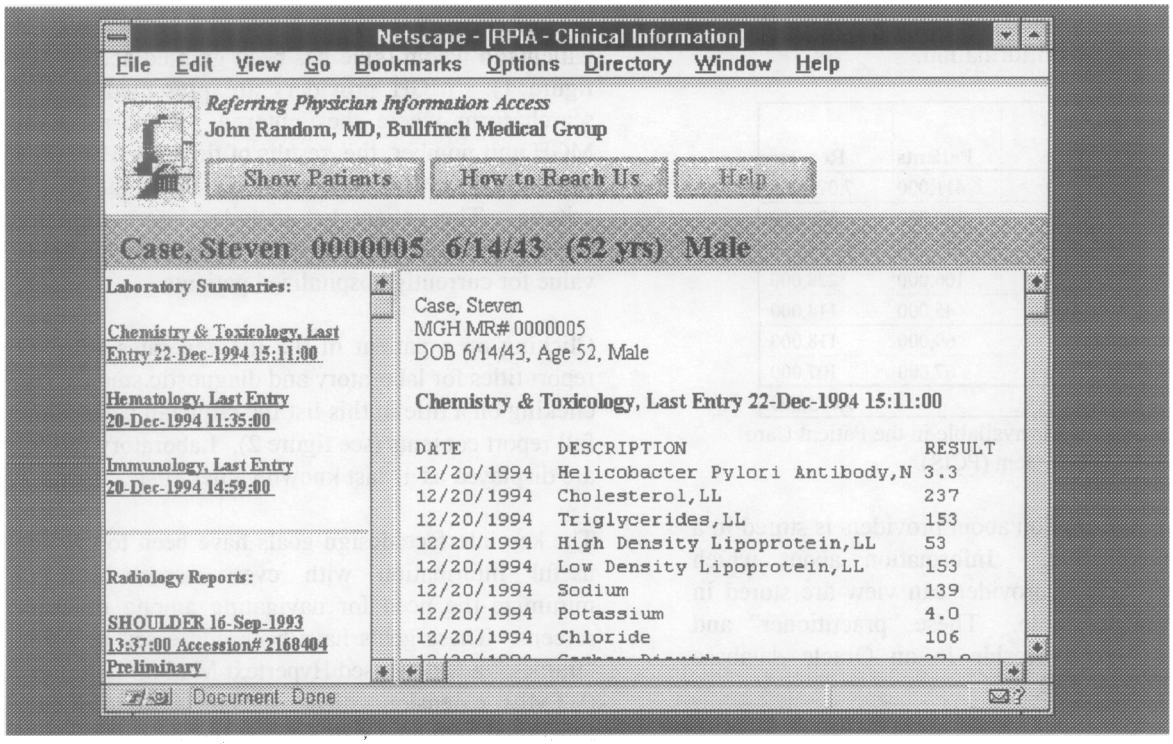

Figure 2: Screen capture showing a sample report page. The provider has selected a patient (from the patient list in Figure 1) and a report to view (from the report titles list on the left side of this screen). Information identifying the current patient is highlighted above the report display area. Other reports can be viewed by clicking on their titles in the report list. The "Show Patients" button, visible in the title area, returns to the patient list in Figure 1, allowing selection of a different patient.

clinician to redisplay the patient list at any time, making it easy to switch between patients. During report viewing, the report titles listing remains visible making it easy to switch between reports.

METHODS

Prototyping of the front end was carried out using HTML mockup pages on a Web browser. The prototype was presented to potential users to obtain feedback concerning concept validity, function and behavior. The prototype underwent substantial modification, including the adoption of "frames" to simplify the user interface. Once a satisfactory user interface was achieved, work began on Common Gateway Interface (CGI) scripting and incorporation of the EMR "middle layer."

Pre-existing EMR Services Employed

An important asset in the development of our clinical information system was the ready availability of EMR services already established for use by the MGH clinical workstation. The services are implemented in Forte, a development environment for distributed, object-oriented systems. The EMR services are distributed objects built to retrieve patient demographics from the master patient index and to extract clinical information from the PCIS clinical information database for integration with other components of a client application. Calling these services with query parameters (e.g. security token, patient id, test id, date range, etc.) provides an easy method for generating remote queries to the PCIS database server. Results from these queries are data objects that can be manipulated for use by the client application.

Communication between the Web server and the EMR application server is made possible by a custom interface using TCP/IP sockets. This is a general-purpose service that allows sockets communication between the remote application and the EMR application server. Authentication is carried out using a network login and EMR services created for user verification and transaction authorization.

New Coding Required for Implementation

A login CGI script receives the username and password from the login form. After authentication,

the username and a unique security token are used to authorize all subsequent transactions.

An essential component of the Clinical Summary is the physician-patient linkage table. This table determines which individual patient records will be accessible to a given physician user. The linkage table will be administrated using a separate application. As no "linkage-based" patient look up was implemented for the EMR, a new service was created. This service looks up the referring provider's "practitioner id" from the EMR's "practitioner" table, then accesses the EMR's linkage table to retrieve the list of patient ids for whom the provider has been granted access.

