MeMDAS: Medication Management, Dispensing and Administration System

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Abstract—MeMDAS is a distributed system of smart medication cabinets and mobile nursing carts. It provides pharmacy and nursing staffs with medication delivery and inventory monitor capabilities, in addition to smart point-of-care tools for prevention of medication dispensing and administration errors. This paper describes its distinguishing capabilities and novel workflow-based architecture and implementation.

Keywords - Automated medication management, bar-code controlled medication dispensing and administration, intelligent mobile carts, multi-user medication station

I. INTRODUCTION

This paper describes the distinguishing capabilities, architecture and implementation of a distributed system of smart medication cabinets, mobile nursing carts, and software tools for the purpose of preventing medication dispensing and administration errors. The system is called MeMDAS (Medication Management, Dispensing and Administration System). Figure 1 shows how MeMDAS complements computerized physician order entry (CPOE), clinical decision support, and electronic patient health and medication records (ePHR and eMAR) systems [1-4] in the chain of tools that support medication use process.

II. CAPABILITIES AND COMPONENTS

Again, MeMDAS is a system of medication stations and mobile carts that supports the dispensing and administration stages of medication use process as depicted by Figure 1. It provides nursing and pharmacy staffs with the following tools and capabilities:

- Medication delivery and inventory monitoring capabilities for containing medication use costs;
- Smart bar-code controlled medication dispensing and administration (BCMD and BCMA) tools for prevention of medication dispensing and administration errors;
- Modern work and time management (WTM), calendar and information access tools to help the users make the medication preparation and administration schedules of their patients central to their workday plans;
• Tools and user interface functions customizable to support automation to the degrees chosen by the users;
• Labor-saving capabilities, such as generating shift report from data and notes collected during the user’s shift, tracking medication and medical supply usages and automating requests for medication replenishment; and
• Customizable intelligent monitor, alert and notification (iMAN) tool to provide the capability of detecting event and action sequences that have a high likelihood to cause errors and alerting the user to take action to prevent them.

Medication stations such as the ones described in [7-9] typically operate in fully automated mode: When a user comes and selects to retrieve medications for a patient, the station opens automatically all the containers holding the medications due to be administered to the patient at the time. Operating in this mode, a station can serve only one user at a time. In a ward with many nurses (e.g., 5-10) caring for patients on frequent medications, the added burden on the nurses to stand in line for retrieval of medications or to adjust their work plans in order to minimize queuing time often more than offset the advantages of using the station. This is the reason that MeMDAS medication stations is designed to be configurable so that they can also operate in semi-automatic mode. When operating semi-automatically, the station server collaborates with the users and their mobile carts to ensure correct dispensing of medications to multiple users at the same time. The next section will describe this collaborative process.

MeMDAS has two types of mobile carts: iNuC (intelligent Nursing Cart) and BaMU (Basic Mobile Unit). Unlike state-of-art mobile nursing carts (e.g., [7-9]), the software system controlling their operations can be easily configured to make an iNuC work as a BaMU and vice versa.

iNuC 1.0 [10] is a mobile system of tools. Except for BCMD, an iNuC 1.0 offers its user (a nurse) all the capabilities listed above without help from MUMS, and, in events of network and hospital information system outages, can function stand-alone. The newer versions of iNuC can also collaborate with MUMS servers to enforce BCMD.

A BaMU is a light-weight system of mobile tools for use by nurses during bar-code controlled dispensing of medications from MUMS. It relies on a MUMS server to provide work planning, scheduling and monitoring and alert functions. Some BaMU do not have the medication administration and patient record keeping tools provided by iNuC. Some of such BaMU’s are used in wards that have computers at patients’ bedside for these purposes. Such a BaMU can also function as an intelligent medication supply cart for use by pharmacy staff.

Figure 2 illustrates the alternative MeMDAS configurations used for centralized, distributed and hybrid dispensing. In a hospital using centralized dispensing process, the pharmacy prepares and delivers daily to each ward a supply cart with drawers. The daily doses of medications for each patient in the ward are in one or more drawers. As part (a) shows, one or more MUMS are used in the pharmacy together with BaMU’s as intelligent supply carts. Together, they support BCMD and make the process of preparing supply carts less error prone.

Distributed dispensing process is often used for departments and wards (e.g., ICU and OR) where patients’ prescriptions change frequently. Part (b) of Figure 2 depicts the use of MUMS and BaMU in such wards to provide control and safeguard: The pharmacy monitors and stocks the cabinets in the station with all or most medications needed for patients in the ward. At times when some medications are due to be administrated to one or more of her/his patients, each nurse retrieves individual doses of the medications for each patient from the cabinets under the control of the station server and the nurse’s BaMU. We will return shortly to describe this process.

Distributed dispensing tends to increase workload for nursing staff. This is why hybrid processes are common. As Part (c) of Figure 2 illustrates, some medications are dispensed and delivered via supply carts by the pharmacy department. Some patient wards also have medication stations and use them to hold controlled drugs and frequently used medications, making it possible for nursing staffs to get newly ordered medications on a timely basis.

