Interconnection of Laboratory Information System and Hospital Information System. The case of ARETEION University Hospital

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Abstract: - The integration of existing, separately operated Information Systems, which have been established to cover the needs of the same Hospital, is a complex and difficult problem to be solved. "HELIOS", a Hospital Information System and "MediLab Lims", a Laboratory Information System, were, separately, purchased and installed at the ARETEION University Hospital of Athens. In this paper, the integration problem of those separate Information Systems is analyzed and possible solutions are briefly described. Then, the interconnection of those separate information systems, their integration in a unified new system and our experience / evaluation are discussed.

Key-Words: - Hospital Information System, Laboratory Information System, System Integration.

1 Introduction

ARETEION University Hospital (AR.UN.HO) of Athens is the Hospital of the University of Athens. It was established in 1898 and has three clinical departments: Surgical, Obstetrics and Gynecology and Nephrology. In these departments, medical education takes place. Clinical interests of Surgical Department are: General Surgery, Transplantation, Vascular Surgery, Surgical Oncology, Hepatobiliary and Pancreatic Surgery. Clinical interests of Obstetrics and Gynecology department are: Obstetrics, Maternity, Gynecological Surgery, Neonatology, Gynecological Oncology, Fetal Maternal Medicine, Gynecological Endocrinology, Adolescent Gynecology and corrective gynecological surgery, Gynecological Urology, Menopause, Recurrent Abortion and Assisted Reproduction.

In 1995, "HELIOS", a large scale Hospital Information System (HIS) was purchased and installed in AR.UN.HO. In the same time, "MediLab Lims", a medium scale, Laboratory Information System (LIS) was also installed and separately operated.

1.1 The "HELIOS" Hospital Information System

The "HELIOS" HIS, developed by the Greek company "Intrasoft", is a general purpose Information System covering needs of Hospitals. The design of the system has tried to cover many aspects and various daily activities of a Hospital. There are many fields and detailed information included in the patient record but the system does not support the handling of the laboratory tests. The use of the system is often confusing for our non experienced end-users, especially, in the case of details (fields) which are not applicable to the specific needs of some departments. The values of many fields of the patient care record have also to be chosen from specific domains of predefined (and stored in the system) values. In other words, the physicians using the system do not usually type the value of the field: First, they have to see a list of predefined values; second they have to select the appropriate value from the list. This approach simplifies and standardizes the retrieval of patient care records and the extraction of statistical information. However, data entry is often more complicated and confusing for novices.

The "HELIOS" HIS is based on the Relational Database Management System "INGRES" and follows / adopts the client / server architecture. The clients' interface is graphical and operates on Microsoft Windows 9x, NT and 2000.

1.2 The "MediLab Lims" Laboratory Information System

The "MediLab Lims" LIS, developed by the Greek company "Computer Control Systems" (CCS), and supports unidirectional and bi-directional communication between the laboratory analyzers and the LIS computers:

- Unidirectional communication is necessary when analyzers, performing the same predefined set of examinations for each biological sample, are used. In this case (of the unidirectional communication), only results from the analyzers are transferred into LIS database through LIS client computers.
- Bi-directional communication is related to the Programmable analyzers, performing a different set of laboratory tests for each biological sample. In this case, the computers of the LIS communicate with and control the analyzers asking the appropriate set of examinations for each sample. Then, the results are transferred from analyzers to LIS computers (reverse direction).

The new versions of "MediLab Lims" LIS were ordered, installed and operated, in 1999. This new version adopts a Graphical User Interface (GUI) instead of the previous text based one and replaced the record and file based data storage with the Relational Database Management System "Microsoft SQL Server".

1.3 The rationale for systems' interconnection / integration

Lenz, Blaster and Kuhn [1] present the advantages of Healthcare information systems' integration. However, there are some tradeoffs and alternative strategies of integration must be evaluated. Lenz and Kuhn [2] summarize the state of the art in web technology and compare it with the needs of Hospital information systems' integration. They conclude that true integration takes more than transparent access to heterogeneous information systems and it is important to find a common ontological basis for future component based systems.

In AR.UN.HO, the integration or even the simple interconnection of the two Information Systems (HIS and LIS) was decided for four reasons:

- It was impossible to improve the management and support decisions without having a common pool of "unified" data. Even simple statistics and summary information are difficult to be extracted without an integrated system.
- It was obvious that, there was a serious need to keep laboratory results into health care records for supporting the clinical work.
- It was very difficult to control, in a daily basis, the relationship of the patient record with the laboratory results.
- There was also a (financial) need to decrease / eliminate the number of laboratory tests carried out, by mistake, without patients' debit.

In this paper the interconnection (and the integration) of the two separate systems is presented and discussed. As we can see, in the following section 2, the interconnection was selected to:

- transfer orders from HIS to LIS
- transfer results from LIS to HIS.

Next sections discuss our first estimations for the acceptance and use of the new "integrated" Health Care system. Future activities are also presented.

