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Evolution of an Integrated Hospital Information System

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Abstract. In 1991, when the planning phase of the SIR (Rehabilitation Information System) project started, the management and IT professionals of the "Salvatore Maugeri" Foundation were convinced that the development of their Hospital Information System should be an evolutionary process based primarily on integration. This turned out to be the case and a vital requisite in order to make the complex effort worthwhile in terms of investment protection, cost/effectiveness and user-needs satisfaction.
First steps were the design of a suitable model and identification of the available standards in hardware technology, networking, operating systems, database management systems and repositories, user interfaces and development tools.
By the end of 1994 the aims of the second phase of the project had been achieved: namely, the deployment of system procedures in 65% of the planned Operative Units belonging to 4 of the 9 Institutes of the Foundation; their full use, so as to cover the complete activity pertaining to each Unit; the reengineering of obsolete applications; and the interface between HIS and external, strongly autonomous multi-vendor subsystems.
The current phase regards both the enhancement of data structure integration and the improvement of user-interface homogeneity and friendliness, while the next goal will be the realization of a multimedia clinical workstation.
The results obtained so far prove the validity of the initial choices: the whole process has not been easy nor fast but it has shown itself to be possible and the pathway followed seems to guarantee the conversion to total openness, this being the main future trend of the HIS market.

1. Historical overview

Managers of the "Salvatore Maugeri" Foundation, with its 9 Institutes involved in rehabilitation (cardiac, respiratory disease, neuromotor) and primary treatment (oncology, nephrology) concerned with both patient care and scientific research, have been expressing the need for efficient and effective information systems able to support an ever-increasing number of functions since Health Care industry became the complex reality of today.
Consequently, in 1991 the decision was made to start the Hospital Information System project nevertheless, though the revolution involving information technology would have made it advisable, perhaps, to wait until it had settled down in order to profit from the latest results [6], but certainly without underestimating the efforts needed and with an open mind towards any useful innovation.
The keynotes which characterized the project were: *gradualness*, to limit the costs of human and technological resources and to dilute the inevitable functional reorganization involved without upsetting the current situation or giving up the target of optimization; *integration*, to fulfil the need for global communication and to link different but complementary information sets (administrative, financial, clinical); *openness*, to protect existing software investment, to reduce maintenance costs and to be flexible enough to be interfaced with new products regardless the variety of suppliers [3]; *in-house development*,

to make up for the lack of suitable commercial systems and to take advantage of the close interaction between IT and Health professionals for the assessment of real user-needs, trying to maintain accuracy of information and safeguard local peculiarities. By the end of 1995, the System was working in 65% of the planned Units in 4 Institutes of the Foundation. In the Rehabilitation Institute of Veruno alone (300 beds with an average of 4000 admissions per year and site of the pilot Operative Unit, the Cardiology Department, since 1992) more than 28,000 patients, 16,000 admittances and 53,000 examinations had been recorded [2].

2. A Standard Open Technical Infrastructure

In order to compensate for the absence of general directives concerning the technological framework to be adopted for HIS production, industrial 'de facto' standards available on the international market were chosen with a strong commitment to make the evolutionary process feasible enough.
In detail:

- ETHERNET, TCP/IP Local Area Network with NFS as the distributed computing file system; for the adequate transmission of high resolution medical images, the upgrade of active equipment and the network segmentation are foreseen in order to move from the current bandwidth of 10Mb/s to an effective data rate of 100Mb/s.
- UNIX for servers, MS-DOS and MS-WINDOWS for user-workstations.
- INFORMIX database, a widespread relational DBMS based on SQL language; we started with SE, a simpler and less optimized version compared to the current ONLINE release, which requires more complex administration but gives better performance, supplies an embedded data mirroring facility, extends the range of data-types to BLOBS for the storage of images and documents and is structured for total distribution.
- Mini-computers as system servers and database repositories (HP9000-E35, HP9000-832, HP9000-807, SUN-sparc1+); PC's (80386, 80486, Pentium 75/90, 4/8/16 Mb RAM) as user-workstations.

Moreover, although five years ago the adoption of the client-server philosophy would have been considered a risky undertaking, the predicted potentialities and the opportunity to achieve better results at lower cost convinced us of the opportunity of such a choice.
In the light of our experience, the investment had paid off, in conformity with current international specific recommendations: in fact, according to expectations, the application of this architecture has made it possible to limit network traffic principally to sending/receiving SQL messages, to gain in performance with a complete computing capacity distribution and to easily replace the older workstations with the more powerful and up-to-date ones available (see MS-WINDOWS environment and Pentium processors).

