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Adapting User Interface to Expedite Physician Order Entry: A Frontline to Ensure Patient Safety

Chiang S. Jao, *Member, IEEE,* and Daniel B. Hier

***Abstract*—Preventable medical errors are a major problem in healthcare. Maintenance of accurate problem lists and drug lists in the electronic medical record is critical to the practice of medicine and patient safety. We built a simulator of a clinical decision support system that automates the process of maintaining an electronic problem list by processing drug order requests from a simulated computerized physician order entry system. Preliminary results revealed that the productivity of the system increased when the user interface was improved. This study highlights the importance of an enhanced user interface as a frontline in expediting physician data entry, streamlining better system workflow, and maintaining an electronic problem list effectively to reduce preventable medical errors and promote patient safety.**

***Index Terms*—Clinical decision support system, computerized physician order entry, electronic medical record, medical error, patient safety, user interface.**

I. Introduction

PREVENTABLE medical errors are a major patient safety concern. Two common types of physician errors were reported in the 1991 Harvard Medical Practice Study [1]: errors of commission (blatant mistakes associated with an individual clinician) and errors of omission (unrecognized mistakes associated with missing an appropriate step or a needed action in a process). The health care system has a renewed interest in patient safety problems, as highlighted in the 1999 Institute of Medicine report [2] and several follow-up articles [3], [4]. A recent study [5] attributed the major cause of patient safety problems to "errors of omission", rather than "errors of commission."

Entering accurate clinical information in an electronic medical record (EMR) is critical to the practice of medicine and patient safety, especially the ability to capture clinical information and represent it by a unified controlled medical vocabulary [6]. Direct order entry by physicians is vital to a successful EMR implementation [7]. The computerized physician order entry (CPOE) system is the mechanism by which providers select medications, tests, and services. Full use of CPOE and EMR requires clinicians to maintain an accurate and detailed electronic problem list. This electronic problem list can be used to drive decision support systems, decrease medical errors, and increase patient safety [8], [9].

The traditional user interface for EMR and CPOE requires users to adjust their focus among various KVM devices (the keyboard, the video monitor, and the mouse). This data entry process is labor intensive, time consuming, and error prone. Because of these barriers, most of past efforts on improving the data entry process have been limited. The enhanced use of information technology is being recommended as an important strategy to deliver information fast and accurately to the patient, ensure patient safety, and reduce medical errors in the EMR [10]-[13]. Effective user interface design, including versatile functionalities, significantly reduces the complexity of the data entry process [14].

The patient's problem list serves as the logical threads for organizing clinical documentation made by various clinicians. An accurate and complete problem list can trigger problem-specific decision support rules and aid in physician reimbursement, health services research, operations management and public health reporting [15]. Various artificial intelligence approaches, including natural language processing and rule-based expert system, have been applied to maintaining the electronic problem list [16], [17]. Coded problem lists are increasingly an essential part of patient documentation. Maintenance of accurate discretely encoded problem lists and drug lists becomes a major problem for clinicians. [18].

II. Method

A. Setting

The University of Illinois Medical Center (UIMC) is a tertiary care university medical center. It implemented a comprehensive, paperless EMR in 1996 that incorporated a longitudinal patient data repository, a graphical user interface, physician-driven CPOE, paperless documentation of all patient care activities, and electronic results. Use of the system is now mandatory for all inpatient results and documentation (clinical documentation, radiology, cardiology, and all laboratories), all outpatient clinical documentation, and all inpatient orders. Outpatient orders by the CPOE had been successfully implemented by late 2002. Full remote access to the EMR has been extended to the UIMC community-based sites via the use of computers

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by a HIPAA (the Health Insurance Portability and Accountability Act enacted by the U.S. Congress in 1996)-compliant network over commercial internet connections.

