Guiding Patients in the Hospital

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Abstract. Automated patient guidance in a hospital can be a helpful service for outpatients. In fact, they often need to move independently to reach locations where medical cares are provided. The provision of such a guidance service motivated the development of MobiDay, a mobile advisory system for patients. A live user experiment of the first version of MobiDay revealed some shortcomings that stimulated the design of a new improved version that is illustrated in this paper. The new system focus on the exploitation of a workflow management system and on the usage of multiple and distributed user interfaces.

Keywords: Guidance service, mobile services, workflow management, distributed user interfaces.

1 Introduction

Patients visiting a hospital may be involved in rather complex sequences of tasks and may be requested to independently reach the location where medical cares are provided. This may pose problems to them, especially to those suffering from serious diseases or aged. Therefore, patients could benefit from using a personal electronic guidance service that provides support for the execution of hospital activities. For example, they can be instructed in their next task, informed about the location where it takes place, or notified of a possible delay.

The provision of such a service is addressed in the MobiDay research project [11,12]. In this paper we first briefly illustrate the function of MobiDay, and we summarize the results (presented in [12] in details) of the evaluation of a first system prototype performed in a clinic: the oncological day hospital of Meran (South Tyrol, Italy). Then, we describe and motivate the features of a new improved system, addressing three main requirements: (1) extend the guidance service to other clinical processes, in addition to that of the oncological day hospital; (2) provide guidance to a wider range of patients; (3) improve the robustness and effectiveness of the guidance service, overcoming the drawbacks of the first version of MobiDay. This new system, which is currently under development, is based on the use of multiple (including mobile) devices and distributed user interfaces. Moreover, it adopts a workflow system to model and properly manage general clinical processes. In this paper we discuss two research issues:
how to automatically generate and deliver personalized guidance messages (given patients’ workflow and contextual variables); and how to combine multiple information channels supported by different devices. In the current phase of the project we are focusing on message generation and delivery. In particular, we are developing methods for determining the optimal time for sending notification messages to the patients, such as those conveying apologies for time delays. The delivery media we are currently considering is the patient’s smartphone. In a second phase we will move to the use of multiple devices and try to find out which combination of various channels is more adapt for information delivery given the patient’s context, profile, and device preferences.

The rest of the paper is organized as follows. Section 2 illustrates the main goals of the MobiDay project. Section 3 illustrates our experience in the development and evaluation of a first system prototype. Starting from the lesson learned, Section 4 briefly presents the design of a new version of the system. Section 5 focuses on the two research issues mentioned above. Finally, Section 6 concludes the paper.

2 MobiDay: Advisory Services for Patients and Clinicians

The goal of the MobiDay project is to explore the application of (mobile) advisory services supporting patients and clinicians. In particular, we target a system that supports the three services illustrated in Figure 1.
The questionnaire service helps clinicians in the administration and elaboration of clinical questionnaires collecting comprehensive information on patients’ conditions.

The info & tips service provides patients with: information useful to enlarge their knowledge about their diseases; notification of medicines to be taken; and tips on how to avoid side effects of therapies.

The guidance service gives patients directions for the execution of their usual or occasional clinical activities in the hospital.

In this paper we focus on the last service because only this was intensively tested in a first prototype. The design and implementation of the other two is still in a preliminary stage. Then, we will illustrate the most important and innovative features of the second version that we are implementing.

3 MobiDay 1: A Mobile Application for Oncological Outpatients

MobiDay 1 is a mobile application that supports patient activities in a day hospital process [11,12]. The system provides the first and third services illustrated above. Patients can fill out on dedicated smartphones questionnaires on the quality of life. Moreover, a guidance service pushes on the patients’ mobile messages about their next tasks in the hospital. We developed MobiDay 1 for the oncological day hospital of Meran (South Tyrol, Italy). The users are patients periodically visiting the clinic for examinations and treatments. The day hospital process consists of a sequence of three clinical tasks, namely, Blood Analysis, Medical Examination, and Therapy, interleaved by waiting periods of unpredictable length. These tasks and waiting periods are the states of the patient’s workflow.

The guidance service of MobiDay 1 is accessible via a simple touch-based graphical user interface we implemented for Nokia N97 smartphones. Textual guidance messages are sent to the phone when MobiDay 1 recognizes a relevant situation. Message-sending rules, which are implemented on a server component, have been elicited from the clinicians by means of interviews, identifying the relevant situations of the day hospital process and the corresponding information messages. The notification of an incoming message is based on the haptic (vibration of the mobile device) and the visual (popup dialogs) modalities.

