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Multi-Platforms Medical Computer Systems Integration

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Presently, software architects face the challenge of integrating and linking different application software packages built on different computer platforms. Often they inherit various systems, ranging from mainframe to PDA-based applications. The first stage before programming different interfaces is to identify the means of communications most suitable for particular systems.

The experience of the Mount Sinai Medical Center in New York, which combines a hospital, a healthcare network, a research center and a medical school, illustrates common problems faced by a number of medical institutions.

This paper will discuss the various options, including the Internet, software architects have, and how they can use them during the development of an infrastructure for health care systems.

KEY WORDS: software architecture; medical and healthcare applications.

INTRODUCTION

One of the distinguishing characteristics of computer-based systems in medicine and healthcare is the co-existence of multi-platform systems dealing with identical data for different purposes.

Historically, clinical, research and administrative functions were carried out by independent computer-based medical systems. Until recently the organizations, dealing with health information management, seemed to continue to support such a division. According to the American Health Information Management Association, "There are two broad classifications of hospital medical record data: administrative and clinical."(1) The Committee on Improving Patient data of The Institute of Medicine stated, "A patient record system is a type of clinical information

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system. The central focus of such system is clinical data and not financial or billing information."[2]

Moreover, information within clinical systems was further subdivided according to medical sub-specialities. These different clinical and healthcare subsystems could be based on different application software packages and were built on different computer platforms, such as mainframe, client/server and Internet/Intranet. These variations could have been attributed to the fact that initially all of the subsystems were created independently, with disregard to possible future integration. Developed at different times and using software tools most appropriate at a specific time period for a particular application, these systems may very well serve as a real-life illustration of a computer evolution. On the other hand, diverse functions carried by various systems required an assortment of tools and capabilities provided by a mixture of different computer platforms.

To insure smooth operations and much needed systems interaction, systems integration is the obvious choice. Most importantly is the challenging task to select the best suitable platform for future applications.

MULTI-PLATFORMS MEDICAL COMPUTER SYSTEMS

The experience of the Mount Sinai Medical Center in New York, which combines a hospital, a healthcare network, a research center and a medical school, may exemplify common problems faced by a number of medical institutions. This article is dedicated to the description of the efforts to develop an integrated multi-platform computer system in the Medical Center and how the computer systems developed in the Department of Anesthesiology—the most computer-oriented department in the hospital—function as an integral part of the whole system.

The treatment of a typical patient in the hospital usually starts with the admission transaction, carried over by a mainframe-based system Admission–Discharge–Transfer (ADT). A mainframe computer was a standard, if not the only available choice, at the time of development for this administrative subsystem some 20 years ago. The system is based on a hierarchical database. Another mainframe-based hospital-wide system, TDS, contains physicians' orders for laboratory tests and tests results.

Other clinical data regarding the same patient may be found in different systems maintained independently by various clinical departments within the hospital. Most of these systems are based on a client–server methodology utilizing relational databases.

In addition, many departments, as well as administration of the medical center and the hospital, developed a number of Web-based applications.

To draw a full picture, it is necessary to mention efforts to integrate palm-held computers into the system, so physicians and other healthcare providers could enter information during medical rounds.

Unfortunately, despite all these achievements, some patients' files still include a significant number of paper-based documents, although pre-surgery admission is a paper-less operation.

Our current efforts are directed toward the development of a truly integrated electronic patient record. All paper documents will be replaced by their computer images, and medical information from different systems will be linked together.

HOSPITAL ELECTRONIC DATA REPOSITORY (EDR)

Application Overview

The Electronic Data Repository (EDR) is a Web browser-based application deployed on the hospital Intranet. The EDR displays clinical results from several hospital ancillary systems for a selected patient. Physicians, nurses, and other clinical users no longer have to access different hospital systems in order to get a wide variety of patient information. The EDR contains such data as patient demographics, visit history, radiology results and images, cardiology reports, laboratory results, pathology reports, allergies, discharge reports, operative reports, ECGs, medications given, and other classes of data.