To assist physicians entering the patient's problem codes and medications in maintaining the accuracy of the EMR, we set out to design a Windows-based system (*Problem List Expert*, or *PLE)* that simulates both a CPOE for ordering medications and an electronic problem list [17]. The *PLE* is a stand-alone clinical decision support system programmed in Microsoft Access© enhanced with Visual Basic. The *PLE* uses machine learning and backward-chaining inferencing algorithms to update the knowledge base and perform the matching between coded problems and medications ordered. Through the user interface, physicians can create new patients, create problem lists, and order medications. When a new medication is ordered through the CPOE, the *PLE* checks if an appropriate problem is on the active problem list that is an indication for the drug ordered.

The core of the system is four linked database tables: a table of medications, a table of medication-indication relations, a table of indication-disease relations, and a table of disease-ICD-9-CM® (International Classification of Diseases, Ninth Revision, Clinical Modification) relations. There were over 550 drugs in the University of Illinois drug formulary added to the *PLE*. Other key components of the *PLE* are a patient data repository with problem list and a user interface. The system is driven by entry of a drug list and a problem list (Fig. 1). When an ordered drug is matched with a reported problem on the active problem list, the "match" status is reported and counted as both a "possible match" and a "default match." When the above pairing condition is not met but there exists a problem as the default indication of the drug ordered, this default problem will be suggested to add in the active problem list and counted as a "default match." Otherwise, the drug ordered would be superfluous (ordered without indication) or an orphan drug (requiring building a new drug-indication relationship in the knowledge base). The machine learning algorithm is activated to insert new problems and new relations in the knowledge base. The matching mechanism of the *PLE* assists the physician in detecting duplicate or superfluous drugs on the drug list.