2 Materials & Methods

The integration of operational, separated Information systems, which have established to cover the needs of the same enterprise, is a difficult problem, in general. A solution, today, not only is related to well known methods and techniques of system analysis but also have to take under consideration new concepts and tools: data warehousing, data mining, Document Management tools e.t.c.

According to Ullman and Widom [3] (p. 20) the solution of the problem could be outlined as following: Divisions of an enterprise may have invested large amounts of money in their ("legacy") systems (and databases) before integration. For these or other reasons, these systems can not be replaced easily. Thus, the enterprise must build some structure on top of the systems. That is the "creation of a data warehouse, where information of many databases is copied to a central database."

Date [4] (p. 709), writes that Data warehousing arose for two reasons: First, the need to provide single, clean, consistent source of data for decision support purposes; second, the need to do so without impacting operational systems.

Elmasri and Navathe [5] (pp. 853-6) summarize a series of difficulties of implementing data warehouses and an emphasis is given to the fact that the design, construction, and implementation of the data warehouse is an important and challenging consideration that should not be underestimated: "The building of an warehouse is a major undertaking, potentially taking years."

The complexity of such a solution (and financial restrictions) drive us to a simplified (and cheap) planning and implementation of the new system. Hence, only the interconnection of the two systems was selected to ensure that:

- Laboratory test orders from HIS have to be sent to the LIS
- The test results from the LIS have to be stored back into HIS.

More precisely, the solution selected was to store laboratory examinations' orders, firstly, into HIS database instead of storing them, directly, into LIS.

Then, HIS will, automatically, transfer laboratory test orders into LIS. The laboratory examinations can not be carried out without patient debit and laboratory results have to be transferred back into HIS system.

Both systems are based on Relational Database Management Systems (RDBMS) for storing their data. Since LIS was more oriented to laboratory tests, the LIS coding schema for laboratory tests was adopted by the HIS. Having a common coding schema for the identification of laboratory tests in both systems the interconnection was simplified. The transfer mechanism was implemented as a "daemon", a process that runs continuously, and reads and writes to both HIS and LIS databases.

2.1 Types of analyzers

The Analyzers could be classified into four types according to the set of tests they perform and the way they communicate with Computer Systems.

- Batch Analyzers with unidirectional communication perform the same predefined set of tests for every sample and have the ability to transmit, only, results.
- Batch Analyzers with bi-directional communication perform the same predefined set of tests for every sample and have the ability to transmit results and also to receive orders (based on the identifier and the name of patient, e.t.c.).
- Random Analyzers with unidirectional communication perform a different set of tests for each different sample and have the ability to transmit, only, results.
- Random Analyzers with bi-directional communication perform a different set of tests for each different sample and have the ability to receive orders (based on the identifier of the sample and the set of tests to be performed) remotely and transmit results.

In AR.UN.HO there are:

- *Batch Analyzers with unidirectional communication*
- *Random Analyzers with bi-directional communication.*

In the case of *Batch Analyzers with unidirectional communication* the results submitted by the analyzers remain unmapped in the LIS client. It is the operators' duty to fill a table which is used to map the analyzers' sample identifiers (the serial numbers of cups in the analyzers) to LIS sample identifiers.

In the case of *Random Analyzers* the orders, forwarded from HIS to LIS, are available on the screen of the LIS client computers. The operators' duty is to type (on the LIS client) the analyzers' cup numbers where the samples have physically been placed. The rest of the process is automatically performed by the LIS software, which controls the analyzers to perform the requested tests, for each sample, and then receives and stores the results.

2.2 The laboratories

There are four Clinical Laboratories in AR.UN.HO. Table 1 summarizes the total number of analyzers and the number of interconnected ones (to the LIS) for each Clinical Laboratory.

In Microbiology & Biochemistry Lab, only, the Clinical Chemistry section is already interconnected with LIS. In Hormone Lab the integration of Analyzers with LIS have been established. In Hematological Laboratory the Interconnection of Analyzers with LIS is established but people are not completely trained. Nephrology Lab has the same problem as Hematological Lab. There is a plan to completely automate these two labs in the next few months. Tables 2 and 3 depict the workload of the laboratories for specific time periods.

3. Results and Discussion

Apart from the fact that there are two interconnected Information Systems we shall use the term new, "integrated" system. Our first estimations and the evaluation of the success rate (of the "integrated" system) are interesting: The technical credibility / validity of the new system looks excellent. However, the acceptance and use of the system by users is rather controversial. It is the well known problem: People do not like to change their way of doing things.

Some physicians prefer to go to the laboratory in order to get a hard copy of the results instead of using their computer, in the clinic, for a printout. The worst case is that some people in the lab do not want to use the LIS and prefer to program the analyzers manually. Therefore, it is important to train our personnel to change their working habits in order to solve this problem

Another major problem is the "negation" (difficulty) of nursing personnel to use the HIS and also type the requested orders for lab tests. It is a well known problem in the bibliography and can be outlined as following: "Nurses ... carry a heavy administrative burden, much of which can be computerized. Users ... have very specific needs because of a lack of previous exposure to computers and a reluctance to change working habits" [6].