3. A Modular Patient-Oriented Functional Model

According to the evolutionary strategy, the model chosen for SIR was based on the concept that a 'Computer-based Patient Record System must be designed with the patient as the center piece' [7] in order not only to carry out an horizontal approach to information but also to be ready for the transition (much aspired to) from Hospital Information Systems to nationwide Health Information Systems.
The global functionality can be described as a cooperation between autonomous Operative Units (Wards, Divisional Laboratories, Diagnostic Services, Physical Training Units, Administrative Services) that consider the patient as their joint element [1]. The accomplishment of the individual tasks of each Unit and the consequent input of the related non-overlapping data (admission, medical history, events during the hospitalization period, examinations, discharge, follow-up) contribute to the step-by-step construction of the computer-based patient record.

The definition of both the procedural scheme and the minimum common data set, right from the initial stages of the project, has been fundamental for the adopted modular approach: predefined rules in terms of technical, functional and data integration standardize the addition of a new Unit to the System and maximize the re-utilization of all the convenient available modules, with considerable time saving in software production.

4. Enhancement of Data Structure Integration

It is undeniable that the data base design phase was principally influenced by clinical and scientific research activities which are carried on in our Rehabilitation Institutes.
Because the cyclical nature of rehabilitative therapeutical programmes implies a high percentage of recurrent admittances (about 45% of the total), careful attention was paid to the design of specialized data structures (Fig.1, Encounter List: a lifelong list of admissions and examinations concerning each patient) which could allow fast and easy chronological reconstruction and consultation of complex clinical histories.
A detailed and accurate data collection (287 relational tables, for a total amount of 4308 numeric, coded and textual variables), which is an indispensable condition for research purposes, was made easier by the limited number of treated pathologies. Coded information is principally collected in Laboratories and, with the exception of ICD9-CM codes, coding methods follow an internal standard.
Notwithstanding the attention in variables definition, a recent investigation among physicians, which was also borne out by objective statistics on data usage, showed that a significant percentage (15%) of detailed data turn out to be less useful than expected and that the same registrations can be more conveniently carried out in the form of free text; moreover, it has to be considered that a restricted number of variables generally encourages users to completely fill in the electronic forms with a consequent improvement of data reliability.
Milestones of data integration have been taken into account: the same data are recorded only once and stored in a single logical repository; only after electronic validation do they become available to all authorized users in different functional-dependent views [4].
Only proprietary external subsystems (see Clinical Chemistry Laboratory) do not share the common database but they communicate with SIR by means of special interfaces based on a minimum data set defined for this purpose.
In order to avoid unpleasant rewriting of the same information, a particular table called 'Dictionary', which can be defined as a controlled vocabulary containing the agreed translation into natural language of each variable, is used to produce medical reports and discharge letters: related documents, eventually completed with the aid of an integrated standard word processor, are saved as files.
Starting from the principle that 'the way in which data are organized and stored is as important to usage as the way in which they are represented' [8], a partial upgrade of the data base framework is in progress towards total integration and performance enhancement.

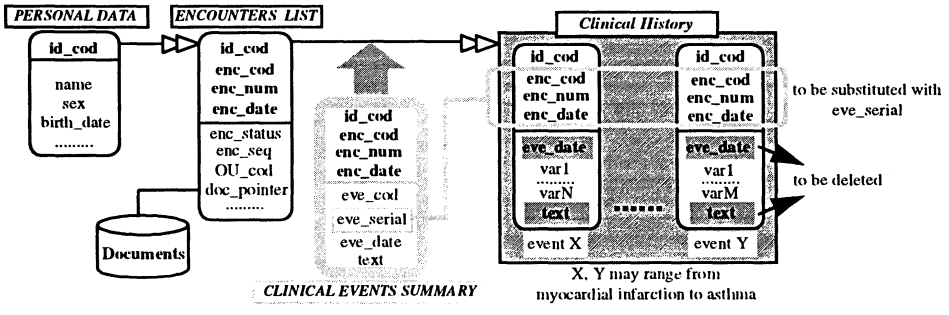

Fig.1. A new data set providing total integration and performance enhancement.