The ICD-9-CM coding system is the primary standard

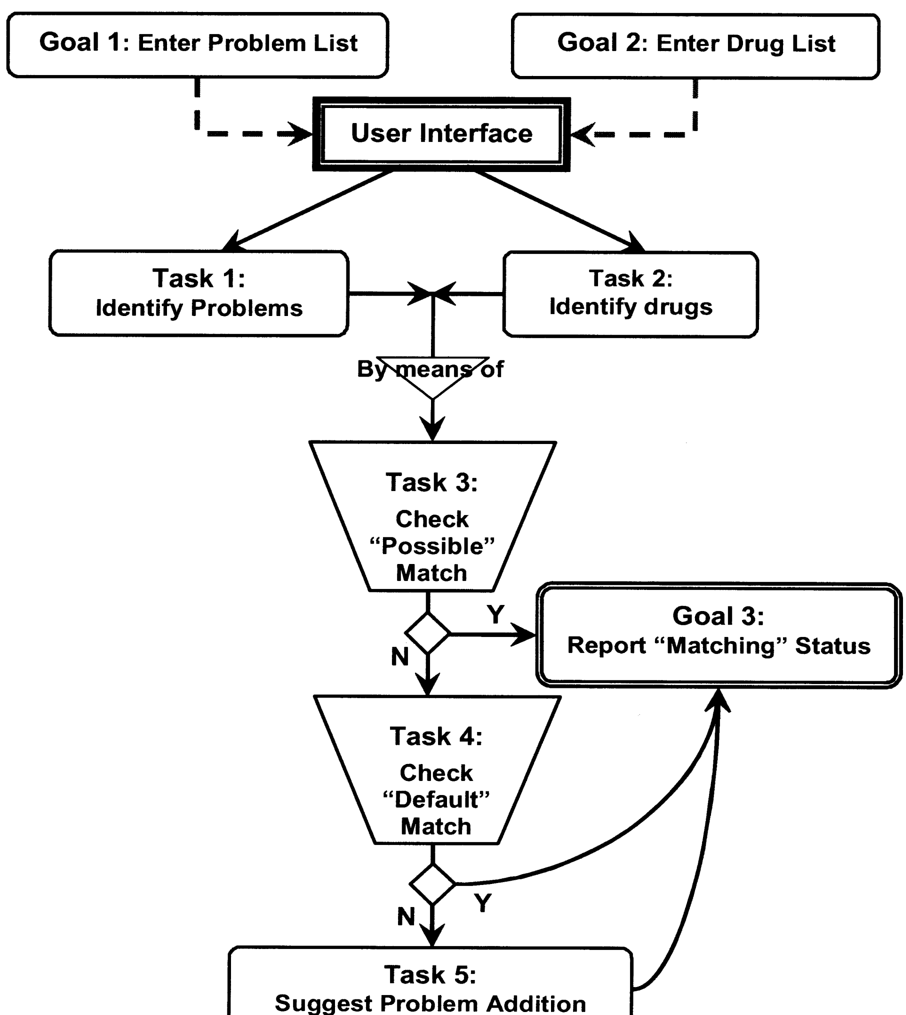

Fig. 1. Fragment of task analysis, illustrating the decomposition of overall process workflow

adopted for coding diagnoses and procedures in the EMR at UIMC while the SNOMED-CT® (the Systematized Nomenclature of Medicine, Clinical Terms) coding system is supplemented as the secondary standard. The ICD-9-CM codes play a key role in the *PLE* to detect any mismatches between the active problem list and the ordered medication list in the EMR. A sample of the active problem list chart is illustrated in Fig. 2. In order to provide the unique coding system in the *PLE*, the SNOMED-CT codes were converted into the equivalent ICD-9-CM codes in the EMR while the same terminologies are applicable.

Name of Problem	Code	Vocabulary	Life Cycle Status
SUBDURAL HEMORRHAGE	432.1	ICD-9-CM	Active
RENAL FAILURE, UNSPECIFIED	586	ICD-9-CM	Active
DIABETES MELLITUS	250	ICD-9-CM	Active
ABNORMALITY OF GAIT	781.2	ICD-9-CM	Active
HYPERPOTASSEMIA	276.7	ICD-9-CM	Active
CORONARY ATHEROSCLEROSIS	414.0	ICD-9-CM	Active
ESSENTIAL HYPERTENSION	401	ICD-9-CM	Active
IRON DEFICIENCY ANEMIA, UNSPECIFIED	280.9	ICD-9-CM	Active
NAUSEA WITH VOMITING	787.01	ICD-9-CM	Active

Fig. 2. A screen capture sample of the active problem list chart, illustrating the layout of active problems

We have previously adapted the *PLE* to maintain the electronic problem list in the EMR. However, the user interface of the *PLE* lacked a direct connectivity to link the *PLE* to the EMR in order to transfer the patient's active problem list and ordered medication list. Preliminary experience on entering data retrieved from the EMR resulted in frustration, especially when the number of reported problems and ordered drugs were lengthy. Early productivity of the *PLE* was low because of laborious data entry. To eliminate the bottleneck of physician data entry into the *PLE*, we implemented an easy-to-operate user interface to streamline workflow.

B. Design

Since the patient's data are displayed as the graphical mode rather than the textual mode on the screen of the EMR at UIMC, we faced a problem that we were unable to capture the screen data needed for the *PLE*. The EMR blocks the use of several screen capture programs to copy needed text data on the EMR screen. To overcome the barrier of direct data entry, a useful Windows-based screen capture and character recognition tool, *Screen OCR* [19], was found and utilized. The user interface of *Screen OCR* is easy to operate as a built-in screen capture tool. *Screen OCR* recognizes any text visible any place of the screen, and copies all captured characters within a rectangular selection as the editable text to the clipboard. The accuracy of the character recognizer is high.

In order to effectively connect the interface of *Screen OCR* with the interface of the *PLE*, we adapted the user interface of the *PLE* to allow physicians to copy multiple lines of formatted textual data from the screen of the EMR. Instead of entering a list of reported problems and ordered drugs in the *PLE* individually, we were able to enter the complete list of required text data in a text block by copying the captured data from the clipboard which was loaded by *Screen OCR*.

