Realizing a Realtime Shared Patient Chart using a Universal Message Forwarding Architecture

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Abstract

The goal of this paper is to describe the clinical needs and the informational methodology which led to the realization of a realtime shared patient chart. It is an integral part of the communications infrastructure of the Patient Data Management System (PDMS) ICUData which is in routine use at the intensive care unit (ICU) of the Department for Anesthesiology and Intensive Care Medicine at the University Hospital of Giessen, Germany, since February 1999. ICUData utilizes a four tier system architecture consisting of modular clients, message forwarders, application servers and a relational database management system. All layers communicate with health level seven messages. The innovative aspect of this architecture consists of the interposition of a message forwarder layer which allows for instant exchange of patient data between the clients without delays caused by database access. This works even in situations with high workload as in patient monitoring. Therefore a system with many workstations acts a blackboard for patient data allowing shared access under realtime conditions. Realized first as an experimental feature, it has been embraced by the clinical users and served well during the documentation of more than 18000 patient stays.

Keywords: Intensive care, computerized patient record, patient data management systems, networking, Health Level 7

1. Introduction

In 1998 the head of the Department for Anesthesiology and Intensive Care Medicine at the university hospital of Giessen, Germany decided to replace it's running PDMS with a new one that was more adapted to the informational needs of a German hospital especially in the fields of statistical data analysis. The system which is described here is called ICUData and has been developed by a small local company (IMESO GmbH, Hüttenberg) in close cooperation with the Department of Anesthesiology and Intensive Care Medicine. The goal of the ICUData project was to develop a cost efficient and highly modular PDMS for intensive care units in both large and small hospitals based on today's standard technologies. From the start of the project it has been very clear that ICUData should allow for the integration of all relevant patient data within its clinical database to support detailed online statistical analysis and medical decision making using clinical reminders. With regard to this concept ICUData stands in the tradition of some well known HIS like
HELP [1,2], Regentreat [3,4] and Columbia University [5,6].

2. Materials and Methods

Clinical medicine as a whole and especially intensive care medicine is a highly cooperative tasks which requires the coordinated and shared work of multiple persons of different medical specialties. These persons are often working at different locations within a hospital. The patients continuous treatment requires decisions that should be based on accurate, complete and actual information. It is one of the most important benefits of an electronic patient record that it allows for simultaneous access by many interested users independent of their different physical locations. Nevertheless conventional forms oriented clinical information systems limit the scope of this data access to a relative small number of data items. Also traditional user interface programs need to poll against the database if they want to get the actual state of its data content. This continuous polling can result in serious performance degradation of the clinical database. It becomes especially difficult in the complex monitoring environment of intensive care medicine with it's massive amount of rapidly changing data. Due to the fact that the quality of clinical decisions lives from both the amount and actuality of visible data it was a central goal of ICUData to overcome the limits of form based data display and continuous database polling. ICUData's graphical data chart is designed for a simultaneous display and access to all clinical data groups and instant propagation of all changes in the patients data pool to all interested medical staff.

Figure 1: The Four-Tier-Architecture of the PDMS

The basic architecture of ICUData (Figure 1) is a message based four layer client server architecture with message forwarders and application servers interposed between the user interface clients and the relational database management system (RDBMS). ICUData currently utilizes an Oracle RDBMS [7] running on Windows-Server 2003 for its
permanent data storage. All message flow between the ICUData components is accomplished using TCP/IP as transport layer and HL7 [8] as a presentation layer. ICUData uses three different logical databases which may also be physically separated over different computers; patient administrative data (ADT), system administration data (ADM) and patient clinical data (LAB). Each application server accesses only one logical database and resides normally on the same computer as the physical database to optimize data throughput. The client layer is also modularized consisting of the authorization and patient management module (ICULogin), the graphical patient chart module (ICUFiles) and a couple of medical device interface processes (MDIP). The basic task of these MDIP's is to transform the vendor dependent content of the medical device data which is received over serial communication interfaces to standard HL7 laboratory messages which could be handled by the ICUData application servers. It's a basic characteristic of ICUData's overall design philosophy that the database design especially for clinical patient data is rather trivial. It currently consists of only two tables which closely resemble the structure of a HL7 laboratory message consisting of header and detail data segments [9]. Also the application servers are rather primitive because their only task is to insert the received HL7 messages into the database or execute HL7 query's. All relevant work regarding to data organization, data manipulation and data presentation is handled within ICUData's object oriented client modules. This has the great benefit of being able to take full advantage of both the logical power of object oriented program design and the computing power of modern workstations. As a result of this strategy, every client module and particularly the graphical patient chart module (ICUFiles) contains always a complete picture of all patient data for its particular domain and a defined timeframe. It is loaded during the startup phase of the program. After the initialization has completed the ICUFiles module has only two ways to expand its actual data set:

