A mobile e-health system based on workflow automation tools

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Abstract

This paper describes the Patient Record Manager and the Workflow toolset of the wireless-based e-health system Ward-In-Hand, developed inside an IST European project and currently in use within three hospital wards: Italy, Spain and Germany. The lack of homogeneity in the healthcare organisations required a suitable implementation of Workflow automation tools to create and manage the execution of the caregiving processes, customising them to local ward needs. Solutions for this problem, as well as the integration of the workflow organiser, to be used by individual health professional during daily activity, with the Patient Record Manager are discussed.

1. Introduction

The paper describes the experiences of the authors in the development of a wireless-based e-health system, called Ward-In-Hand (IST 10479), a project aiming to support the day-by-day activities of doctors and nurses within an hospital ward by providing a tool for workgroup collaboration and wireless access to the patient’s clinical records. WIH is currently being used within three hospital wards, in Italy, Spain and Germany, where the medical personnel is equipped with PDAs, connected by an IEEE 802.11 wireless LAN [1]. Figure 1 shows the WIH system architecture.

Besides the capability to display on the mobile unit (currently an Ipaq 3630) the relevant information contained in the patient’s clinical records, and to update these data by means of the Patient Record Manager (PRM) module, WIH also provides a Personal Organiser (PO) that gives a real time list of tasks to be executed to doctors and nurses. Once performed, a task can require scheduling of new tasks according to “workflows”, or processes, that have been configured for
that particular installation. A typical example is a drug prescription by a doctor, which will trigger a new task (or perhaps a repeated series of tasks) for the nurse to give the patient that particular drug.

Figure 1. The overall architecture of WIH system

The major problem met, but also the major challenge for such a system, is the lack of homogeneity in healthcare organisation that required design choices to enforce adaptability to local needs. Differences are due, for example, to the different roles used for the personnel (nurse, head nurse, pharmacy, single or group responsible and so on), different languages, various databases and information systems, different kinds of clinical tests, drugs, and treatments depending on ward specialisation. The most evident difference lies in the different structure of the caregiving process, and to some extent also in the difficulty of giving a well-structured description of it.

These problems required a suitable implementation of WorkFlow automation tools to create and manage the execution of the caregiving processes, customising them to local ward needs. In the following we will describe with some technical details the Patient Record Manager and the WorkFlow tools organisation, and the solutions adopted to solve heterogeneity problems rised during the WIH prototype testing phase.

2. Patient Record Manager & Patient Record Database

The Patient Record Manager (PRM) is the application that allows doctors, nurses and any other authorised user operating in the ward, to navigate, update and modify the information concerning each patient admitted in a ward. The PRM consists of a server-side part, supplying the logic of the application and the access to the patient information, stored into the PRM database, and of a client side Human Computer Interface (HCI), that is in charge to present in an efficient, customised and device-dependent way, the information required by the user.
The HCI of the PRM can be displayed by any browser, either on a desktop PC, when a user is working from his office, or, and this is the most relevant and interesting innovation of the WIH system, on the small screen of a PDA that doctors and nurses can carry in any place of the ward, particularly at bedside. Two examples of such pages are shown in Figure 2.

![Figure 2. The main page of the PRM and the vital signs of a sample patient](image)

On small, keyboard-less devices like PDAs, some input methods, alternative to or improving the use of the pen on the Ipaq screen, have been considered, and a couple of solutions have been implemented. The WTX input mechanism is a possible alternative to the virtual keyboard that supplies to the user, depending on the context in which it is used, a list of most likely words. A command & control mechanism, based on voice recognition, has been implemented and tested. This solution, absolutely innovative and helpful in principle, suffers for some technological limitations, first of all the necessity to perform recognition remotely on the server and not directly on the Ipaq [2,3].

The PRM consists of a set of Java servlets, running on the server and executed through the JSWDK Java Servlet Engine that, depending on the request performed by the user through the Human Computer Interface, retrieve information or performs modification on the Patient’s data. The result of any request is a new page that is prepared by the PRM servlets and displayed on the Ipaq or on the desktop by the HCI, that is essentially a browser. Patient records are XML files that are physically stored in a MySQL database.

Technologies beyond PRM development reflect the desire to be:

- flexible and portable (Java as a programming language and a browser as a human interface make the PRM completely portable on different OS: we tested the compatibility with Pocket Linux environment)
- economical: Java, XML and MySQL are open source technologies that do not require any licence.

3. The Workflow Tools

The Personal Organiser used by hospital personnel to deal with daily activities is part of the more complex WorkFlow system, that includes several tools: the WF Designer, that allows to create definitions for WF processes; the WF Engine, that creates the processes instances, recorded on the WF database; the WF Administrator tool, that allows the administrator to control the activities of the ward, and the WF Scheduler, to remind doctors and nurses about next tasks to be done, thus ensuring processes completion. An important remark is that the Workflow
implementation has been designed in accordance with the principles stated by the WorkFlow Management Coalition standards [4], so that it already complies with most of such standards.

Not all workflow tools have been designed for medical users interactions: only three of them are intended for personnel use, namely the WF Administrator, the WF Designer, and the Personal Organiser. Specifically, the latter is intended to be accessible to every user, while the former two are intended for restricted use, by ward responsible (or responsibles). Hereafter we shall give more details about them.

3.1. WF Administrator

The WF Administrator tool allows to manage the ward positions into a department structure and to establish the internal staff hierarchy. Members of the personnel, identified by name, surname, job title, wards and password, can be enrolled or erased. Thus, it is used mostly whenever a staff reorganisation is taking place.