The EDR application provides an easy way to retrieve clinical information by physicians, nurses and other users to support efficient patient care. Patient information is available from multiple historical visits. Some of the data currently stored in the EDR is no longer put into the patient's paper medical record, so the EDR is considered an electronic component of the official medical record of the patient (Fig 1).

Application Platform

The EDR was internally developed by the Mount Sinai IT staff over a period of one year. A physician advisory committee with representation from many disciplines met regularly to plan and review development. The front end is written in Java and JSP using Weblogic and is run on a Solaris Web Server. The backend is written in C++ and loads an Oracle database.

Application Structure

Functional Flow

Application Access. The EDR application is accessible on the hospital intranet inside the network firewall. This allows it to be accessed throughout the hospital network on office PCs, thin-client workstations (Citrix), and remotely via a secure virtual network.

Login Security. EDR uses the created User ID and Password and a defined User Role from the hospital order entry system. Each User Profile has an ID, Password, Password Expiration Date, and defined User Role. The EDR grants access to each Role according to Rules defined by the Medical Records Department. The access rules govern what the users can see. An example: Nurses can only view patients in their hospital location, and physicians can view patients from all hospital locations. Auditing logs are created to capture who accesses which patient, and what types of data they viewed.

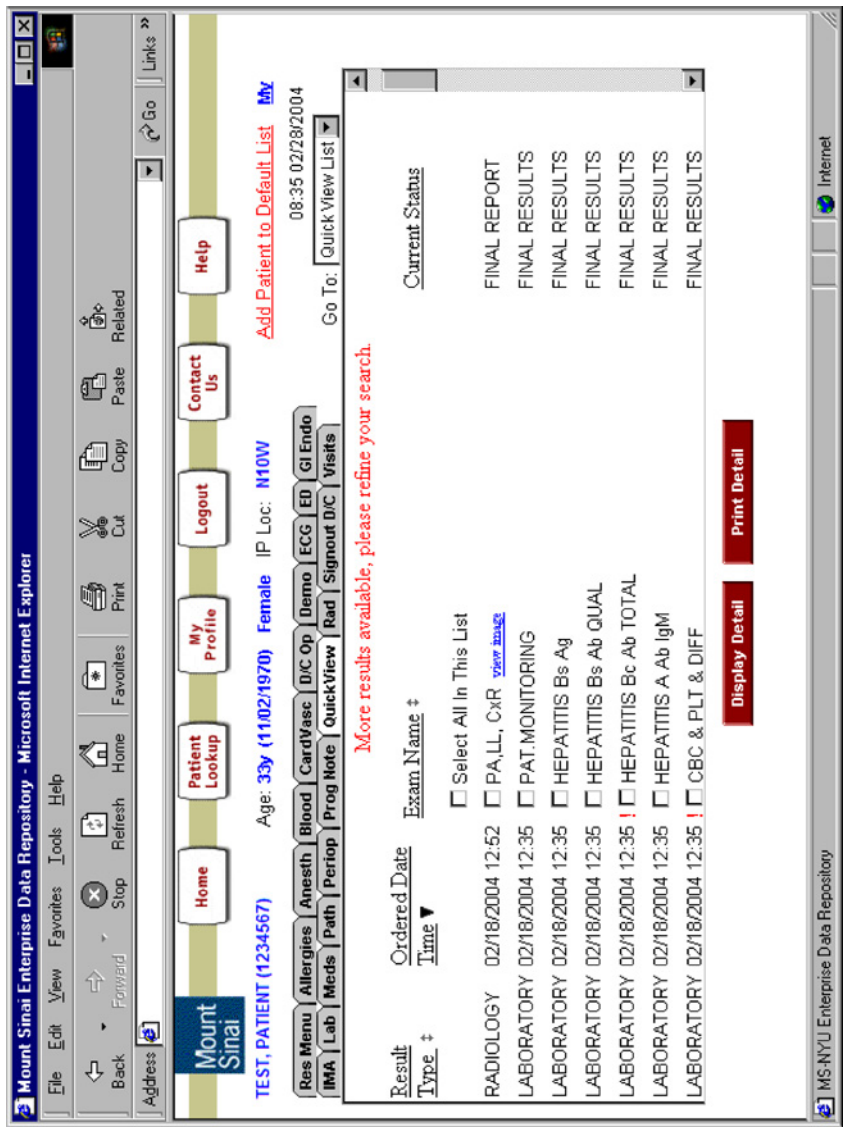

Fig. 1. Mount Sinai EDR.