In wards where dispensing is centralized or hybrid, nurses uses iNuC for BCMA: To put the medication drawer of a patient under the control of an iNuC, the nurse removes the drawer from the supply cart, scans the bar-code patient id in the drawer to capture the id and then puts the drawer in any empty drawer slot of his/her iNuC. Sensing that a drawer is placed in the slot, the RFID reader of the cart reads the tags on the drawers. In this way, the cart acquires the association between the id of the new drawer, its location in the cart and patient’s bar-code id. From this information, it creates the mapping between the drawer location and the patient id. Later, when the patient is due to take some medication(s), the nurse can have the cart open the patient’s drawer at bedside by scanning the patient’s bar-code id in the wristband worn by the patient.

III. BAR-CODE CONTROLLED DISPENSING PROCESS

Figure 3 shows a design of MUMS that can operate in both fully automatic and semi-automatic modes. Each medication container in MUMS has a label. The label has the name and the bar-code of the medication inside. Each drawer also has a small LED display. When the station is configured to work in the semi-automatic mode, the LED’s on the drawers holding the patient’s medications display the names of the nurse and the patient when a nurse comes to the station and selects to retrieve
medications to be administered to a patient. Thus, the displays help the nurse locate the containers, which remain closed.

Figure 3 Multi-User Medication Station

Figure 4 depicts a scenario to illustrate the semi-automatic BCMD process. In the flow cart, solid arrows indicate communication between the cart and server, and dotted arrows represent passage of time, user actions, etc.

Figure 4 Scenario illustrating semi-automatic BCMD process

The scenario starts when a nurse (named Robin in the figure) signs in the MUMS server at the start of his/her shift. Hereafter and until the nurse signs off at the end of his/her shift, the server keeps track of his/her patients’ medication schedules. Whenever it is time for administering medications to some of the patients, the server sends reminders to the nurse via devices previously specified by the nurse.

The use scenario assumes that there is a medication drawer tagged with RFID for each patient in the ward. The mapping of

drawer id and patient bar-code id was created by the MUMS server when the patient arrived at the ward. The ward has mobile BaMU on carts for plugging in patients’ drawers.

When a nurse receives a reminder, she finds an unused BaMU (cart) and logs in. Until she logs out, she is the sole user of the cart. The server maintains the mapping of the ids of the nurse and the cart and uses the mapping to keep track the actions of the nurse.

In response to the nurse’s selecting RetrieveMedication, the server sends to the cart names of patients due for medications at the time. After working with the nurse to make sure that the medication drawers of all these patients are in the cart and locked in place, the cart displays the patients’ names. (The ids of the drawers and their locations are discovered by the cart as described earlier for iNuC.) This is illustrated by the left half of the fourth row in the flow cart.

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medication administration and patient medication record keeping tools. Clearly, the usability and cost-effectiveness of MeMDAS would be diminished if a hospital using the system were forced to stock three different kinds of carts. This is a reason that configurability is essential.

The approach we have taken to achieve configurability, as well as customizability, is to have the MeMDAS software system and tools designed and built around a workflow-based architecture. Workflow approach has been widely used in enterprise computing systems for automation of business processes. Indeed, the workflow engine provides a flexible platform for integrating reusable components.

Figure 5 shows the workflow-based structure for iNuC 1.5 to illustrate how flexibility can be achieved. The block diagram intends to highlight the commonalities among iNuC, BaMU and MUMS Server: Only boxes representing the host and state machine workflow are labeled by “iNuC” because the systems differ primarily in these parts. In particular, the state machine and module local services interfaces in all systems are the same. Similarly, the workflows provided by other modules are identical: Each module provides the capabilities required by all the systems. By replacing iNuC state machine workflow with a BaMU state machine workflow, we can make the GUI, and thus the cart, behave like a BaMU.

Figure 5 Structure of workflow-based iNuC

V. SUMMARY AND FUTURE WORK

We present in previous sections an overview of the capabilities and the architecture of MeMDAS. The primary objective of the system is to prevent medication dispensing and administration errors. The system also provides workflow and time management support to nurses and pharmacy staffs for the purpose of improving quality of care for patients and reducing stress for staffs and monitoring, automation and labor saving tools to help the institution contain costs of care delivery. Details on it capabilities and design and prototyping process can be found at http://sisarl.org.

iNuC 1.0 [10] is a relatively mature prototype ready for use and experimentation by nurses at NTUH. It works only with centralized dispensing process. The source code of this version has been released under GPL license. We are building iNuC 1.5 along with the development of workflow-based BaMU and MUMS server. We expect that the code for them to be completed and system tested by the end of this year.

This version of MeMDAS prototype runs on Windows Embedded Standard and .NET Workflow Framework (WF).

By leveraging the mature design and development tools available within WF, we have been able to focus our design and development efforts on the functionalities and quality of the MeMDAS software. The implementation of MeMDAS on Windows .NET WF is providing us with an invaluable case study on the use of workflow-based designs. This work is a part of our effort in exploiting the workflow approach to make embedded systems flexible. We have built and continue to enhance EMWF (an embedded workflow foundation) [11] as middleware for embedded automation systems and will replace WF by our own enhanced version of EMWF when it is ready.

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REFERENCES


