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Accessing to electronic medical history using a mobility intra hospital system

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Abstract— **The aim of this paper is to describe the solution that has been developed in Valencia Region (Spain) to provide health professionals (physicians and nurses) access to all the functionalities of a Hospital Information System (HIS) already available at fixed clients workstations. These functionalities are adapted to the care process carried out at patient bedside. In this way, professionals will have access to treatment and administration, recording of vital signs, nursing assessment, scales, care plan, extractions, medical records, progress notes so that they have all necessary information at the bedside, and record swiftly changes that occur in-situ. In addition, clinical safety is reinforced, including RFID patient identification mechanisms and barcode readers for blood samples or unidosis medication.**

I. Introduction

Valencia Regional Health Department has developed its own hospital information system (HIS) and electronic health record (EHR) called Orion Clinic (1). On the top of the HIS we have implemented a mobile client to provide access to all HIS services elsewhere in the hospital on mobility. The main objectives of the system are:

- To provide mobility to the health worker: allow access to professional and record information related to the care process at the bedside of the patient, adapting the existing functionality on the desktop client to the needs arising from this scenario and to the devices which it will interact with (nursing carts, bedside TVs, Tablet PCs, etc.).
- To improve clinical safety: in-hospital care processes are scenarios where clinical errors are frequent. These errors can be detrimental to patient's health, while producing an additional cost to the hospital (2) (3). The aim of the mobile client, used in process, which are potentially risky to clinical errors, is to provide mechanisms for verification and warnings to detect and prevent errors before they occur.

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II. Materials & methods

A. Functional Analysis and Usability

The design and analysis of the application is addressed in two directions: for the medical staff to carry out their tasks within the process of care at the bedside, and to redesign and optimise these processes incrementing the global efficiency. This modeling process will always be determined by each hospital to suit their particularities. During functional analysis, the following lines have been adopted and finally implemented in order to fit the professional needs:

a) **Analysis process adapted to bedside care.** The application should be configurable to be used in different contexts by both, physicians and nurses. However, the design should not be disruptive with respect to the general HIS GUI design, which professionals are used to work with everyday, reducing the learning curve and sources of mistake and reject.
b) **Multiplatform use**: the application will work regardless of the characteristics of the device used: medication cart, Tablet PC, TV or bedside table with chairs integrated TV, being the care process which determines whether a device is more useful in a situation or another.
c) **Job listings tailored to the needs of the professional and mobility scenario:** the map of beds throughout the hospitalization area and nurse's care tasks to perform on each patient should be automatically programmed beforehand.
d) **Tasks of the patient with centralized access and information of tasks to be done**: since the mobility client application will primarily be used in the presence of the patient, access to tasks or activities will be a pivot of the application. The tasks appear depending on the professional profile. Application will include information on planned activities, still to be made and already done, using color codes, giving the patient-related information in a helpful way for the professional. Definitely, this and the previous specification address the optimization the delivery of care tasks and efficiency.
e) **Organization of the summary information and easy to change**: The HIS where the system will be primarily installed offers a wealth of information on some of the tasks that the professional can perform to the patient, for example on nursing assessment or prescription. However, the screen layout should be designed from the standpoint that, at the bedside, it is important for

professionals to see just the needed data and be able to modify them in an effectively manner. Therefore, the practitioner should have optimized access to summary views, allowing changing the data very quickly at the bedside.

f) **Clinical safety**: based on the following points:

i. Automatic identification of the patient before any activity related to the patient bedside is carried out. The professional, through the mobility client may automatically identify the patient in a way that enhances safety of the patient. System should be prepared to identify the patient in different ways depending on the device used by the professional: close reading or approximation reading.

ii. Barcode reading and cross-data: the system will read bar codes on samples of blood, transfusion and unidosis components in the process of extraction, transfusions and administration, so that they can cross check the identification data with the actual read data and the schedule for each care's task. This comparison will allow automatic verification that the corresponding task is performed correctly or give an alert otherwise.

iii. Clinical safety warnings very visible: the system provides clear, concise and very visible alerts and warnings related to clinical safety to avoid errors by the professional. The goal is zero errors with full use of the system. Clinical safety mechanisms can be settled on or off in case the hospital to have or not necessary identification devices. They may be aborted too, to avoid the professional to take any action at the bedside due to poor operation of these devices.

g) **Fluid navigation through the application:** it is of utmost importance to define a clear way of navigation through the application to allow the professional to concentrate in their job regardless of the device in use. The common feature is the touch screen interface, which was preferred by most of the interviewed professionals of the hospital center, although different form factors must be supported.