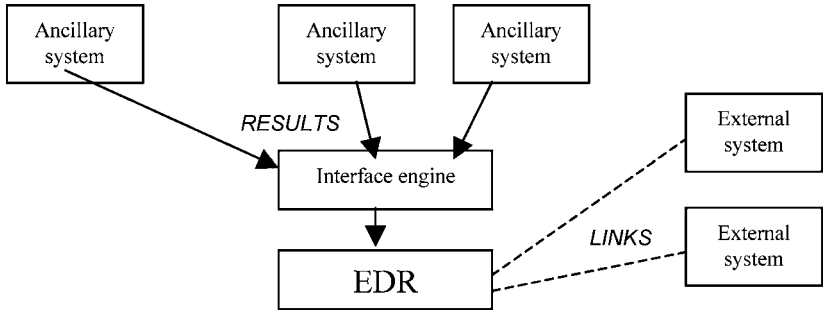

Fig. 2. Interface engine.

Data Flows

The EDR back end works with the Interface Engine to collect data in real time from the hospital admission–discharge–transfer system and the ancillary result systems. The EDR also links to patient data in some of the hospitals web-based ancillary systems such as radiology images, and cardiology reports (Fig. 2).

Application Modules

- The Main EDR Code handles the User Interface to display and link to Results and other patient data.
- The EDR Profile module within the Main User Interface enables the User to configure how and what data they want to be displayed as defaults.
- The EDR Admin Tool is a separate application that provides User Access control, Role management, and other functions.

Continuous Development

The initial version of the EDR contained ADT data, lab results, and radiology reports. The development has added all the other data classes available one at a time in a continuous process of enhancement overseen by the physician advisors. After three years of deployment in the hospital, the EDR is now used by almost all of the inpatient housestaff and most of the attending physicians. The nursing and other clinical support staff also now uses it often. It is used by the medical records department, researchers, and auditors to easily access comprehensive patient data. The EDR now handles about 10,000 patient data lookups per month. The majority of these lookups, 61% are for lab and radiology results.

DEPARTMENTAL SYSTEMS

Data Integration in the Department of Anesthesiology

The IT division of the department has developed miscellaneous databases and computer programs that were designed for research, clinical and administrative

applications. Obviously, these computer systems had different goals, structures, users and data. Integration of these systems involves identification of common data elements, design of universal data structures and development of interfaces between the systems. These elements may include, but are not limited to patients' demographics, clinical data, test results, available medical providers and their credentials, and various medical codes.

Most functions of current and future medical computer systems are interrelated. Therefore, in the process of designing the system architecture we attempted to develop a common approach and considered these systems not as isolated pieces of software, but rather as subsystems of an integrated computer system, presented in Fig. 3.

This approach allowed us to eliminate duplications in data entry and redundancy in computer files, share information between different systems and applications and use clinical data for administrative/billing functions. In addition, it insures uniformity in data presentation and visual interfaces across various applications and platforms. This integrated anesthesiology system is linked to a hospital information system and, therefore is a part of a patient electronic medical record.

In the integrated system each data element is entered, maintained and updated in one location by a designated computer subsystem, and is accessible by other subsystems for retrieval. This greatly reduces the chance of entering incorrect or misspelled data, or maintaining outdated information. Data used for research is stripped out of identification information according to HIPAA regulations.

