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Functional and Control Integration of an ICU, LIS and PACS Information System

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Abstract. The need for collaboration and data sharing among systems dedicated to individual functional areas and user groups has initiated major efforts towards the development of an integrated hospital information system. Major issues in the development of any integrated architecture that incorporates autonomous departmental systems include the development of commonly accepted interaction mechanisms, standardisation, the structure of the computerised patient record, its extensibility, as well as limitations multimedia data impose. This paper presents work done within project IHIS, a nationally funded project for the development of an integrated hospital information system that provides ICU staff with access to both the ICU assisting laboratory information system's data as well as radiological multimedia data.

1. Introduction

Hospital organisation diversity, complexity of clinical protocols and procedures, as well as the different preferences of various user groups make it extremely difficult for a single monolithic information system to effectively serve the needs of an entire health care organisation. Thus, information and telecommunications systems must primarily provide the infrastructure to permit the effective integration of distributed and heterogeneous components, ensuring overall integrity in terms of functional collaboration and information sharing.

The physically distributed resources of the health care sector and the diverse requirements of different medical facilities and clinical departments require that specialised autonomous information systems are used to support different needs, while they interact transparently to the user as a federation of autonomous systems. This approach ensures the transfer and integration of consistent information throughout a network of health care facilities, without imposing constraints on the operation of individual units.

This paper's objective is to elaborate on the architectural framework that has already been presented in [1] and to present an integrated environment, that can collect, validate, record, recall, process and communicate multimedia information related to the patient under medical observation and recovery in the ICU. This approach supports data sharing among several departments, while at the same time individual domain-specific information systems sustain their autonomy.

2. Integration Types

The logic, as well as the data structures used in clinical information systems are not only complex but also incompatible. The institutional patient meta-record (PMR) concept [2] permits the seamless integration of distributed computerised patient record (CPR) segments. The different types of integration required are *data*, *functional*, *presentation* and *control*.

The distributed architecture presented here, consists of individual clinical information systems, each of them dedicated to its particular clinical requirements and having the ability to function independently from the others. As a part of the integrated architecture each of the clinical information systems can communicate with all the other, transparently from users, and exchange information when this is necessary. This approach supports information retrieval and propagation that can be accomplished:

- by allowing direct access on the servicing department's data base server,
- by having information systems exchanging work-lists and reports either event-driven or on on-demand, and
- by allowing users to request information on particular examinations

3. Workflow Management

Workflows are activities involving the co-ordinated execution of multiple tasks performed by different processing entities [3]. In the health care domain, activities correspond to work lists, task correspond to diagnostic service requests and processing entities are the servicing information systems.

Important requirements for the efficient and reliable operation of applications supporting workflow management include deep understanding of the process to model, as well as workflow implementation and automation. Separation of work activities into well-defined tasks with certain roles, well-defined rules and procedures allows for the modelling of health care processes in a rigorous and comprehensive way. This is a prerequisite for the development of an integrated hospital information system to support automation of processes.

The Center for Medical Informatics and Health Telematics Applications (CMI-HTA) of the Institute of Computer Science (ICS), Foundation for Research and Technology - Hellas (FORTH) has designed and implemented a Work Flow Manager (WFM) agent that acts as a co-ordinator among hospital-wide spread work list managers. This agent maintains information on available services provided in the integrated hospital environment and acts as a mediator among heterogeneous information systems. In addition the WFM supports a set of services capable of providing distribution of available services in the integrated hospital environment, work list decomposition and routing, appointment reservation as well as report composition. The WFM also keeps a record of all the intra-hospital examination request and report traffic.

4. Work List Management

The outcome of a diagnostic service request is the receipt of all or some of the examination(s) results, as well as the related reports by qualified recipients. To service a diagnostic request, the requester, as well as his authorisation, should be identified. The validity of the requested procedure types, as well as their steps should be also verified. Important factors affecting the scheduled procedure steps are the availability of the attending physicians, the technical personnel, the required equipment, and of course the patient. As a result the service request procedure produces a series of instructions for the patient, the requester, and the performer, concerning each of the scheduled procedure steps.

The CMI-HTA has designed and implemented a Work List Manager (WLM) that can support patient admission to the requesting department and give the opportunity to authorised personnel to place a diagnostic service request (i.e. to schedule patient examinations to the appropriate assisting clinical information systems).

When the requesting WLM communicates with the performing WLM it has to provide information like requester identification patient related data (like demographics, patient location and mobility, etc.), requested date and time, urgency, clinical data, as well as the destination for the supplied results. Upon completion of the exam(s) that correspond(s) to the procedure step(s) that compose the requested procedure, the final report is constructed and transmitted to all pre-requested recipients. After the receipt of the report by the last recipient, the diagnostic service request is considered to be complete.

5. ICU Information System

The ICU consists of a ward, with a limited number of patients and a small group of users [4]. Under *normal conditions* the ICU monitoring devices function properly, the patient's state is steady and the medical personnel's responsibility is to watch the patient and treat him/her accordingly.

When one or more monitoring device alarms are active, then there is an *emergency situation*. Immediately after such a situation it is very important to have the patient's record updated about the injected drugs, the medical acts, as well as the acceptance or rejection of certain data recordings during the alarm period.

Another critical point for the proper health care delivery in an ICU is the seemly *shift change*. The major issue here is the critical patient information that has to be passed along, which is associated to special treatment needs. What is important here is not what has to be done, rather than what has preceded.