B. Devices

The system being developed should be multiplatform so it can run on different devices. The scenarios and functionalities must operate independently of the device used, but obviously there will be scenarios that fit only in more reduced number of devices than others. It will be up to the hospital where the system is implemented, to choose the most appropriated to their needs.

The minimum set of devices for which the system must operate are:

- Medication Cart type Artromick Avalo Serie (4): cart medication dispenser with a computer type M1726 Arbor PC (5) and touch screen, which will also have a continuous monitor, a label printer and a barcode reader.
- TV on the bedside: touchscreen computer in the form of television (M1726 Arbor (5))
- Tablet PC with a touch screen type Barco CliniScape MTCP-0110 with a size of 10" (6)

Figure 1 shows how the devices look like: in the left, a complete medication chart for nurses, in the middle an integrated TV on the bedside, in the right a Tablet PC for the physician.

Figure 1. Devices

III. RESULTS

A. Implementation of the mobile client

To meet the functional and technical requirements, the mobility client is a thin client, mainly the graphical interface, through which the user reads and modifies data. Given the mobile nature of devices that implement the client, the server connection to the HIS will usually be performed through Wi-Fi network. The connection between client and server is done via web services because hospitals typically have strong restrictions on the firewall to wireless connections. In the current implementation, web services are generated over EJB 3.0 (7).

The technology used for the graphic component is JavaFX (8) which has been chosen because of the potential in both the development of advanced interfaces and in its integrability with the HIS server and the hardware used in the project. JavaFX is a family of products and technologies from Sun Microsystems for creating Rich Internet Applications (RIAs) that can run on a variety of devices. The current release allows the construction of desktop, browsers and mobile phones applications. This technology makes it possible to build liquid interface applications (resolution independent) and visually appealing.

The mobile client has a number of modules that let hardware connections such as: vital signs monitor, identification systems, tracking systems, the nursing car (opening and closing drawers), bar code readers, card reader system, microphone and speakers for making voice memos. To connect these devices a set of integrations were implemented:

- **Integration with monitoring stations:** The objective is to integrate the mobility client with different vital signs monitors that support a HL7 (9) interface. In order to optimize the maintainability of this integration, the proposed solution uses the Rhapsody (10) (11) integration engine that already implements similar functionality for the integration of monitors connected directly to the network. Rhapsody is responsible for translating every HL7 message to a defined XML format and returns it to the mobile client as well as response messages necessary to answer the monitor (ACKs for HL7 response messages). The client processes locally and displays the XML message monitoring data on the screen while recording them in the HIS DB through the same business service exposed by the server for manual entry of measurements.

- **Integration with identification, location and tracking systems based in radiofrequency technology, RFID** (12) (13) (14)**:** external identification system means a system consisting of "tags", or identification bracelets worn by the patient. In the current implementation the hospitals uses the TSB's SPHERAhospital (15), location and identification system. The identification system must provide a USB interface I/O (keyboard type) to allow reading a bracelet or tag that comes close to a few inches and automatically enter the patient ID. As an added functionality, these services can connect to the external system of identification, tracking and location, either through direct EJB calls or Web services.
- **Integration with other systems:** There is a need for other integrations such as those carried out with barcode readers, with the nurse cart, with a card reader or the need to take voice notes. The current implementation provides integration of bar code readers and interoperation with the cart, so that once professional authenticate in the application, the cart is automatically activated. Finally, physician profile allows saving voice notes instead of typing.

As in the desktop HIS client, there are a number of managers and helpers which performs core functionalities: context manager, boot manager and configuration profile manager, exception model and centralized logging, internationalization, and delegation of services manager. Figure 2 show the architecture implemented.

