MobiDay: a Personalized Context-Aware Mobile Service for Day Hospital Workflow Support

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ABSTRACT

The quality and the effectiveness of the communication between patients and clinicians is a key aspect of an eHealth system. Mobile communication technologies can help addressing this problem providing ubiquitous and personalized information access. In this paper we illustrate the architecture of a mobile service, integrated in the hospital information system, aimed at supporting the user task in a day hospital scenario. The mobile device provides to the patient information messages related to her disease or her current task. Message delivery time is personalised using recommendation technologies that exploit contextual data such as the patient's position and current activity, and the history of user's previous message reading behaviour.

Keywords

Mobile Services, Recommender Systems, Personalization, Message Push.

1. INTRODUCTION

Mobile phones are becoming a primary platform for information access [4][13]. Hence, it is important to understand the capabilities of this channel and the information access behavior of mobile users, in different contexts of usage [5], and in particular in eHealth applications in the hospital environment [10][5][15]. Moreover, as the amount and complexity of information services increases, it becomes more and more difficult for users to navigate their user interface, and find the right information or to complete a particular task. For this reason, in the last years, many Web-based information systems have been augmented with Recommender Systems (RSs). RSs are information filtering and decision support tools aimed at providing product, information, and service recommendations personalized to the user's needs and preferences at each particular request context [1] [16]. RSs have been largely used in eCommerce applications supporting PC clients, but are now emerging as useful techniques for improving information services accessed by mobile devices (PDA, mobile phones) [14]. In this scenario the main issues are related to the limitations of the user interface, i.e., small screen and keyboard, and limited computational power [9]. Moreover, other important limitations and constraints come from the context of usage, i.e., the user is typically accessing the system when she is on the move and several disturbances and interruptions make the interaction more complex, intermittent and shorter [9].

At the same time, the evolution of mobile devices, e.g., personal digital assistants (PDAs) and mobile phones, the ubiquitous availability of wireless communication services (e.g., wireless LAN and GPRS/UMTS) [17] and the development of position detection techniques (e.g., RFID beacon-based and GPS [18][19]) have fostered the development and commercialization of new and sophisticated location-based services suited to the needs and constraints of mobile users [4] [13].

In this short paper we illustrate the motivations and the state of the development of MobiDay; a mobile and personalized information service in the hospital, aimed at improving the quality of the communication between the medical staff and the patients in a day hospital scenario. MobiDay is using pervasive technologies and contextual information in an oncology unit, to provide up-to-date, context dependent information to the patients and to let them to enter various information required by the doctors to asses their state. The ultimate goal of this system is to provide not only a valuable set of information to the patients (e.g., what to do next, or information about their status) but also to learn from their actions (opening and reading messages) better and better strategies for delivering personalized support. The practical effect of the learning procedures is to increase the effectiveness of the information and the user interface. We carried out our entire project in close collaboration with clinicians. During the design of MobiDay, we used feedback from the clinicians to iteratively refine it and in the next future this new mobile service will be fully integrated in the existing information system of the hospital in Meran-Merano (South Tyrol, Italy).

The rest of this paper is organized as follow. Section 2 describes the system functions and Section 3 illustrates a typical usage scenario to give a better overview of MobiDay functions. Section 4 describes the system architecture and Section 5 illustrates the key technical issues and solutions that we faced. We conclude this short paper by describing the experimental evaluation that we plan to run in the next months (Section 6) and providing some concluding remarks (Section 7).

2. SYSTEM FUNCTIONS

MobyDay system is aimed at supporting the patient in a typical day hospital scenario of an oncology unit. Its main function is the personalization of the messages sent to the patients, and the support for filling user questionnaires (e.g., on quality of life). Messages sent to the patients can provide tips about how to improve the quality of life on certain circumstances, or simply instruct them about what to do next. This information flow is ultimately aimed at supporting the user task execution (analysis, treatment, and doctor's interviews) with the help of a mobile device (a mobile phone with Wi-Fi connectivity) used by the patients during the full day hospital process. The main functions of MobiDay are listed below:

- **Personalized instant messages:** information that is of interest for a patient, in a specific step of the day hospital workflow, is generated by MobiDay and forwarded to the patient on a time identified by the system. MobiDay is aware of the user context (location and current activity) and can decide whether this context is appropriate for the user to receive the message.