The usability of MobiDay 1 and the performance of the guidance service have been evaluated in a 4-month-long user study [12]. In the experiment, 20 patients were given a smartphone equipped with MobiDay 1 and they used the system for two consecutive visits in the day hospital. MobiDay 1 transparently logged all the message reading actions performed by the patients and sampled their feedbacks on the appropriateness of the messages by explicitly requesting the patients’ opinions. After two visits, the patients were asked to evaluate the system usability by filling a standard questionnaire (CSUQ [13]) that we extended with some specific questions about the performance of the guidance service. This
study showed that \emph{MobiDay 1} was in general well accepted, although not all the subjects felt completely comfortable using the system. In particular, the guidance service was evaluated as effective, the content of the guidance messages was considered helpful by the patients, but the timing of the messages was not always perceived as appropriate. By inspecting the system logs we derived some explanations for this weakness:

- One third of the messages were read much later than when actually received, hence they were obsolete and not useful anymore. We conjectured that they have not been noticed because of the selected notification mechanism, i.e., the vibracall. This was confirmed by some patients, who reported that the vibration of the smartphone was too weak.
- For some patients, the system recorded a sequence of activity steps that did not follow the correct order (i.e., \emph{Blood Analysis}, \emph{Medical Examination}, and \emph{Therapy}). In fact, we discovered that this was caused by wrong state changes made by the nurses. Because of this, some of the sent messages were not appropriate for the patient’s situation.

4 MobiDay 2: an Enhanced Web Based System

The lesson learned from the evaluation of \emph{MobiDay 1} and the goal of expanding its applicability to a larger number of hospital scenarios motivated a new system design that focused on three main objectives:

1. Provide a single web-based access point to all the system services introduced in Section 2 namely: \emph{clinical questionnaire filling} for the patient; provision of \emph{personalized information and tips} on the patient’s disease; and \emph{guidance in the hospital} (discussed in this paper).
2. Adopt a workflow management system to model and manage a larger set of clinical processes. The goal is to extend the scope of the guidance service to other hospital units and to increase its robustness and tolerance to human errors.
3. Support a collection of distributed user interfaces. This is aimed at extending the guidance service to a wider range of patients and at improving the convenience of the service, giving to the patients the choice of accessing the system with the preferred and more suited device and interface.

Starting from these objectives, we have designed the logical architecture of \emph{MobiDay 2} including three types of components: \emph{portlet}s (which interact with the GUI), \emph{internal components}, which implement the business logic of the system services, and \emph{wrapper components}, which implement the access to external legacy components such as the workflow management system (see Section 4.2), the application for the elaboration of clinical questionnaires, or the system databases.

In the rest of this section we will detail each objective and describe the status of its development.
4.1 Mobile Web Solution

*MobiDay 1* was implemented as a J2ME [14] native application that must be installed on the phones used by the patients during their visit. Not all mobile phones support J2ME and therefore we provided the patients with special phones (Nokia N97). But this forced the patients to use a new device and to learn how to use it. That decreased the usability of the system [11]. In order to overcome this problem and to enlarge the number of potential users, we have decided to design *MobiDay 2* as a mobile web application. It will be accessible via the standard web browser that is available on many mobile phones, and also on other types of devices (e.g., tablets, kiosks, and PCs). However, mobile web development is still at an early stage, and there is a large variability in the level of support for mobile web standards (e.g., CSS [19], or HTML 5 [18]) in the available mobile web browsers [8]. For this reason, special techniques are required to adapt a mobile web application to multiple devices.

To address this issue, we have adapted the questionnaires service of *MobiDay 1* to many classes of smartphones, tablet-like devices, and PCs. All the service web pages have been written in XHTML Mobile Profile; the most popular markup language for mobile devices. The web application reads, in the request headers, the device’s user agent. Then, it queries the Device Atlas database [2] to access the device features. Accordingly to these features the web pages are rendered using five customized CSSs, each one adapted for a major class of device displays. For example, Figure 2 shows the rendering on a smartphone of the interface used by the patient to fill out a questionnaire on the side effects of her therapy. A similar design solution will be adopted for the other services of *MobiDay 2*.