We tested a number of consecutive cases on the new user interface for the *PLE*. We performed the assessment of the user interface setting by documenting information flow, task execution, the counts of matches completed, and the time of task execution. Two analyses were conducted in this study: (1) a qualitative analysis on illustrative matching events and trends across cases and (2) a quantitative analysis of task duration on physician order entry and problem-to-medication matching activities.

III. Results

Adapting the user interface of the *PLE* was proven to be a successful implementation that expedited the data entry process. In the past, the user spent more than one minute to enter 14 individual problem codes on the *PLE*. The data entry process was error-prone and delayed by mistaken keystrokes or other incidents (for example, interruption by incoming service requests). The optimized user interface reduced the entry speed for the same data set to approximately 10 seconds. In the meantime, the new operation took approximately 16 seconds to process 19 consecutive drug order requests as well as to match reported problems, compared to 3 minutes or longer with the previous interface setting. Performance assessment revealed that the time for ordering medications and matching the active problem list was affected by three factors: (1) the number of reported problems on the problem list, (2) the number of ordered drugs on the medication list, and (3) the number of default matches (Fig. 3). Preliminary results showed that the overall system workflow was accelerated by the new data entry interface.

The *PLE* was used to simulate the ordering of medications on 15 consecutive patients admitted to the inpatient unit of the University of Illinois Hospital. The mean number of reported problems per patient on the active problem list was 6.9 ± 3.4 and the mean number of drugs ordered per patient on the medication list was 10.9 ± 4.5. The *PLE* decision support system correctly suggested the addition of 3.3 ± 1.2 problems for each patient and was able to match 77 % of the ordered drugs to problems on the active problem list. The mean number of "possible match" problems per patient was 3.3 ± 1.8 and the mean number of "default match" problems per patient was 8.1 ± 2.8 (see Table 1).

TABLE I

OUTCOME ANALYSIS OF CONSECUTIVE TEST CASES (N=15)

	Mean	Standard Deviation
Reported Problems	6.9	3.4
Ordered Drugs	10.9	4.5
Possible Matches	3.3	1.8
Additions	3.3	1.2
Default Matches	8.1	2.8
Matching Ratio	76.7	13.4

IV. DISCUSSION

Adapting the user interface of the *PLE* by integrating the use of *Screen OCR* expedites physician data entry and workflow. The productivity of the *PLE* increased after the bottleneck of the data entry process was eliminated by an enhanced data entry interface. The saved time in expediting maintenance of the electronic problem list was noticeable. The operational improvement streamlined the workflow of the decision support system.

Screen OCR is excellent at recognizing numeric characters. However, the screen typeface on the EMR limits the effective use of *Screen OCR* in the recognition of a few vowels. For example, lower-case "l" was misinterpreted as capital "I" whereas it was the first letter of a line within the rectangular selection. A small number of problem names and drug names containing these letters were not recognized by the *PLE*. These minor errors could be fixed by adding a machine learning algorithm to automatically correct the misinterpreted letters.

PLE uses a backward-chaining inference algorithm ("goal-driven" reasoning rather than "data-driven" reasoning) [20], [21] to match reported problems on the active problem list to drugs ordered on the medication list. Since several ordered drugs can treat multiple problems on the list, the matching logic needs to be amended so that the main patient's problem on the active problem list can match

