# *Smart Dosing*: A mobile application for tracking the medication tray-filling and dispensation processes in hospital wards

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**Abstract.** Traditionally in hospitals the task of dispensing medications to patients can be strenuous for the hospital staff, as many variables have to be considered, such as searching for a particular medicine in shelves, finding alternative active components and possible interactions, verifying the amount or dosage of the medicine, keeping in mind the intake timings and other meticulous details. In addition to that, the dispensation process is the combination of many manual and computerized steps which do not function together. In this work, we have gone a step forward towards automating the whole process by combining information from different sources and providing it on a single centralized rich internet application. The application Smart Dosing helps nurses in performing the filling and dispensing of the medicine tray more efficiently. The application allows nurses to keep history of the medication distributed and dispensed to patients, as well as it makes the whole process smoother by improving the patient safety. A survey was conducted among nurses to validate the application prototype usability.

**Keywords:** eHealth, Health care, Hospital, Ubiquitous Computing, Medication Tracking, Dispensation, Usability

## 1 Introduction

From 700 to 1700 lives are claimed every year due to hospitals medical errors in Finland [5]. Medicine dispensing related-tasks can be seen as a major cause

among these errors. During the last five years, over 340,000 incidents of medical errors and patient safety incidents were registered in Finland's hospital districts [5]. Nurses have to perform manual and computerized tasks which could lead to potential oversights and hence, result in errors. In order to enhance the usability of the dispensing system, different tasks involved in the dispensation process can be combined in a web application. Such applications can be useful for the nurses if they can access real-time patient data and monitor and track hospital tasks accordingly [11]. Likewise, nurses can benefit from such applications running on portable devices such as smart phones and tablet PCs. This paper addresses the mentioned issues by proposing a *Smart Dosing* application [10], which can reduce the work load for nursing staff and minimize the chances of mistakes.

Data synchronization can become a bottleneck in such dynamic situations. To address this issue, changes done by one nurse will be immediately visible to any other nurse. The application can make the decision making process convenient for the nursing staff in two phases. In the first phase, it assists the nurse when filling the medicines into dispensation trays for multiple patients; while in the second phase, it helps assisting the process of medicine dispensation to patients. Generally, the application keeps track of each task performed by any nurse for a specific patient.

The rest of this paper is organized as follows. Section 2 presents existing applications and devices for health care and medication intake tracking systems. Section 3 details how the medication dispensing processes happens in Finnish hospitals nowadays [11]. The proposed Smart Dosing application architecture and functionality is presented in Section 4. Section 5 presents a survey conducted among nurses to validate the application usability, and Section 6 details conclusions and further work.

## 2 Related work: medication tracking

As the population is getting progressively older, the need for higher quality and better efficiency in health and medicine, both at home and hospitals, is becoming more important. It is obviously a requirement for the patient in order to increase comfort, but it is also valuable for the society to increase efficiency and provide cheaper health delivery.

A side problem both at hospitals, and also when it comes to automedication, is keeping treatment adherence in patients [8]. In this section we describe some applications that share these aims concerning both medication preparation and intake.

*Wedjat* [15] is an application that uses medicine properties and prescriptions to remind patients about the next medication intake time. For example, if the patient forgets or cannot take the medicine, Wedjat recalculates the next dosage time by considering properties such as prescription and dosage.

*Healthcare at Home* (H@H) is a healthcare system [14] with three subsystems: automatic medicine dispenser (AMD), fall detection and communica-

tion device, and entry hall detection system. The AMD subsystem takes care of dosage and intake times.

The *e-pill* system [1] is another device which alarms and dispenses the medicine in a cup included in it. Medicines and dispensing instructions are fed to the system by the medical staff, and the device is adapted also to patients with disabilities such as the deaf or blind.

*Smart TV Medicine Tracker* [16] is a medicine intake support system that aims at notifying the user about the intake and keep records of all taken medicine. As any recent TV could be transformed into a Smart TV by attaching the set-top box to it, the TV setup includes what, when and what amount of medication to take. Then, the TV can display a subtle notification in the top area of the screen, and notify with a sound. However, the most challenging task in medicine reminder applications is how to check that the user actually takes the medication.

*Life Capsule* [6] is an adherence enhancing application for medication intake, based on *a pill box that tweets*. Once programmed, the box lets the followers know if the owner forgot to take the pill. Other application for medication adherence is *MediSafe* [3].

A comprehensive solution in [13] is proposed to enhance adherence for the mild and moderate Alzheimer patients, involving not only the patient but also other participants, such as the nurse and/or relative, the drug store, the physician and the hospital. The solution includes the development of an automatic medication dispenser and the corresponding software applications. The first hardware and software prototypes are described in [13].