4.2 Workflow Management

The guidance service implemented in the first prototype of *MobiDay* was developed for an ad-hoc scenario. Actually, hospital processes are more complex: they are composed by tasks having various kinds of execution (e.g., sequential, parallel, or alternate); they involve many actors (e.g., patients, doctors, nurses, administration staff, or caregivers); they need to synchronize with other processes (e.g., the blood analysis process with the oncological day hospital process). A valuable patient guidance service should be based on the full model of the hospital processes. But, at the same time, this additional complexity must be hidden to the patients and exploited only to give them better and more precise information.

Business process and workflow management systems offer tools to deal with this complexity: (semi-)formal notations to represent the interplaying of hospital activities; engines for the controlled execution of workflows; automated logging of workflow execution; and, process mining to extract knowledge from event logs. The research on workflow management in healthcare is very active. Research works have been recently published on the modeling of hospital processes [16], on the dynamic compilation of web services to support workflow management in a hospital [20], on adaptive clinical workflows [17], on agents that monitor...
the patient’s workflow and send alerts to clinicians \cite{23}, or on the application of process mining in healthcare \cite{15}.

We have selected the workflow management system to be introduced in \emph{Mobi-Day 2} by considering the requirements imposed by the specific processes of the Meran hospital and the suitability for the development of the guidance service. In particular, we were interested in a tool that:

- Provides messages as first class objects and support their management, e.g., program their conditional delivery. This helps in the definition of a message posting mechanism, more flexible and robust than the ad-hoc rule-based algorithm currently implemented.
- Allows the modeling of processes including tasks of different types, in particular permits the design of workflow in which human tasks executed by different actors (e.g., nurses, doctors, or patients) are interleaved with tasks performed by the system (e.g., the automated decision on generation and sending of the guidance messages).
- Can constraint the tasks in the workflow that are executed by humans. This, for instance, allows to prevent or at least to reduce the errors made in \emph{MobiDay 1} by the nurses when changing the state of the patients. In practice, the GUIs used by the nurses to perform the state change must permit the activation of only the patients tasks that follow the current one in the workflow.
The workflow tools that we considered were jBPM [3], Activiti [1], BONITA [6], and YAWL [22]. The former three systems are commercial (even tough open source), while the latter is an academic research tool. From our evaluation YAWL appeared more complete: it has a formal semantics, provides full support for workflow patterns [21], allows to model workflows that are dynamically adaptable, and produces logs that can be inspected by process mining tools. On the other hand, the notation used to represent workflows is not standard and there is one single implementation. The other three tools use the standard BPMN 2.0 notation for workflow representation [24], have a wider community of users, and can be more easily integrated into information systems based on standard technologies. This latter consideration was decisive for the final choice of BONITA, as well as the fact that this system is being adopted in the hospital of Meran also for other projects.

We have started to model the Meran hospital processes using BONITA. Figure 3 shows the model of the day hospital workflow. With respect to the simplified workflow informally considered in MobiDay 1, we have been using BPMN 2.0 to represent the steps of the patients (Blood Test, Medical Examination, and Therapy) and the transitions between them. We have also extended the model with two tasks (Dismissal and Transfer) that we did not consider in MobiDay 1. The transitions among tasks are the step changes that the nurses are allowed to perform. That is, the structure of the workflow constraints the options that are shown to the nurse by the system. Tasks with multiple out-transitions represent steps that can be followed by various activities depending on the clinicians’ choices. For example, in Figure 3 the medical examination can be followed by the chemotherapy, or the patient can be hospitalized because her conditions are critical (Transfer), or she can be directly dismissed (Dismissal).

![Fig. 3. Oncological day hospital workflow modeled with BONITA](image)

### 4.3 Distributed User Interfaces

*Distributed user interfaces* is an active research area developing methods and technologies that allow users to interact with information systems via multiple devices and GUIs. Some research works (e.g. [45]) have investigated the use of distributed interfaces for the coordination of the clinicians’ activities in the
hospital. To our knowledge, their usage for implementing guidance services for patients is still an unexplored field. In fact, the coordinated use of multiple communication channels is important to reach as many users as possible, by making the same information accessible in alternative ways, and letting the user to select the most convenient one. In particular, several studies have been recently considered the combined use of mobile phones and wall displays in public places (see for example [10], [9]). The focus of these research works was mostly on the interaction with a wall display in various public settings, using the mobile phone to obtain personalized information related to what was currently displayed.