A second CGI script handles all incoming queries for clinical information and formats all output for return to the browser. A new Forte service was created to receive query data passed from the CGI, and pass the query parameters to the EMR services for processing. The resulting data objects returned from the EMR services (e.g. a list of report heading information or the contents of a report) are converted to fixed format text strings and returned to the CGI. The CGI script inserts HTML tags required to format results for display and embeds query information into links for further requests, before returning the results as output to the Web browser.

Security

Remote access is via a dial-in line to the modem pool. Users are provided an account and password for use in establishing this connection. Transmissions between remote browsers and the Web server will be encrypted using asymmetrical key encryption as implemented by Netscape's Secure Sockets Layer (SSL). [7] Internet access to the application is not allowed as presently deployed. The Web server resides inside the hospital firewall, with a router positioned as a hub between the modem pool, the Web server and the hospital network. The router screens transmissions by MIME type and blocks direct communication between the modem pool and hospital network.

Password protection on accessing the system is provided using a network login. Users are provided with a network account. At login, the user name and password are validated on the network security server and a security token is generated. The token is passed as a hidden value in all subsequent session transactions. An audit trail is maintained for all transactions. To discourage inappropriate browsing by authenticated users, a warning is displayed when accessing patient records flagged highly sensitive.

New hardware and software acquisitions required to transit from the development to production platform have been minimal. A dedicated Web server running the Netscape Commerce Server has been installed, along with a network firewall. Dial-in lines to a modem pool have been added.

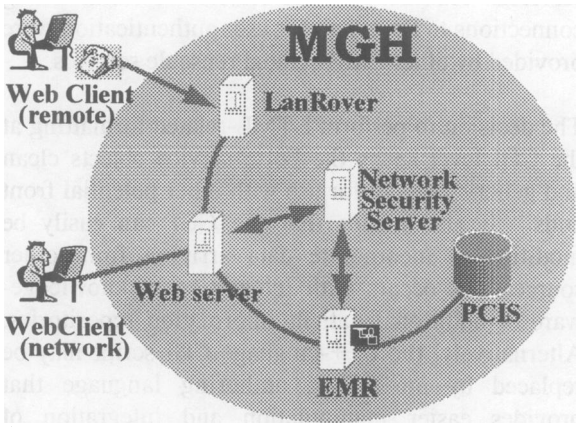

Figure 3: Functional architecture. Forte services, running on the EMR server, handle access to PCIS, and the network security server. Referring providers (remote users) will connect using dial-in lines to a modem pool managed by a LanRover. MGH users can access the Web server directly via the hospital network.

FINDINGS

During review of prototypes and a first-pass implementation of the clinical information system, users expressed acceptance of the Web front end using frames. The absence of keyboard equivalents for button clicks is an inconvenience for some users, but not deemed serious. Users proposed a number of scenarios for tailoring the list of report titles to their needs. An initial modification based on these requests has been to remove multiple portable chest x-ray reports and EKG reports, leaving only the most recent of each. There was considerable interest in "drill-downs" to previous laboratory results, accessing most recent abnormals, and alternative views of lab data such as trend graphs. Initial reaction from MGH testers, the first clinical users of the system, has been positive.

DISCUSSION

Since only minimal code is required to parse the parameter string passed from the CGI and to convert

the result objects to text strings prior to returning them to the CGI, the Forte service objects written to handle these functions are straightforward. The EMR services supply the application interface with PCIS, including the failover and load-balancing needed to provide a stable environment. We estimate that more than 90% of coding burden involved to handle queries and retrieve PCIS results was eliminated by the use of these pre-existing EMR services. Additionally, the services for establishing connections to Forte and for user authentication were provided by other EMR-related reusable services.

The decision to perform HTML-related formatting at the CGI level keeps the Forte service objects clean and generic enough for use with other potential front ends. It also means that the CGI can easily be modified to incorporate data arriving from other sources, as occurs with integration of knowledge-ware or additional patient information repositories. Alternatively, the C++-language CGI script may be replaced by an HTML authoring language that provides easier manipulation and integration of information.

Knowledgeware integration is easily accomplished in the Web-based application environment. We have begun experimenting in this area by imbedding links to information about prostate specific antigen (PSA) screening at points where PSA results are displayed. Initial reaction suggests this may prove a useful method of distributing knowledge resources in a way that supports clinical work flow. More patient-specific integration of knowledge sources such as DXplain diagnostic support or Medline literature searches are possible. [4] For this purpose, conversion to a standardized vocabulary (e.g., UMLS) and data format will be considered.

CONCLUSIONS

Our experience in designing and implementing a clinical information retrieval system by using pre-existing EMR services to interface a Web front end with our PCIS database suggests that this approach will be valuable in integrating and updating the interfaces to a variety of information and knowledge systems. We are currently beginning work on integration with DXplain.

Developments in computer and communications technology continue to redefine the state of the art in medical informatics. We believe that the emergence of World Wide Web technology constitutes one significant milestone on the road to efficient development and deployment of clinically useful systems. Using "middle layer" services to adapt existing information and knowledge systems to new front ends provides the cost containment and ease of integration necessary for new systems development in a rapidly changing environment.

Acknowledgments

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