*Epocrates* [2] is a clinical decision support system for diagnostic and therapeutic guidance that aids the prescription procedure. It allows to visualize drugs, interactions, notifications, resource centres, FDA alerts, safety considerations, pharmacology, and to contact manufacturers.

As it can be seen in this section, as an extension to [11], there are many solutions that help remind, guide and motivate on medication intake, such as [8]. However, our aim is to build a mobile application to aid the medication preparation procedure, previous to the dispensation process within hospital wards, i.e., filling the medication tray, as well as its dispensation to patients. As a follow-up to the lessons learnt in a pilot test observing nurses at the hospital ward, conducted in [11], in this paper we focus on building an application that can support them saving time and reducing errors, as well as reducing the workload in the medication dispensation task. We evaluate the application's usability. The current process and our proposed application are detailed in next sections.

## 3 The medication dispensing process in hospitals

Nowadays, dispensing medication to hospital patients is carried out manually. We realized a field work study at the hospital where we observed the nurses' performance of their daily tasks through eye-tracking glasses and a stress sensor and we reported on the most time consuming subtasks [11]. It was found that a lot of time goes into double checking the list of medications (including

the shape/colour of the pills out of their boxes), and writing notes on papers on exceptions or substitutions, among other subtasks. Since there is space for improvement on the medication preparation procedures, we propose a mobile application to optimize the process [11].

The medication dispensing task involves a set of smaller subtasks [11]. The first one is to print out the medication lists of the patients from their electronic health records. The printed lists are then cut to the right size to fit and be added in the tray slot. The next subtask is to sterilize the work area and hands. The following step is to organize different medicine cups to be filled [11]. Each colour of the cup represents a specific time for dispensing during the day (such as yellow for 8 h, red for 14 h, green for 16 h and blue for 20 h). The next job is to fill the medicine cups with medicines according to the medication list. In case the required medicine is not found in the cabinet, nurses have to look up the medicine in the *Pharmaca Fennica* [7] equivalence catalogue and find a substitute. When the filling is done, another nurse will check the medicines and carry the tray to the ward where the medicines are dispensed to the patients. Patient records are in a separate database, and therefore, nurses often have to go to double-check patient or treatment information there while dispensing. Figure 1 summarizes the current process.

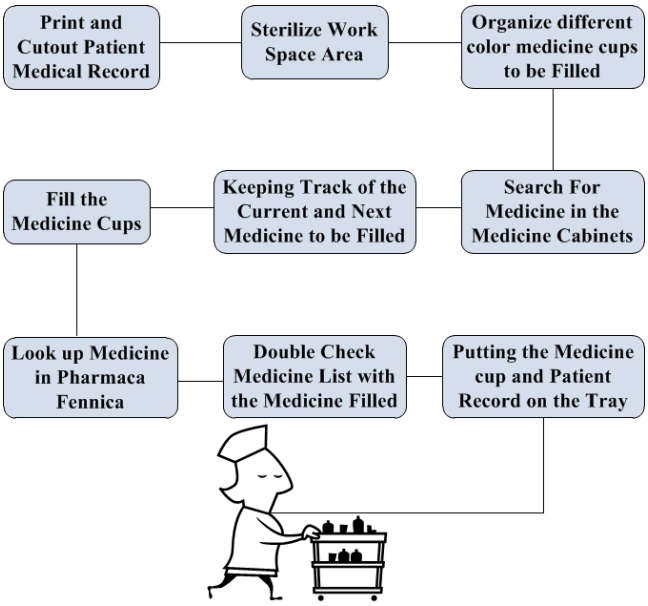


**Fig. 1.** Current medication dispensing process in hospital.

## 4 *Smart Dosing* mobile application

We developed *Smart Dosing* as a mobile rich internet application with the characteristics of a native desktop application. It is built with Vaadin [4], an open source Java-based web application framework for server side and client side development, that allows to develop client-server based applications in the same way as traditional desktop applications. In this way, the framework hides the complexity of the back end to the developer.

Observing nurses in the hospital in our pilot field test [11] allows us to draw some functional requirements for Smart Dosing. The system should aid nurses in filling the medicine tray by displaying patient information, the current state of the medicine tray they are filling at the moment, the image of the medicine they have to fill, and indicate the glass colour (or tray slot) where the medicine should be filled in. When the medication is to be dispensed, the patient information and the associated tray slot in which the physical medicines are placed, should be pointed out. A special remark for the medicines stored elsewhere, e.g., strong narcotic, fridge or injectable medications, helps the nurse in the process. Every action performed by a nurse should be stored in the system log. Direct search of equivalent alternative active component substitutes should be reachable with one click, and the system should allow the nurses to report when a medicine is out of stock, for it to be ordered automatically.