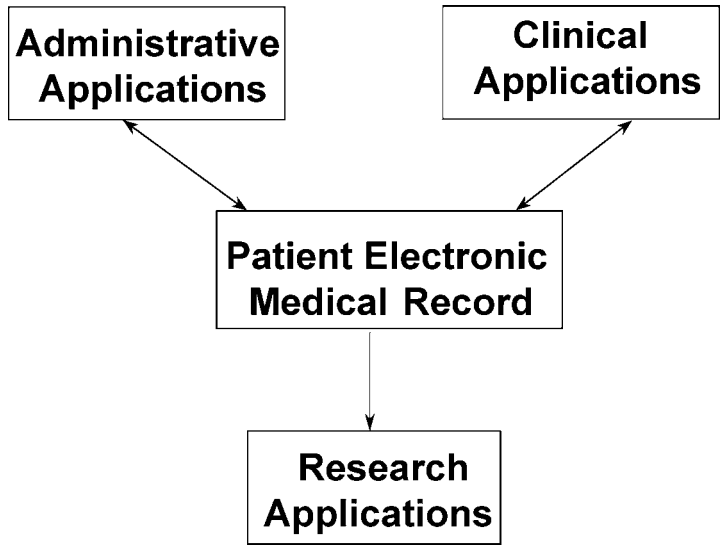

Fig. 3. Medical computer system.

Functionality

The integrated computer system in the Department of Anesthesiology carries out the following functions.

- Assisting attending physicians in their clinical practice.
- Performing some administrative functions, such as record keeping, accountability for drugs and supplies, billing, etc.
- Collecting and maintaining data for medical research.

This approach to operate an integrated multi-platform medical system, as natural as it may seem, is still rarely implemented due to some difficulties. Development of such a system in our department was encouraged by an earlier successful implementation of the Pain Management System,[3] and later expanded to a departmental-wide system. The conglomerate of systems currently functions as one unit in the Department of Anesthesiology. It is presented in Fig 4.

Clinical Systems

Perioperative Subsystem. This system registers information related to each surgery. The centerpiece of the system is a Compurecord module developed by the Anesthesiology Recording Inc. (Pittsburgh, PA). The primary goal of this system is on-line monitoring of patients' conditions during surgery, registration of major events, medications given, humodynamic data, and saving computer-based patient's anesthesia documentation for future QA, research and administrative purposes. The system's graphical interface is presented in Fig. 5. SQL-Server database is a central data depository for over 40 Operating Rooms in the hospital. It receives information on patients admitted to the hospital. Thus, the required information, such as

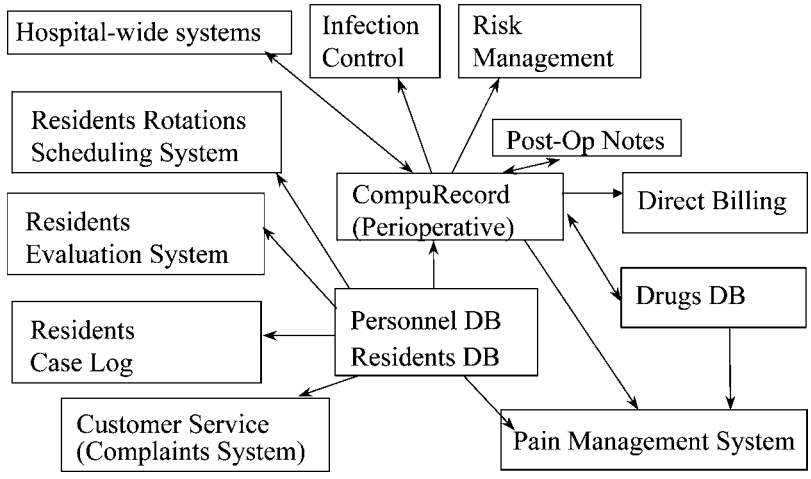

Fig. 4. Department of anesthesiology computer systems.

Fig. 5. Perioperative system graphical interface.

medical record number or insurance data is available for retrieval and recording, eliminating the need for re-entering data and reducing the chances for errors.