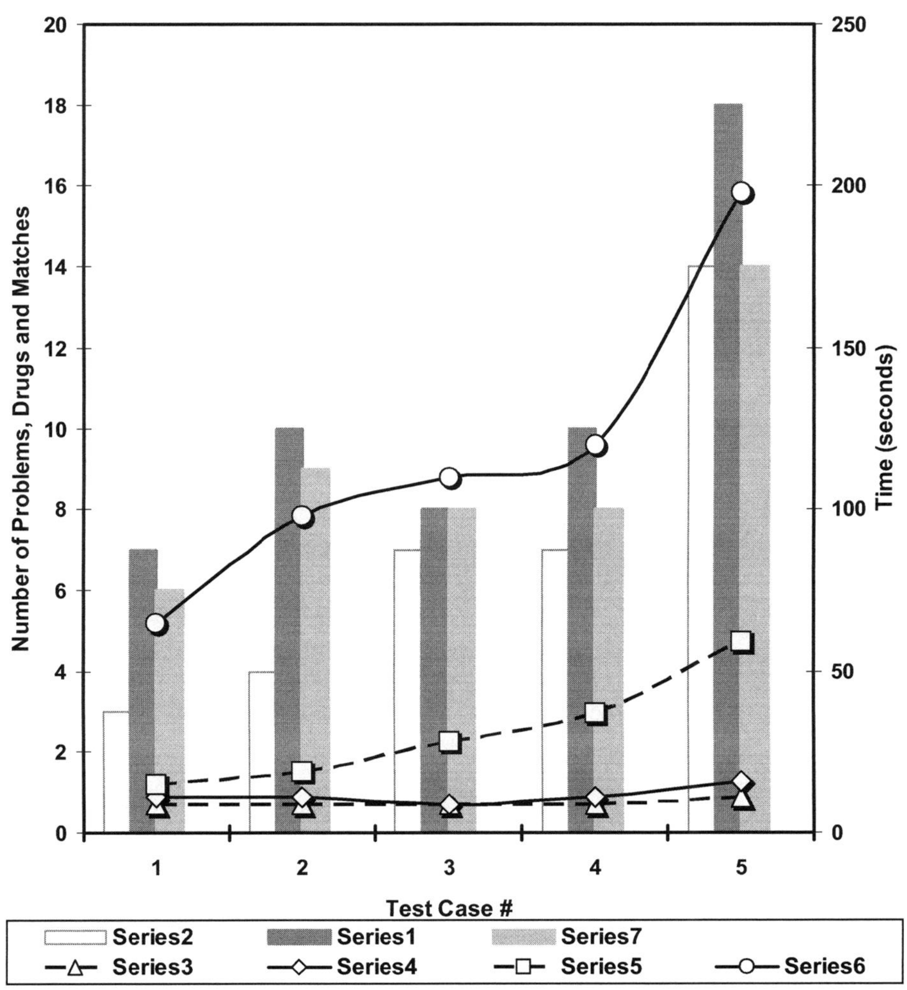

Fig. 3. Results of performance assessment on the *PLE* by comparing previous and new user interface settings for physician order entry (N=5) reveal the significance of performance improvement. The time needed for data entry and matching is affected by several factors: (1) the number of reported problems in the problem list (Series2), (2) the number of drugs in the medication list (Series1), and (3) the number of default matches (Series7); Legend Series3 and Series4 represent the time to enter whole reported problems ordered drugs respectively by the adapted interface setting, legend Series5 and Series6 represent the time to enter individual reported problems and ordered drugs respectively by the previous interface setting.

to ordered drugs most relevant to the patient's condition. We adopted another machine learning algorithm to add new problem codes and to add new relations in the knowledge base of the *PLE*. Machine learning algorithms enhance future performance of the *PLE*.

This study highlights the importance of an enhanced user interface accelerate data entry and improve system workflow in a stand-alone decision support system. Although the EMR and CPOE improve information retrieval of patient data and physician order entry, there is still a critical need for decision support systems to provide corrective actions and audit preventable medical errors in the EMR. The intermediate drug-to-problem matching ratio (77%) coupled with chart audits shows that current physician compliance with maintaining the problem list is deficient because of their reluctance to update electronic problem list. Our approach is to adapt the *PLE* to be a tool that helps maintain the electronic problem list. Adapting the user interface of the *PLE* significantly accelerates physician data entry and makes decision support more accessible to physicians.

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