The filling of the tray can be done in order, by grouping first by patients or by medication. The system should be only accessible to the nurses or personnel allowed to deal with the medicines. The system should also allow nurses to skip filling/dispensing a medication and register the reason to skip it. Nurses should have access to all information about patients, medicines and contact information of other nurses within 1-2 clicks.

Regarding non-functional requirements, we identified the need to allow the application to run on any mobile device, as well as keeping easy interface for versatile and fast usability.

Smart Dosing user interface, as shown in Figure 3, shows an overview of the current status of the tray which is to be filled. The state of the tray is dependent on the number of patients that have been or are going to be given their medication. For each patient whose medicine is filled for, the medication is shown on a particular slot on the tray to help keeping track of the iterative task. On the top right corner of the interface, there is a figure of coloured medicine glasses which specifies the timing for medicine intake. Different glass colours represent different time of the day in which the medicine should be taken (usually there are four times per day). The interface also shows, below the glasses indications, the appearance of the medicine package to be searched for in the cupboards, and a picture of its interior pill (if available or applicable) to recognize it once it is outside its original package. The interface for the *fill tray* task provides more functionality to the nurses. The first one is the possibility of searching equivalent medications (by active component) if a given medicine is not available. The second option provides the nurses with an overview of the treatment prescribed by the doctor to the patient whose medicine they are dealing with at the time.

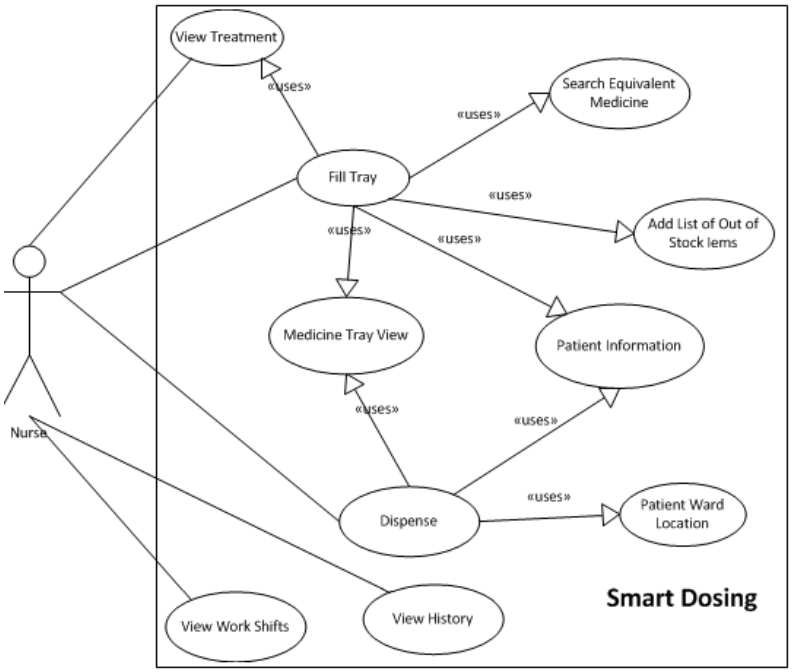


**Fig. 2.** *Smart Dosing* application use cases

Another functionality is the provision of a report of all medicines out of stock. In case the nurse is filling a medicine in the tray and it runs out from the storage, the nurse can report that medicine as being *out of stock* and indicate the required ordering amount. A schema of use cases for the Smart Dosing application can be seen in Figure 2, where actors (nurses) interact with the different functionalities of the system described.

In the *dispense medication* task interface, as shown in Figure 4, there is one other option for the nurses to skip the medicine. When the nurse clicks the *skip medicine* button, she can enter the reason for skipping a particular medicine. The most common reasons to skip the medicine are provided, but if there is any other reason, it can be annotated and saved as comment in the register. Examples of reasons to skip the dispensation of the medication are, for instance, changes in treatment due to surgery, the patient perhaps does not feel well, or there are cases in which the patient keeps the medication with him, as when it relates with some chronic disease.

The time of dispensing, the medicine and the nurse who has dispensed the medication is updated in the *History* view. In case the medicine is skipped for any reason, then the reason for skipping the medicine is shown in the history, together with the dispensation time and who dispensed which medicine to which patient. The aim of these functionalities is to help nurses performing the medicine preparation and dispensation more safely and efficiently. Other func-


**Fig. 3.** User interface for the *filling tray* process


**Fig. 4.** User interface for the *dispensing tray* process

tionality, apart from medical records integration, should be the overview of the shift schedule of the nurses for coordination purposes. A log with all timed events on filling and dispensation of trays facilitates the sharing and synchronization of information.