Pain Management Subsystem. Pain management system contains patient information to assist pain management anesthesiologists in their daily clinical practice. This creates billing records and keeps data on discharged patients as a base for medical research. It consists of a password-protected multi-screen graphical interface where a physician may navigate through four functional subsystems that are supported by four sets of relational database tables. The first set is the active patient roster that includes inpatient identification information, medical history, medications, date and type of medical services provided (with billing codes) and the physician that performed the service. The second contains information about discharged patients. The third is an itemized summary of the services provided and the CPT billing codes for each patient. The fourth is a supporting set of tables common to all subsystems.

The patient care subsystem assists medical providers in collecting and displaying medical data on active, discharged and ambulatory care patients. The administrative services subsystem is responsible for billing and reporting functions as well. The billing system prepares a summary of the services provided and automatically generates database records whenever a patient is added to the active patient roster, discharged, or when a specific procedure is provided. A daily billing report is generated for each physician. The complete billing information in Access database format is delivered to the billing company, which prevents transcription errors, coding errors and saves time collecting a patient's account.

Several backup and safeguards have been integrated into the database, including intentional structural redundancy in the database design, internal archival and physical backups.

Quality Assurance Reports. Based on the data collected by the Compurecord system, the following reports are periodically generated for quality assurance purposes.

- Mortality and morbidity report (monthly)
- Infection control report (quarterly)
- Risk management (returns to OR report) (quarterly)

These reports are requested by the Infection Control Center and the Risk Management Group of the medical center and also used internally by the department.

Administrative Systems

Personnel/faculty/residents database is located in the protected subdirectory of the departmental network. Sensitive information is stored locally on personal computers. The Residents Rotation Schedule application is directly associated with this database. Other subsystems in the department use this database as the source for up-to-date information on attending physicians and residents.

Direct Billing System creates files with billing information to be used by a billing company. The data is collected from the Compurecord system and transferred to the billing company via dial-in connection.

Ad hoc Reports include *Equipment Utilization*, *Operating Rooms Turnover Times* and *Operating Rooms Utilization* reports.

Educational Systems

Several systems were designed in the department to assist faculty members and residents in training and education, such as *Residents Evaluation Database System, Residents Rotation Scheduling System* and *Case Log for Residents*.

Paperless Office

Paperless office solution for the Day-of-Admission and Ambulatory Surgery office incorporates computer files, images of paper documents, lab analyses,

faxes and other forms of computer-based documentation into patient medical record using the OnBase Integrated Document Management System from Hyland Software.

Paper documents are scanned into OnBase. Faxes are received through an electronic fax server. Documents are automatically indexed using information from the hospital's data repository system and are associated as related documents. The Face Sheet is produced by one of the hospital's information systems and contains all of the pertinent patient information as it relates to the impending surgery. It becomes the controlling document within the workflow.

Mount Sinai intends to utilize this solution in other departments and enable doctors and laboratories to submit and view documents through the hospital's intranet system.

INTERFACES

Several departmental and hospital-wide computer applications, such as EDR, Perioperative Compurecord system, hospital scheduling system, Post-Op notes and numerous reporting systems are based on various relational databases: Oracle, Microsoft SQL-Server and MS Access. These databases are communicating with each other by means of ODBC connection. HL7 messaging communication format is used in all transactions

Outside billing company is using dial-in connection to access and download billing files created in the department from the perioperative system.

Internet-based applications are using databases that are also available to other hospital systems. TDS-order entry system is accessible through a virtual private network.

SYSTEM ARCHITECTURE

As a result of integration, all individual subsystems are enabled to utilize common features and elements in design, are able to share information, and are distributed among users, servers and personal computers within the department and hospital.

Mainframe

Gradually old mainframe applications are converted to other platforms, such as client/server and Internet due to more user-friendly interfaces and distributed environment.

Nevertheless, mainframes are still useful for data storage. Due to their immunity to computer viruses they are considered to be a safe environment. Mainframe-based ADT system is used for a single point of data entry for patients admission and provides one-way data transfer to client server and Web-based applications.