With the above information in mind the requirements that any ICU-oriented information system should fulfil are:

- **On-line data acquisition from various sources:** This, combined with the ability to compose new information can lead to new data presentation methods, and can provide the practitioners with new possibilities for efficient treatment.
- **Automatic data validation:** This way human errors can be minimised, and equipment malfunctions can be isolated.
- **Integrated data presentation centred around the different data modalities:** This can reduce significantly the time spent by hospital personnel moving to and from various assisting laboratories, and thus improve the productivity of the ICU.
- **Fast data manipulation:** The amount of real-time data should not cause bottlenecks.
- **Reporting, and charting:** This way documentation quality can be improved significantly.
- **Adherence to international standards:** This is the only viable solution to the problem of integration. Functional interfaces among the different systems/components of the IHIS require significant effort towards standardisation.
- **Scalability:** It should be easy for the architecture to be expanded with the addition of more clinical information systems. It should be also easily incorporated in a wide-area network of integrated hospital information systems.

The IHIS project ICU monitoring system implementation consists of three autonomous components, each of which is responsible for managing different data types. Patient data, vital sign display of both simple measurements (SM) and continuous recordings (CR) provide an integrated bedside display for ICU practitioners. Support for several viewing modes (real-time data display, daily overview, charting mode and the patient record import/export functionality) is also provided.

6. Laboratory Information System

Laboratory data can be of different type and they can be transformed to useful information only after they reach a physician. The clinical personnel's most critical actions are mainly data analysis and reporting. The procedure begins with the receipt of the physician's request and ends with the delivery of the laboratory procedure report to the receiving physicians. The intermediate steps which the procedure has to undergo are, issuing of the order request, specimen collection and processing, data acquisition and analysis, results verification and reporting.

Data acquisition is performed through the standard serial interface most of the instruments provide. After the necessary two-phase validation procedure, for eliminating transmission and data errors, data are transferred into the patient's record. For devices supporting manual data entry, only data validation is performed.

In addition the LIS, developed within the IHIS project, supports automatic patient demographic data, as well as examination schedule insertion, initiated by the local WLM, eliminating thus valuable time for data re-entry. This makes the LIS an active information system, in the sense that it is capable of responding to other information systems requests.

7. Picture Archiving and Communications System

Medical images are very important sources of diagnostic information. The Picture Archiving and Communications System (PACS) is the information system that allows for the collection of diagnostic quality images, their efficient management, the fast and reliable access to them, as well as for the intra-hospital communications of medical images [5].

Figure 1 shows the architecture of the PACS system developed by CMI-HTA, ICS-FORTH as part of the IHIS project. The architecture consists of several components that function as an integrated information system over the distributed application environment.

The Medical Multimedia Archive Server manages the permanent storage of images, while the WLM Archive Server stores the records of ordered work lists. The User Interface Component allows for browsing through the PACS PRS, the Acquisition Component is responsible for the acquisition of diagnostic images, and the Clipboard is an intermediate buffer between acquisition and the PACS PRS. The Medical Mail Client is used for the exchange of multimedia medical images for remote consultation, while the Medical Mail Server acts as a filter for medical-content email. The WLM, as has already been described, facili-

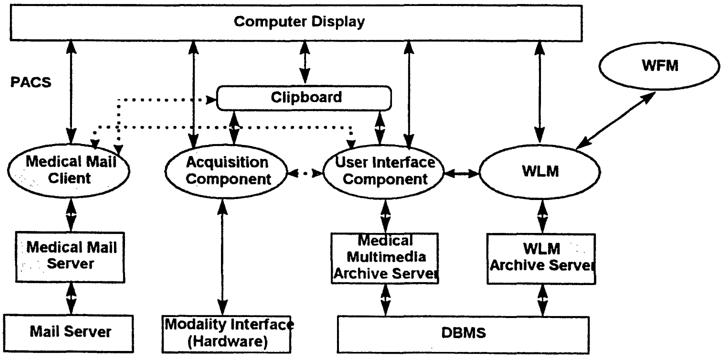

Figure 1. The PACS Architecture.

tates both the referral and the reporting process, automating medical acts by means of the WFM.

8. Teleconsultation Services

Bearing in mind that health care is an important telematics application domain, the CMI-HTA of ICS-FORTH is developing a scaleable architecture and reusable tools for the integration of domain-specific autonomous information systems. As part of this effort a simple multimedia communication component through electronic mail, for remote opinion request, has been developed. Asynchronous teleconsultation is achieved through the exchange of medical content Messaging Application Programming Interface (MIME) attachments over the Simple Mail Transfer Protocol (SMTP). This service has already been integrated with the PACS application, as shown in Figure 1.

Synchronous consultation between the radiology department and the ICU is supported by the CoMed application [6], also developed by CMI-HTA, ICS-FORTH. CoMed is a desktop medical conferencing application that allows for interactive real-time co-operation among two or more conference participants.

9. Discussion

An architectural framework for the development of an integrated hospital information system is being evaluated with the IHIS project. Although a single hospital is autonomous and devoted to the delivery of a particular set of services, the desirable continuity of care requires that different medical centres, offering complementary services and different levels of expertise, exchange relevant patient data and operate in a co-operative working environment. The sharing of information resources is generally accepted as the key to substantial improvements in productivity and to better quality of service.

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