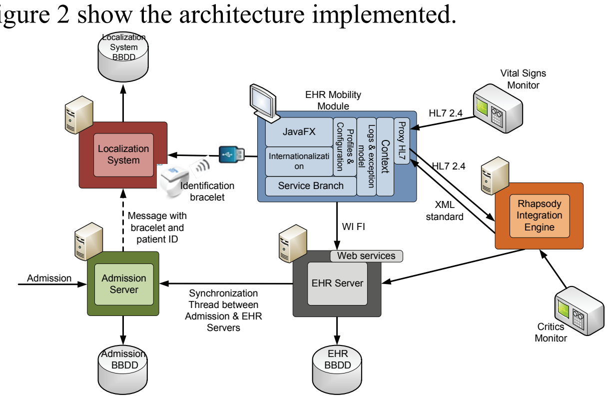

Figure 2. System Architecture

B. *Evaluation*

For the purpose of evaluation, 20 nurse carts were equipped with the mobile client and interfaced with the location system, bar code reader and the multiparametric vital signs monitor type SureSigns VS3 from Philips (16). They were assigned to the traumatology area (3 units), pediatrics area (5 units), neurology area (3 units), gynecology area (3 units), internal medicine area (3 units) and pneumology area (3 units). Through the mobility client, nurses access to their personal profiles in a secure and contextualized way using username and password. As well they can access the map of beds of the clinical area for which they are individually responsible, including background information and patient's data access.

C. *Nursing Care Activities*

20 nurses were trained in the operation of the cart to perform routine care tasks to patients admitted in the clinical areas. Patients were informed on the use of the location system bracelet. During two months, nurses performed daily care activities using their respective cart. A total of 637 patients were attended and 4.462 interventions performed. Activities were divided on:

a) Patient automatic identification: this was done when the nurse and the cart enters in the individual patient room. Clinical record and care tasks and schedule are popped up upon successful identification.
b) Medication administration: nurse bar code reads the unidoses samples. System cross check medication and doses against medical prescription in the clinical record. Alarm or confirmation is issued. Nurse proceeds properly and edit the record on the screen.
c) Vital signs measurements: nurse take prescribed measurements that are automatically recorded on the system: blood pressure, pulse, temperature, SpO2, and ECG. In case of measurements that are not built-in device, recordings are made manually.
d) Nurse assessment: allowing an easy access to 14 needs defined following the model of V. Henderson (17), which, based on human needs, categorizes nursing activities into 14 components, i.e. breathe normally, eat and drink adequately, eliminate body wastes, etc.
e) Nurse's note of evolution: allows nurses to record the information entered for a patient and they follow up.

Preliminary results show that:

a) 98% of positive unambiguous identification was achieved when the cart is approached to a distance less that one meter from the patient's bracelet. The other 2% were cases where the system detected two patients (one in the neighbor room). It needed nurse intervention. No differences were found respect to the clinical area.
b) Once identification is confirmed, 100% of the cases the clinical record is popped up, with activities and medication scheduled. A mean access time to the clinical record first time was 12sec ± 5s. The relative long waiting time is mainly due to the server response time and network congestion in the wireless sub-net. No errors of matching between prescribed and unidoses were found. A double check was manually made by the nurse to confirm.
c) Vital signs measurements, both automatic and manual did not present any relevant problem. 100% of measurements were accurately recorded in the EHR.
d) Exceptions: 28 cases were reported when neither identification nor access to the clinical record was possible, due to network down or server overload.

IV. DISCUSSION

The developed system is prepared for medical personnel to interact securely with the patient's clinical record in mobility, so they can carry out the process of care in a more efficient way, performing the complete care activities including recordings at the bedside. The system also offers improved clinical safety with the introduction of active RFID patient identification and checking data from the barcode reading of blood samples and drug packaged as unidosis. Thus, the use of this solution will allow innovation in in-hospital care process, improving the efficiency thanks to client mobility, reducing administrative time. The preliminary results are promising. The evaluation is going to continue extending the scenarios of use in other clinical areas such as surgery areas. Longer time evaluation currently in progress in the Hospital La Fe (Valencia) is necessary to validate the hypothesis of reduction of medical errors and cost efficiency.

A comparative study of mobility applications implemented in hospitals in Europe and US allows us to conclude that the future of electronic systems in hospitals will follow these trends in mobility, functionality and integration of services. It can be concluded that the system presented is one of the most advanced and integrated one allowing: identification, location, tracking, barcode reading and cross-data for samples of blood, transfusion and in the process unidosis components of extraction, transfusions and administration among other functionalities. (18) (19) (20) (21)

V. Conclusion

An innovative technological system has been design following the requirements of experimented care professionals and the functionalities already implemented on top of current HIS used in the hospital. The development and deployment has been carried out in a real environment, the new Hospital la Fe of Valencia. The system is now running and under evaluation, thus work is underway on a new version that adds new features, such as request manager, voice notes for physicians and blood transfusions management.

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