- **Questionnaire and form filling:** questionnaires about the quality of life, which are provided and analyzed by CHES, are converted into a format that is suited for the mobile device. CHES is a system developed at Innsbruck Hospital enabling questionnaire filling on a tablet PC, and data analysis [12]. We aim at providing an additional input channel, which could be as usable as the standard paper-based and PC-based versions. The questionnaires are displayed and filled on the patient's personal mobile device. The filled questionnaires are sent back to CHES for data analysis and reporting.
- **Workflow support:** the day hospital's workflow is integrated and exploited by MobiDay. This means that the mobile component is aware of the status of all the patients in the workflow: it is informed when a task is finishing and when a new task is starting. The patients, by means of the mobile system, may get a better overview of their therapy's status and see when the next steps should be executed (see [6] for a similar functionality).
- **Identify the user-context with active RFID tags:** an important aspect of the user-context, in addition to the user's activity, is the user location (e.g., the waiting room or the doctor office). In our day hospital environment MobiDay exploits an indoor localization technique based on active RFID transponders. The user position is checked to decide the best time for the user to receive such messages.
- **Web interface for the medical staff:** in addition to the information delivered to the patient (mobile device) the medical staff can operate the system by providing additional information and by sending instant messages to the patients. Similarly to the automatically generated messages, the decision about when to send the messages is optimized by MobiDay.

3. SCENARIO

This section describes a typical usage scenario to give a better overview of the MobiDay system functions and how they are used in the day hospital. An oncology patient enters the hospital for a scheduled visit and treatment. She approaches the registration desk where a nurse is waiting for her. At the registration the patient receives a badge (active RFID transponder) and a mobile phone (Nokia N958GB). After that, MobiDay can recognize the patient using the RFID transmitted data, and can send to her a welcome message.

The nurse informs the patient to proceed to the waiting room and to wait there. The patient can see on her mobile device that the next activity is blood analysis. Then, she receives a new message informing her that a nurse is waiting for her in the therapy room for the blood analysis. The patient moves there and the blood sample is taken. After this step, she is sent back to the waiting room.

MobiDay recognizes from the current patient's context that the patient may have time to fill out a questionnaire about her quality of life. Because of that, MobiDay retrieves the right questionnaire from CHES and sends it to the patient. The patient's mobile device vibrates and shows an information message. "Prof. Brown would like to know some more information about your state". The patient is presented a questionnaire (see a snapshot in Fig. 1).

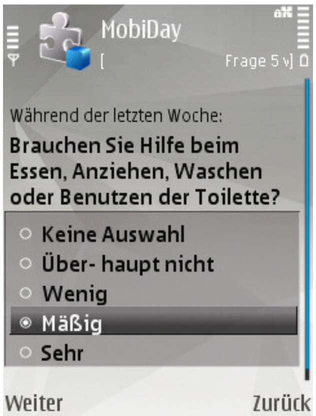

Figure 1. MobiDay user interface

The patient can fill out the questionnaire and confirm her choices. After a while, the questionnaire is sent back to CHES, the doctor is informed and can analyze the questionnaire.

Then, the patient receives a new message with feedbacks on this questionnaire. MobiDay has recognized from the patient's context description that she may be interrupted by this message (she is back in the waiting room). The patient gets an additional message telling her that the doctor Brown is waiting for her in room E354 for the next ward round. The patient also gets a message instructing her about how to deal with some collateral effects of the therapy she has received today.