A second function supported by the WF administrator is the possibility to check the ongoing WF processes of the last 24 hours and modify some of them. Thus, the responsible of the personnel may respond to emergency situations by reassigning duties to the personnel.

3.2. WF Designer

The WF Designer allows plotting the WF processes, introducing new schemes or modifying the existing ones. Its graphical input form provides a simple and efficient way to analyse and to revise the working habit and policy for the best organisational purposes. Icons are provided, representing activities, variables, applications, staff groups, rules, that can be dragged on the layout and connected by arrows, allowing to simplify a truly complex series of steps. Moreover, each icon is rapidly characterised by its properties by clicking on the mouse. Figure 3 shows the WF icons and a WF process definition.

![Figure 3.a. WorkFlow Designer icons](image1)

![Figure 3.b. A WorkFlow process](image2)

At each ward, the responsible only is allowed to design workflow processes, since they are crucial in defining current caregiving practices. The experience of the first doctors using such a tool shows that a specific training was needed, and that designing workflow processes requires both medical and computer know-how. From the implementation point of view, it turned out that the WF Designer user interface is a critical feature. Thus such a GUI has been prototyped and heavily experienced in order to produce the final system.

The workflow objects (instances of processes) need to be integrated with other applications running on the PDA. These applications are external information systems needed by employees for the completion of a workstep, and can be executables or applications, to be accessed from web browsers using the HTTP communication protocol.
Two possibilities can be selected when a workflow is instantiated, and some tasks have to be assigned to medical personnel. In the first approach, the WF designer assigns a task to a specific user that belongs to a group of people with the same job description (i.e. Doctor Smith). In the second approach, the WF designer assigns a task to all users that belong to a group of people with the same job description (i.e. Doctors).

By default, WIH takes the second choice, that is, duties should be better attributed to a category rather than to a specific person. Most wards indeed prefer this kind of approach, which also simplifies the production of web pages to be shown on the PDA. In fact, when there is a big number of people in each group, the visualisation of the whole list is too much space consuming, and goes in contrast with efficiency and speed of use. However, the selection of a particular person is maintained in the PO as an option.

The WF administrator and the WF Designer applications use a database, named “WorkflowDB” to store the definitions created. Microsoft Data Engine (MSDE) is supported and one of them must be installed at the ward. Transactions are handled by the use of Microsoft Transaction Server (MTS), which can also be installed locally, or on a remote machine over the network. The Graphical interface has been realized using Visual Basic.

### 3.3. Personal Organiser

The tools discussed above work on the WIH server and the operations are performed “off line”, using a desktop. Instead, doctors and nurses use on their PDAs a Personal Organiser. The PO works together the WF Engine, a transactional Windows application, based on the Component Object Model (COM) technology, which elaborates complex WF processes that are defined using the WF Designer. The core of the Workflow Engine is an MTS COM object, which encapsulates the entire business-logic, involved in the processing of workflow processes. The Engine uses MSDE as the data tire for storing/retrieving run-time workflow data, while it provides data to remote Personal Organiser clients through the WF WEB interface.

Based on the definition of the specific process, the WF Engine retrieves workflow data from the WF database, and rebuilds the definition model at run-time. These data include process activities, associated applications, job titles, employees, rules, conditions and workflow variables. In each step in the process, the WF Engine can make decisions and automatically creates workitems for the participants in the next step(s), based on the rules, the specified conditions and the data provided by the client.

The Personal Organiser client is an Internet/Intranet based application that runs inside a web browser and thus provides the user with the capability of accessing his/her worklist/workitems remotely. Through the PO client, doctors and nurses may start a new process instance (i.e. new tasks for colleagues or themselves): when clicking on the “Workflows” icon, the Workflow Engine will display all the processes, which the current user has the appropriate permissions to start, and the selected one shall be started by clicking on the appropriate link. The Workflow Engine will automatically create a new instance of the workflow, and will generate workitems for each employee associated with such a workflow activity. Real time updates on the PDAs of other users shall appear at once, if they are connected, or as soon as they connect to the PO (Figure 4 below shows a sample PO page).

Each member of the staff has access to the process instances, possibly limited by the respective job title: when entering the system, his/hers duties are immediately shown. The process instance is identified as an activity to be performed, and have variables such as date of starting, patient, bed, daily frequency. The cooperation of different person to perform some activity is thus supported.
4. An Example of successful integration: the PRM and the PO

One of the most interesting “challenges” of the WardInHand project was, since the begin of the development phase, to find a flexible and efficient way for integrating the two main applications of the system: the PRM and the PO. The difficulty was due to the different “philosophies” the PRM and the PO were based upon: a flexible and portable Java based approach for the first module, a Microsoft-based approach for the second one.

At the same time, the natural requirement that had to be satisfied by the integration was that the PRM application could be associated with any workstep of a workflow. Association means that a user can use the PRM application during the “execution” of any workstep. Of course, a user would want to open a specific part of the PRM application that is specifically needed for the execution of a workstep.

A standard communication interface has been defined using the HTTP communication standard. In that way the PO and PRM applications can communicate using HTTP Response, and HTTP request as a bi-directional way of communication following specific rules. The HTTP response/requests are predefined during the design of a workflow. Furthermore also the Applications’ user interface has been integrated (i.e. Same buttons, background images etc.). All applications have the same entry point. A login page where the user provides his login name and password in order to use either the PRM or PO.

![Image of switching between PRM and PO]

Clicking on the “Select Patient” link, the user directly access the list of patients displayed by the PRM, from which he/she can select a patient and go back to the PO.

5. References