Use of secretaries and the employment of data entry personnel have partially solved the problem.

Now, the nursing personnel put checkmarks to preprinted forms / lists of all available tests and then the lists have to be forwarded for data entry. This intermediate step uncovered some problems:

- The first problem arises when a nurse sends a sample to lab and forgets to forward the list for the data entry. Then, these orders are not transferred to the LIS and are not available to the LIS user monitors.
- The second problem is encountered when a list is passed for typing, by mistake, the next day of the (tests') requested day. Then, there are orders available to the LIS users monitors but there are not samples in the lab.

Another problem was encountered in the case of new patients coming into the Hospital. The physicians, often, order laboratory tests earlier than the time the patients' relatives visit the reception office to give the necessary information to create a new patient care record. In such a case, there is a period of time where there are laboratory test orders that can not be typed into HIS. Hence, these orders could not be done in the laboratories.

As a general conclusion describing our experience: "The more automation is established the less deviations (from the specified way of using the system) are allowed."

4 Conclusion and Future activity

The given solution of the interconnection problem is technically simple and reliable. However, there is a serious disadvantage. Our approach offers a proprietary solution related to the specific separate Information Systems. If we want to add to our "integrated" system the functionality of a third Information System to cover new emerging needs we must solve the same interconnection problem again. Analyzing this situation we have studied the Health Level Seven (HL7) standard [7-9] which seems to offer new possibilities in solving the interconnection problem.

This HL7 standard is designed for electronic data exchange in healthcare environment. The standard, currently, specifies the interfaces among the systems sending / receiving various types of data: patient admissions / registration, discharge or transfer data, queries, resource and patient scheduling, orders, results, clinical observations, billing, master file update information, medical records, scheduling, patient referral, and patient care. HL7 is designed not only to support a centralized patient care system but also to serve a distributed environment where data resides in departmental systems. It was a key question / discussion, in the analysis and design phase of the interconnection of the two systems (HIS and LIS), if we could use HL7 messages as a pathway for information exchange between the two systems. Unfortunately, HL7 is not supported by 'HELIOS" (our HIS). Hence, the only possible way to exchange information between the two systems was the usage of the "daemon" program that can read and write data from / into both HIS and LIS databases. Some new products [10, 11], that provide HL7 integration solutions to "legacy" Healthcare systems, were released. In the future, there is a plan to improve our HIS in order to support HL7 messages (and other features).

As a conclusion, and from a technical point of view, the interconnection of HIS and LIS in ARETEION Hospital was implemented, successfully. Some improvements could be done in the future. However, the use of the new "integrated" system is controversial, now, and much work has to be done for the desirable improvement of cooperation between Laboratory and Clinical departments.

More precisely, the following main needs could be extracted / specified:

- There is a major need for an essential involvement of the top (and not only) management to influence the final acceptance and use of the integrated system. Since, 1995, the Information System has been widely used only for supporting financial needs (accounting, suppliers, etc) and, partially, as a general tool for some secretarial assistance of the doctors and the lab staff.
- "The more automation is established, the less deviations are allowed". New tasks, the way of doing things, etc., have to be clear. Advantages have to be analyzed and discussed, in depth.
- "People have a reluctance to change their working habits". We must support them.
- Nursing personnel have difficulties in using the system. The use of secretaries and the employment of data entry personnel seems to partially solve the problem, but it is also a source of possible mistakes. Some procedures have to be re-designed.
- Fortunately, nurses are rather familiar and use the forms including all the available laboratory exercises. They have just to put checkmarks to the appropriate tests. Hence, a possible next step is to use palm computers for the same task, to automate data entry and reduce possible errors.
- Proprietary interconnection demands the solutions of the same problem each time we want to interconnect a new, system to the integrated

Health Care environment. There is a need for a general solution of the integration problem.

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[11] www.neotool.com

Table 1. Number of Analyzers per laboratory

Laboratory	Total Number	Interconnected	Actually used
Microbiology & Biochemistry Lab	6	4	3
Hormone Lab	5	3	3
Hematology Lab	3	3	2
Nephrology Lab	4	3	1

Table 2. Number of orders (samples) per laboratory and various periods

Lab	1st quarter 2001	1st quarter 2002	4th quarter 2002	1st quarter 2003	Whole 2001	Whole 2001
Hematology	621	696	871	1242	2337	3032
Hormone	1695	1637	1762	2093	6090	6725
Microbiology & Biochemistry	1753	1769	2086	2008	6050	7466
Nephrology	10	53	98	144	65	275

Table 3. Number of tests ordered and performed per laboratory and various periods

	1st quarter 2001		1st quarter 2002		4th quarter 2002		1st quarter 2003	
Lab	Ordered	Performed	Ordered	Performed	Ordered	Performed	Ordered	Performed
Hematology	7470	0	9353	0	11683	0	23118	0
Hormone	5449	5449	5668	5667	6891	6891	7538	7509
Microbiology & Biochemistry	61464	2060	60342	0	70737	0	69890	0
Nephrology	147	0	829	0	1310	636	1993	1650