4. ARCHITECTURE

MobiDay comprises a server component, which interacts with the departmental systems of the oncology unit, including CHES and ONCONET, and two client components: one used by the patient and another by the nurses and the doctors (see Figure 2). CHES manages the questionnaires on the patients' quality of life. These questionnaires are displayed on MobiDay Client, running on the patient's mobile device (Nokia N95 phone). ONCONET is used to retrieve the patient's personal record and the workflow data. MobiDay server is responsible for collecting these data and to generate instant messages and questionnaires for the patient.

MobiDay server stores log data describing the user activity on the mobile device: actions performed in context (reading messages, reply to questions). This information is then used to learn how to process future messages for the patients, identifying the right user-context for sending them.

The client application is a J2ME (Java 2 Micro Edition) midlet that is installed on the patient's mobile devices. Each patient is also wearing an active RFID tag that is sending identification data to a collection of RFID readers deployed in the hospital. This identification data is used to provide the localization information to various components of MobiDay.

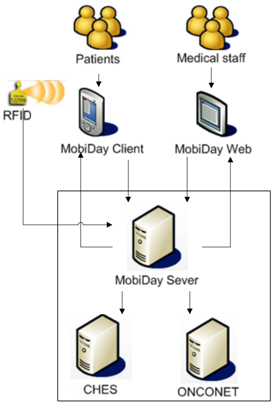

Figure 2. MobiDay architecture

In addition, the medical staff can interact with MobiDay using a Web application (MobiDay Web). MobiDay Web can send instant messages that can't be generated automatically by MobiDay Server. In this way, the communication between medical staff and patients can be further improved. Finally, this application provides also an overview of the patient's current workflow and interaction with the mobile application (e.g. the questionnaires already filled by the patient).

5. TECHNOLOGIES

5.1 Mobile User Interface

In the design of the MobiDay Client application we addressed two key issues. The first relates to how to better respond to a set of questions that the patients may have:

- Do I have new interesting information to consult?
- Do I have a questionnaire to fill out for the doctor?
- What are my next activities?

The second key issue relates to the fact that patients will access the system in various contexts; when sitting in the waiting room, or under the therapy procedure or when they are on the move. The success of this mobile service is therefore also determined by the interaction design that must facilitate system usage in various contexts [9].

First of all, we designed the mobile interface with standard usability heuristics. The patient should have a clear and simple overview about what should be done next. Therefore, the interface offers a main panel where on top a status message is informing if any messages should be read or a questionnaire is to be filled out. In the lower part of the interface, the patient can access an overview of the current and next workflow activities. In this way, the patient can easily check at any time and context (e.g., when he is walking or sitting) the most important information.

Urgent incoming messages or questionnaires are automatically displayed on the screen without user intervention, when the user is not interacting with the system. The VibraCall ring is used to get the patient's attention, without disturbing other patients. This speeds up the interaction and guides the patient faster through workflow activities (e.g., the questionnaire has to be filled out).

Questionnaires are somewhat longer actions (5-10 minutes to fill out a questionnaire) compared to other activities performed with the help of the system. Therefore, questionnaires are only sent when the patient can dedicate to them the needed attention. We think that this will occur only when the patient is in the waiting room and she is not engaged in a particular activity. We tried to make it as simple as possible to fill out the questionnaire, avoiding in particular open ended questions that require the usage of the text input on the mobile device. Most of the input requires only joystick navigation and multiple choice selections.

Most of the user-context information is collected in the background by the mobile device application. Therefore, the patient is normally not concerned with that data collection. An exception is made when we require an explicit user feedback, when we want to obtain some reliable knowledge on the appropriateness of some messages. The patient interaction is simplified by following the rules listed below:

- The explicit feedback is only requested rarely.
- The request of an explicit feedback ("have I disturbed you?") is integrated in the message text at the end of the message. No additional dialogs are popping up requiring additional user interaction.
- If the patient has not read the message in 10 minutes after it was received, the message is not displayed anymore on the screen. This fact provides also an indication that the time we sent the message was not appropriate. Actually this may have other motivations, e.g., the patient did not have time to read it because she was doing another activity, or because she was not interested to read the message. We will further investigate this issue in the course of the project.