In our application scenario public displays will be only used as output devices, for displaying anonymized information (e.g., Patient: P1, Room: 2.60, Waiting time: 5 mins). Conversely, private mobile phones and kiosks (whose displays are not publicly visible) will be used to provide personalized details. We have designed and partially implemented the interfaces for public and private devices. For example, Figure 4-(a) illustrates the interface that has been developed for displaying messages pushed to the patient’s mobile, informing her about the next medical examination. Figure 4-(b) shows a view, displayed on demand on a kiosk, where the patient can pull the status (either done, or ongoing, or to-do) of her activities in the hospital. We will support the patient interaction with mobile phones and kiosks using two modalities: autonomous access to the information about the patient hospital process; or browsing of the push messages sent (only) to the mobile.
5 Research Issues

The design choices of MobiDay 2 open several research directions. Here we briefly introduce two interesting topics: how to automatically generate and deliver the guidance messages; and how to design a more effective and usable guidance service based on a human-system interaction via various devices and interfaces.

When MobiDay 1 must notify the starting of a new task, it sends the same message to all types of patients. It is interesting to investigate how the system could automatically generate personalized messages. A first knowledge content to be used in this personalization is the pattern followed so far by the patient in her clinical workflow. The personalized calling message for a specific activity could depend on this knowledge, i.e., the tasks that the patient has previously performed in the workflow. For example, the message could include an explanation of the reason why a specific examination or analysis is needed. Another dimension to exploit is the personal attitude of the patients towards the messaging service. Some patients could prefer notification messages structured differently; or they would like to receive apology messages in case they are waiting too long for their next activity. There are studies (e.g., [7]) that investigated how to generate personalized motivation messages that push users to conduct physical activities. We believe that similar techniques could be applied also for generating the content of guidance and apology messages.

As for the timing of delivery, the right time for sending a message might depend on the profile and on the context of the patient. For example: people who are particularly anxious may prefer, when waiting for the next activity, to receive frequent updates on the status of their process, so that they are reassured that the hospital has not “forgotten” them; but, on the other hand, these messages would be useless or even annoying for people having a calm attitude. For messages that notify the starting of an activity the situation is different: they have to be delivered immediately as soon as the workflow changes from a “waiting” state to an “execution” state. However, it may happen that the user misses the notification, e.g., because she was distracted by other patients or was focused on another activity. In these cases the system, provided that it has detected correctly this situation, could send a reminder. Developing context-aware strategy for guidance message delivery is another research direction we want to investigate.

In MobiDay 2 we are currently considering two types of messages: call for activity and apology. A call for activity message is sent whenever there is a step change in the workflow. Apology messages are sent if the patients have waited too long for an activity. The time for sending an apology message depends on the workflow step, the patient’s psychological profile and the patient’s context. The patient’s psychological profile is derived from the answers to a questionnaire on the quality of life. The patient’s context includes the waiting time of the patient, the time from the last message, and the time from the last patient call for activity.

We hypothesize that a more effective and usable message notification service can be designed by exploiting multiple channels (devices and interfaces) for in-
formation provision. Obviously, to achieve that objective these channels must be suitably coordinated. Many coordination strategies can be envisaged: e.g., adaptively limit the use of the push interaction modality; or duplicate information on different channels; or provide complementary guidance data in selected interfaces.

Finally, various metrics can be adopted for measuring the effectiveness and usability of MobiDay 2. The effectiveness could be measured by monitoring the average difference between the time a calling message is sent and the starting time of the activity. The usability of the guidance service could be assessed by standard usability questionnaires, for example the CSUQ questionnaire already adopted for MobiDay 1.

6 Conclusions

Automated guidance in the hospital is an important service for patients. In this paper we have briefly presented MobiDay 1, a mobile application guiding patients during their day hospital process. We have illustrated some of its weaknesses that emerged from a field user study. We have presented the major ideas for the design of a new improved version: MobiDay 2. First, the adoption of a workflow management system to model and properly manage the clinical processes in the hospital. Second, the introduction of multiple and distributed user interfaces for offering guidance to a larger number of patients and for improving the effectiveness and usability of the service. The current status of development of MobiDay 2 has been described. We have identified two main research issues. The first is related to how personalized guidance messages can be generated. It should be based on the analysis of the workflow patterns executed by the patients and adapting the notification strategy to the patient’s personal profile and context. The second relates to the analysis of the most suitable strategies for the coordination and distribution of guidance information on multiple devices and interfaces, in order to maximize the overall usability and effectiveness of the service.

References