Client/Server

Client–Server-based systems are currently most widely used on the departmental level in clinical, administrative and research applications. Perioperative Compurecord and pain management systems are examples of client–server clinical applications. Resident evaluations and case-log systems are administrative systems that utilize the same platform.

For instance, in the perioperative system Compurecord, the data is saved using SQL-Server database as central data storage for all the operating rooms in the hospital. Compurecord is linked to various systems in the hospital. On the receiving end it is connected to a hospital mainframe-based Admission–Discharge–Transfer system to receive information on patients admitted to the hospital.

Internet

Internet represents the next logical step in development of integrated computer systems in medicine. Based on existing infrastructure Internet applications become the vital link for processing information and connecting all parties in the system. The aforementioned EDR is used as an information hub serving multiple hospital systems. Security issues are resolved by limiting access to the program from within the hospital only (Intranet) and by requiring an application-specific logon-id and password. Other Web-based systems in the medical center include bed board system for hospital rooms scheduling, CANOPY case management system, SIGNOUT inter-physician communication. Two latter systems are fed with information from the mainframe ADT system

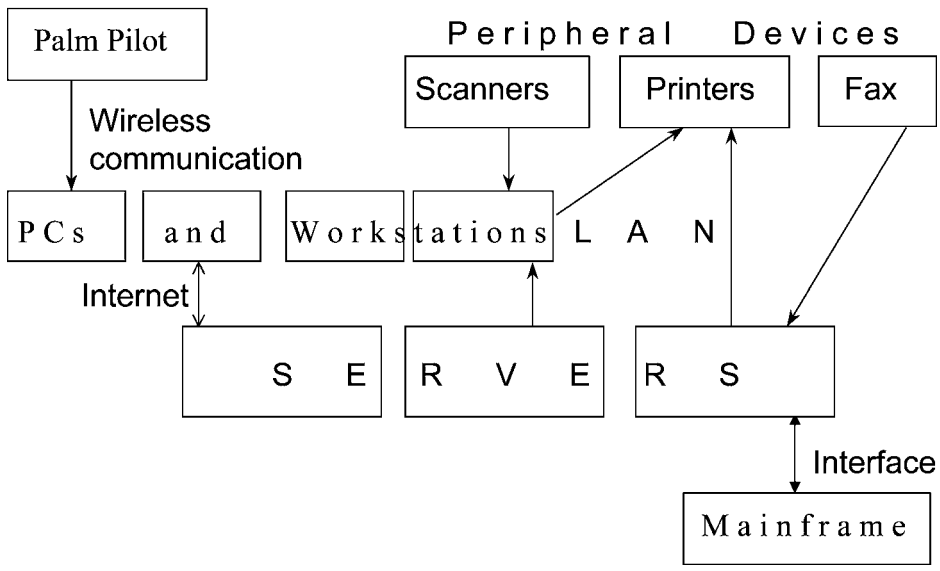

Fig. 6. Levels of data integration.

Multi-Level System Integration

The system architecture for multi-level multi-platform system integration is presented in Fig. 6. It unites multiple platforms and uses different types of interfaces described earlier. LAN and Web servers communicate with each other as well as another components such as mainframe, PCs, peripheral equipment and hand-held devices.

RECOMMENDATIONS/CONCLUSION

In recent years our medical center successfully integrated existing and newly developed software applications into a multi-functional integrated compound.

Our approach in system architecture design was to create interfaces between working in-house multi-platform systems. A costly alternative would be a painful process of acquisition, development and replacement of existing system with a universal platform-based software applications.

Web-based software applications were chosen due to their relatively cheap and rapid development. It obviously is and will continue to be, a platform of choice for present and future medical software applications.

We learned from experience that the best way to deal with a project of such magnitude is to build it in small incremental parts. Additionally, it is very important to get physicians actively involved in the early stages of software design, as well as at the testing and acceptance phases. Their perspective towards the applications is from a very different angle and advice from them can be very helpful, because, in the end, they are the software users.

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