## 5 Application usability evaluation

To validate our first prototype of the Smart Dosing application and understand the behavior of nurses regarding its usability, a survey was conducted. 13 nurses participated in the survey, belonging to the age group of 24 to 42 years old, with a working experience ranging from 2 to 14 years. All participants are working in different hospitals in Turku, Finland. The main motivation for conducting this survey was to verify the application design and its usability with its end users, which are nurses working at different hospitals.

Eight questions were formulated in the survey questionnaire. Participants were asked to score their response between 1 and 5 (1- Unlikely, 5- Likely). The questions and average answers are summarized in Table 1. Most of the participants reported a high level of satisfaction in terms of usability and how Smart Dosing would help to minimize their workload.

**Table 1.** Statistics for user experience regarding the application usability.

| **Questions** | **Score 1** | **Score 2** | **Score 3** | **Score 4** | **Score 5** |
|---|---|---|---|---|---|
| Overall Experience | 0 | 1 | 4 | 7 | 1 |
| Using the application would improve the job performance | 0 | 2 | 6 | 2 | 3 |
| Using the application would make it easier to do the job | 0 | 3 | 4 | 6 | 0 |
| Do you find the application would be useful in your job | 0 | 0 | 5 | 5 | 3 |
| Learning to operate the application would be easy | 0 | 1 | 4 | 7 | 1 |
| It would be easy to become skilful at using the application | 0 | 0 | 4 | 6 | 3 |
| Ease of use of the interface | 0 | 0 | 4 | 7 | 2 |
| Are there elements in the application interface that you believe could be improved | 1 | 2 | 8 | 2 | 0 |

The survey results with average score answers are in Figure 5. Around 64% of the participants think that the application will make the job of the nurse easier. This percentage depicts that there are still some tasks which the nurses have to perform manually. Approximately 76% of the nurses think that it can be useful to use the application in the hospitals. Nearly 70% participants have the opinion that using the application will improve the job performance of the nurses. The evaluation survey shows that the adoption of Smart Dosing application in hospitals can bring positive changes in the medication dealing processes, as it indicates its ease of use and adaptability to the nursing daily tasks.

Participants were asked for feedback for improvements in the application, and features such as vital signs measurement annotation tools or sound notifications were suggested for next development steps.

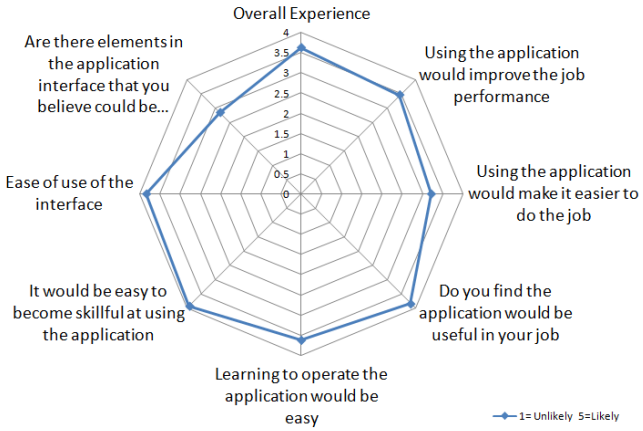


**Fig. 5.** Spider chart for the questionnaire's average responses

## 6 Discussion and future work

Chances of human errors during the medicine dispensation tasks are mainly due to the non centralized information about different databases, as well as due to the tedious work inherent to the meticulous task. For instance, the fact of using pen and paper annotations, having the work done by different nurses and work shifts, as well as due to the absence of a system that tracks all medicine preparation and dispensation history together [11]. As information is collected from various computerized and manual sources, we propose Smart Dosing application to gather all relevant information and make more versatile the tray filling and dispensing processes.

Despite the fact that a large amount of time is spent searching for medication in the shelves, after Smart Dosing is deployed, we expect the time spent double checking, by different nurses, the content of the tray, can be reduced. We also expect that errors can be minimized, and time is saved for more relevant tasks.

In a future pilot test, after further development and deployment of the application in hospitals, we expect to reduce the nurses' time spent on dealing with medications by making the task, at the same time, less tedious and error prone. The survey conducted evaluated the application in terms of its usability and therefore, future work needs to deploy the system to prove if the system actually eliminates or reduces errors in the long run, as well as the workload, in a real world usage validation. We are aware that the relatively low values in the questionnaire may indicate that some nurse requirements are not met yet, and we need to make sure the expenses for learning and deploying such a system pay off, and that the introduction of the software into the working clinical settings does not come with adverse effects such as in [9] and [12]. The latter works show that the deployment of a computerized physician order entry system unexpectedly but significantly increased mortality rates from 2.8% to 6.57% after its implementation.

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