The proposed solution is the introduction of a special table (Fig.1, Clinical Events Summary) which will act as a unifying factor in the pre-existing scheme of clinical history, which is composed by a set of tables each related to a specific clinical problem.
It will be sufficient to access this new data set in order to reconstruct each patient's clinical condition regardless of the structural differences among the numerous tables that collect clinical events; besides, there will be no loss of information because the 'text' variable in the 'Clinical Events Summary' contains not only optional notes but also the exact translation of all coded and numeric variables (Fig.1, var1 to varN) in the 'Events' tables.
At the end, the detailed collection will be used only for data entry and select procedures: the evident redundancy (both the coded and textual forms of the same data are stored) is the price to pay for flexibility.

5. Improvement of User-Interface Effectiveness and Friendliness

A well-designed user-interface has always been a major challenge for software specialists especially when target users are as demanding for versatility and effectiveness as health care personnel: in the clinical setting a great number of difficulties are correlated with the large number of different tasks, different needs and different individual preferences, and the main problems arise when attempts for standardization are considered as constraints.
Trying to limit failures, we involved end-users in the development process, so as to better assess their real needs, to evaluate capabilities and levels of expertise and to increase their satisfaction by providing as many benefits as possible.
Up to the first half of 1994 we used a development tool (INFORMIX 4GL RDS for MS-DOS, the original program language of the adopted database) for the production of character-based user-interfaces.
As a consequence, we directed our attention principally to ease of use, learnability and consistency of style and terminology. But the results, although promising, were not up to the effort: the method for recording and consulting information based on schematic forms, even if supported by contextual menus, on-line helps, alternative input modalities such as bar-code readers and the integrated word-processor, were not as efficient as expected and, apart from repetitive and clerical tasks, some timeless and binding procedures seemed even worse than the equivalent manual ones.
This critical phase has been overcome with the long-awaited move towards modern operating systems and development environments such as MS-WINDOWS and PowerBuilder, a top-level tool for designing Windows compliant applications typically oriented to database management.
The graphical screen layout has been arranged in order to minimize navigation and scrolling of electronic pages, to place the largest amount of data at the user's disposal in a single frame and to keep the right balance of windowing, which can be found confusing when it exceeds a certain limit.
MS-WINDOWS itself has played a key role in the standardization process not only by proposing a universal style of working which can be applied in user-interface development, but also by providing an open environment for different third-party medical software.
The idea of embodying a predictable behaviour in the SIR user-interface to make it intuitive and easy to learn has been forced upon us by the expensiveness and the time-consuming nature of end-user training, especially for those unused to human-computer interaction, such as nurses and technicians: expressive icons and prepared lists of patients to be treated are two examples of such adaptation.
On the other hand, physicians have always wished to use both interfaces more similar to their mental model than the conceptual model proposed by IT professionals [5] and equipment able to simulate the 'pen and paper' method: in fact, those devices are still regarded by the majority as the ideal tool in terms of flexibility and usefulness and do not represent an

uncomfortable barrier between doctor and patient as the traditional workstations. The feasibility of a note-pad solution was evaluated but the available products were too expensive and would have required a greater amount of programming than could be justified; consequently, much time has been spent in the study of a meaningful substitute, or metaphor, for the paper writing-pad: the first example of the projected metaphor, enriched with contextual helps for writing out of free but controlled text, is in use in the Cardiology Out-patient Surgery of the Medical Center of Veruno with fairly good success. Obviously, the final goal is to migrate to real pen-based technology as soon as this becomes feasible, i.e. when cheaper and more portable equipment is available as predicted.
In the context of a specific project concerning the assessment of the global quality of SIR procedures, the validation of efficiency, learnability, likeability and usefulness of the user-interface is in progress with the aim of collecting meaningful results and suggestions for the formulation of future-applicable general guidelines.

6. Towards a real multimedia clinical workstation

Along with the completion of SIR deployment, short-term plans concern the following:

- the storing and sharing of medical images;
- the introduction of smart cards in order to speed up patient data-handling in time-critical Operative Units such as Physical Training Units;
- the adoption of note-pad technology to provide an effective solution to physicians' needs for convenience and mobility especially when they are involved in asynchronous activities such as the prescribing of therapy;
- the use of voice input systems, which will certainly prove a valid alternative for speedy and hands-free data entry when they become speaker-independent and able to understand extensive vocabularies at normal speech speed.

7. Conclusions

According to our experience, the following conclusions can be underlined:

- a Hospital Information System must follow the evolution in technology and medical knowledge if it is to prove itself up-to-date and effective in fulfilling its mission: the costs of this never-ending development process have to be taken into account since the planning phase;
- the impact of the introduction of new technologies can be softened by both careful advance planning and the adoption of hardware and software standards;
- an almost sure failure could be avoided only if users believe in the benefits that such a system can provide and if results are up to expectations.

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