5.2 Push Messages

Personalized information services are either based on (i) passive (also known as organic), (ii) pull or (iii) push information delivery techniques [16]. The first technique provides item recommendations related to the user's currently viewed item (e.g., the feature "customers who read this item also read…"). The second technique provides information to the user when she is explicitly asking the required information. Both techniques are seen as non intrusive because the user is consuming information only when she is receptive of doing it. On the other side, the last technique, i.e., "push", provides information to the user when the service provider thinks that it may be beneficial for the user. However, this technique often leads to annoyed users, who are getting overtaxed by unsolicited information at the wrong time and place. The same may hold for a patient in an oncology day hospital. As already mentioned before, one of the aims of this project is to identify a methodology for learning the right user-context for sending messages using pervasive technologies in an oncology unit. We want to achieve this by concentrating on three types of messages (identified by the clinicians) that will be sent to the patients:

- **Workflow dependent messages:** these messages are connected with the patient's workflow, e.g., a patient has to do blood analysis test now. Hence, a message is generated to invite the patient to perform such activity. Workflow dependent messages are triggered on specific moments, i.e., when the activity must be executed.

- **Information on possible side effects of the therapy**: these messages contain information about the therapy side effects observed in the patient in the last weeks. The messages are intended to give tips about how to avoid or deal with certain side effects. Normally, the content of such messages is equal for all the patients. This is normally identified by the doctor during the ward round. After that, the doctor decides which side effect tips should be sent to a patient. MobiDay will then decide when to send them exactly.

- **Dynamic messages:** the content of such messages can't be defined in advance and they provide a way for the doctor to freely interact with the patient. The content changes dynamically during the therapy and is inserted by the medical staff manually. These messages do not have a precise temporal or workflow dependency.

As we mentioned above we want to improve message management with a personalized context-dependent recommendation process. During the experimental phase of this project (see Section 5), we will collect precise, contextually tagged, usage data. The contextual information is basically including the following two types of information:

- **Logical location:** patient's location is the most important data that is collected. We obtain it with active RFID technologies. In fact we decided to mark some precise locations of the hospital (e.g., the waiting room or lab) and we are able to identify in which room the patient is located.
- **Workflow step and time of the current action:** the workflow management system in the day hospital (implemented by ONCONET) is a crucial component and source of contextual data. But, this information is not always correct, e.g., it may indicate that a patient has to undertake a chemotherapy task but she might have already finished that task, and the medical staff missed to update the system. However, this information, in conjunction with the location information provides strong clues about what the patient is doing.

Moreover, the push message service will use some other user data such as demographic and disease information. We also plan to use information about the psychological state provided by CHES (to personalize the presentation of the information). Finally the explicit and implicit feedbacks of the user to the delivered messages will be stored. We have implemented a specific interface that, in-context, is asking the patient if the message arrived at the right time or not. We will sample the user reaction in a pseudo-random approach. In addition to that, implicit feedback will also be collected, e.g., the reading actions of the patients. The data will be analyzed and several context-based recommendation technologies will be tried. First of all the contextually tagged data will be analyzed for understanding what contextual data are actually relevant for deciding what messages to push. This will be based on wrapper methods that try to automatically check the relevance of contextual data while making the message relevance prediction [2]. Secondly we plan to use some techniques, which have been exploited in the personalization of the human-computer interaction process, and that are based on reinforcement learning techniques [11].

5.3 Localization with Active RFID

We think that the patient location is of primary importance in order to provide appropriate contextual-dependent messages to the patients. Considering the day hospital environment, localization techniques based on GPS, network cell towers or Wi-Fi access points do not offer the precision or convenience required for determining the room visited by a patient at a certain time instant. Therefore, to deal with that situation an approach based on RFID technologies has been followed.