- if the user enters new data or manipulates existing data values
- if it receives patient specific data from another data source (e.g. second ICUFiles module which has the same patient open or MDIP receiving monitoring data Mean arterial pressure (MAP) and heart rate

To accomplish data updates from other sources without actually polling the database the ICUData architecture introduces a fourth level of communication between the client modules and the application servers. It's called the ICUMaster communicator. The ICUMaster communicator realized as a Windows service without a user interface. It acts as a universal message forwarding instance. No client server communication can take place without passing an ICUMaster communicator process. The ICUMaster communicator actually gets it's knowledge about the location of specific clinical database services (which are work units within a specific application server) from a configuration process called ICUMapper. Requests to the ICUMapper are realized as UDP broadcasts. Therefore multiple copies of the ICUMapper could coexist within a network as long as they are sharing a coherent view of system resources. This allows for dynamic relocation of database services without any visible interruption.

The interposition of the ICUMaster communicator into every message flow also opens the way for the most important side effect of this architecture; the realtime shared patient chart. The key to this feature is the introduction of the logical concept of a patient master communicator and related "enter shared communication" messages. The patient master communicator is the ICUMaster communicator which resides on the bedside machine of a patient. Within the overall ICUData communication architecture the patient master communicator takes the role of a centralized forwarder for all data messages related to this specific patient. Any patient chart module residing on another machine at the network can register itself at the patient master communicator by sending an "enter shared
communication" message to it. After this registration any message which flows through the patient master communicator (e.g. vital signs monitoring data, user entered data) is also passed to the client module which issued the "enter shared communication" message. The message must be renewed every minute to detect client modules that might have crashed. If the client module on another machine has finished it's activity, it normally terminates the communication with the patient master communicator by sending a "leave shared communication" message. Using this messaging technology the data image of all open patient chart modules could be easily synchronized in realtime. This means that any monitoring data that arrives at the patients master communicator is immediately displayed on all client machines that share the virtual chart. Also if any user drags a data item over the patient chart at one machine the dragging is visualized at all registered machines within the virtual data pipeline in realtime without any polling to the database servers. As a result multiple users may share the same virtual patient chart throughout machines at different locations in the hospital using it as a blackboard for the communication of their patient related decisions.

3. Results

The initial release of ICUData system has been introduced at the surgical ICU unit in February 1999 after one year of development. This short development time was only feasible because all members of the team had some years of experience in developing either hospital information systems [10, 11] or anesthesiology information systems. Since that time more than 18,000 patient stays have been fully documented using ICUData. Most of the strategic data for patient treatment could be moved to the electronic patient record so the need for paper based documentation could have nearly been eliminated. This was only possible through the tight integration of other major HIS resources like central laboratory, microbiology and radiology and even the close coupling to the anesthesiology information system which guarantees an uninterrupted data flow during the surgical treatment of a patient [12]. Especially the data integration benefits from ICUData's strong communication oriented basic architecture. Until now ICUData has also been introduced into the other 5 ICU (interenal medicine, pediatric and neonatology, neurology, neurosurgery, cardiac surgery). Also a intermediate care unit for internal medicine, a ward for pain treatment and two outpatient clinic have been equipped. Throughout all this installations ICUData's ability for realtime sharing of the electronic patient chart (EPR) has been welcomed by the users. The main reason for that may be that the informational model of ICUData is based on an order-performer approach which is strongly supported by the realtime communications aspects of the EPR. Also the basic task of overlooking the data of all patients through the attending physician is simplified because it's possible to put multiple patient charts on a single machine and watch for all the incoming data in realtime. With regard to this aspects the ability for realtime sharing of the electronic patient chart has become an indispensable feature of ICUData in the minds of most users.

4. Discussion

Until now we have detected lots of triggers within the overall systems state that are not directly related to a single patient and therefore not handled with our current forwarding mechanism. These are events like patient bed swaps, patient admissions etc.. We plan to forwarded them by introducing the new instance of a ward and even departmental master communicator. Handling the propagation of these events using a message forwarding architecture could dramatically reduce the frequency of related database requests by simultaneously increasing the correctness of data on all machine's.
5. Conclusion

Whereas the implementation of the ICUData master communicator was an integral part of the ICUData communications architecture to allow for multiple client modules, the project of a shared patient chart has been considered at the first glance as somewhat exotic and experimental for the initial release of ICUData. Surprisingly this exotic feature became very rapidly a central part of the end users daily work exposing some reliability and performance problems of the software. Once accepting the strategic role of this feature the problems could be fixed within the next two months of practical use. Since June 1999 the shared patient chart works rather well and has been established as an integral part of the daily work.

6. Acknowledgements

The authors thank the members of the ICUData developer team of the IMESO company for there support and critical review during the preparation of this article.

7. References

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