Radio-frequency identification (RFID) techniques allow the identification of objects by means of radio waves [19] [18]. In this approach landmarks (objects) are tagged with RFID transponders (tags). The market offers two types of RFID tags:

- passive RFID tags, which require an external power source to initiate signal transmission;
- active RFID tags, which are powered by a battery and can transmit their signal autonomously.

We have selected the second type because active RFID support a longer transmission range, which is roughly 25 meters in a typical indoor situation (with the particular kind of transponders that we have used). As mentioned above, active RFIDs are able to receive and transmit data, and can be programmed so that it is possible to exploit a peer-to-peer model of communication between tags [3]. Moreover, transmission power can be modulated to customize the transmission range to the specific needs of the environment (in our case approximately 5 meters). This feature has been exploited in our project and allowed to detect and broadcast "contact" events, for example, two transponders seeing each other, i.e., being in communication range.

We have deployed a system configuration consisting of one transponder for each room taking part to the workflow of patients. Moreover, each user participating to the experiment also wears a tag. This simple design enables the identification of the previously mentioned "contact" events between patient and room transponder, thus locating the user among one of the tagged spaces. To receive the signals transmitted by these transponders, in the area of the day hospital unit three RFID USB-readers have been installed in fixed locations. Each reader is then connected to a laptop that receives the packets broadcasted by transponders and, through a local network, it can forward the received information to a server for further processing. Here the server processes the transponders' packets and provides the computed position of the patient to MobiDay server. The transponders and RFID readers that we used are developed by OpenBeacon.org.[1]

6. EXPERIMENTAL EVALUATION

In the next months we plan to conduct an experimental study in Meran-Merano hospital. We want to first identify possible major usability issues of the user interface of the mobile system (we already performed a heuristic evaluation with the clinicians).Indeed, deploying mobile technologies as those presented here can raise several usability and privacy issues that

[1] We would like to thank C. Cattuto and ISI Foundation for their help in setting up the system. They have provided to us the devices, the knowledge and the software needed to acquire and process the patients' positions.

must be considered and faced with appropriate solutions [8][15]. In fact, the main objective of the study is to compare the quality of the support provided by the mobile device, in the questionnaire filling task, with that offered by the CHES Tablet PC application, and with the standard paper-based form. In this experimental evaluation the system will collect precise log data of users' interactions with the system in order to perform the analysis described in Section 5.

We plan to use a within-group experimental strategy where users will use for a period of time the mobile device and then, for the same period, one of the other two variants (Tablet-PC or paper). Two other groups will perform the same experiment but in the reverse order. This study will involve approximately 40 patients (10 per group). Hence, the study will be subdivided into two phases: in the first one, consisting of two sessions of one day treatment in the day hospital (separated by two weeks) the patient will use one type of interface. In the second phase, which also consists of two sessions of one day, the patient will use another technology. We will measure the subjective user's evaluation using one quiz test after each single phase, and in a final questionnaire the users will be asked to express their preference over one of the two form filling methodologies that they have used. Our basic hypothesis is that the mobile system can be as much usable as the tablet version and will be positively accepted by the younger patients. We also expect a more efficient interaction, because of the simplifications we made to the user interface.

7. CONCLUSION

This short paper describes the current status of a research on a mobile, personalized information service in the hospital, aimed at improving the communication between the medical staff and the patients in a day hospital scenario. We have defined the main system functions, the system architecture, and addressed the key technical issues related to the required techniques: the user interface for the mobile client, the personalized context-dependent push messages service, and the localization technique exploiting active RFID transponders. The development of this system is completed and we are now pilot testing the prototype before executing the experimental evaluation. The future work will consist in testing our research hypothesis about the usability of the mobile service, and in testing a set of recommendation technologies used to learn the best context for each type of message delivery. It is worth noting that this system is addressing a limited context of usage, i.e., the day hospital. In the future we would like to offer a better communication and support when the patient is at home.

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