Knowledge-Based Drug Prescription Clinical Decision Support System in the Ethiopian Context

Kassahun Zewdie
HiLCoE, Computer Science Programme, Ethiopia
kassahunalpha@yahoo.com

Mesfin Kifle
HiLCoE, Ethiopia
Department of Computer Science, Addis Ababa University, Ethiopia
kiflemestir95@gmail.com

Abstract

Although prescription errors have been proved to exist in Ethiopia, clinical decision support systems are not employed to reduce these prescription errors. Nevertheless, in Ethiopia, the electronic medical record system (EMR) called SmartCare is currently deployed in government health centers and also it was noticed that some private hospitals in Addis Ababa use their own version of EMR. This is an opportunity for utilizing Clinical Decision Support System (CDSS) in drug prescription (i.e., alerts and reminders at the time of drug prescription) because this decision support system integrates with patient history and gives patient specific advice so as to reduce prescription errors. Still, commercial CDSSs are expensive for most health care providers in Ethiopia; especially, public health care providers because of budget constraints.

Hence, the general objective of this work is to investigate, design and implement knowledge-based drug prescription clinical decision support system in the Ethiopian context (in cost effective manner). The system is based on knowledge-based paradigm and is implemented using object oriented analysis and design.

The prototype of the proposed system has been tested and is shown to be effective in displaying alert messages in case of potential drug prescription errors which are incorrect medication dosage and frequency, ignoring potentially significant drug-drug interactions, and inadequate dose adjustment for renal or hepatic function. It can be used to reduce potential prescription errors.

Keywords: Medication Error; Prescription Error; Clinical Decision Support System; Drug Prescription Clinical Decision Support System; Knowledge-Based System

1. Introduction

A medication error is any preventable event occurring in the medication-use process, including prescribing, transcribing, dispensing, using (administering/self-administering) and monitoring, that results in inappropriate medication use or patient harm [6]. Prescription errors are the most common medication errors [2] and can take many forms, but commonly involve wrong dose and frequency, ignoring potentially significant drug-drug interactions and inadequate dose adjustment for renal or hepatic function [2]. Thus, health care organizations are turning to electronic CDSSs to increase quality of patient care and promote a safer environment [4]; computer-based decision support is more effective than manual processes for decision support [6]. A CDSS is an interactive expert system designed to assist physicians and other health professionals with decision making tasks such as diagnosing and designing the treatment plan for a disease [3].

This paper addresses drug prescription clinical decision support system (or CDSS for drug prescribing) - one of the applications of CDSS that will display alert message(s) or reminders in case a physician prescribes a drug having potential prescription error(s). In Ethiopia, the electronic medical record system (EMR) called SmartCare is currently being deployed by TUTAPE (Tulane University's Technical Assistance Program for

Ethiopia) in partnership with Tulane University, the Center for Disease Control and Prevention (CDC) and the Federal Ministry of Health of Ethiopia (FMOH) [5]. Over 100 clinics and hospitals in the Dire Dawa region, covering the entire area, have successfully deployed this system for building and maintaining electronic medical records, which will improve both the quality of health information as well as patient care [5]. This is an opportunity for utilizing CDSS in drug prescription (i.e., alerts and reminders at the time of drug prescribing) because CDSS works with patient history. However, commercial CDSSS are expensive for most health care providers in Ethiopia; especially, public health care providers because of budget constraints. The total health spending in Ethiopia is still far from adequate to provide good health care [13]. Therefore, it is better to develop CDSS in drug prescription in the Ethiopian context.

The methodology we used involves data acquisition to gather relevant data about the functional requirements of the proposed system. We collected primary data using questionnaire to be filled by medical doctors. This was supported with discussion and personal observation. Post Study System Usability Questionnaires (PSSUQs) were distributed among representative users to collect user feedback on the usability of the system. Personal observation is employed to understand clinical work flow and to gather relevant data to usability testing.

We also reviewed relevant literature to gather relevant data such as the needs and functional requirements of CDSS (e.g., what the system is expected to do), methods of CDSS and best practices for CDSS design and implementation. Analysis of open source clinical decision support systems in drug prescription is carried out to exploit knowledge and experience for specifying the requirements and designing and implementing of the proposed system. Document review is conducted to identify the attributes of prescription.

As pointed out in [1], due to the fact that non-knowledge-based CDSSs are systems based on machine learning, i.e., their knowledge is learnt from past experiences and/or find patterns in clinical data, they cannot explain the reasons for their conclusions (they are so-called "black boxes" because no meaningful information about how they work can be discerned by human inspection). Most clinicians don't use them for reliability and accountability reasons. Consequently, our approach is based on knowledge-based paradigm.

2. Related Work

In this section the CDSS approach our system relies on and knowledge-based paradigm are reviewed. Then, best practices for CDSS design and implementation and some of the lessons learnt & experience through review literature and analysis of open source clinical decision support systems in drug prescribing are presented.

A general model of knowledge-based CDSS is depicted in Figure 1 [7].

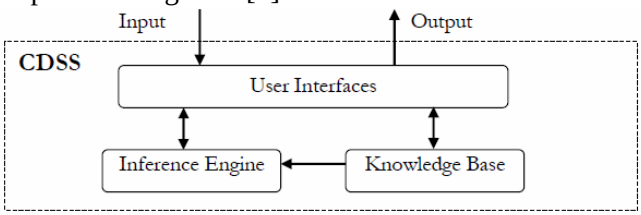

Figure 1: A General Model of Knowledge-Based CDSS

From the general system structure as depicted in Figure 1, there are three essential system components in a knowledge-based CDSS. The first component is a knowledge base which includes clinical domain knowledge that is often, but not always, represented in the form of traditional 'IF-THEN' rules. If this was a system for determining drug interactions, then a rule might be that IF drug X is taken AND drug Y is taken THEN alert user. The second one is an inference engine which contains algorithms or formulas for combining or matching clinical rules in the knowledge base to input clinical data. The third part is a user interface which is a communication mechanism between users and the system allowing users to provide input composed of clinical signs, symptoms, laboratory tests, etc. into the system and also get output including automatically generated

diagnostic and therapeutic recommendations from the system to help to make final clinical decisions.

There is a growing literature of best practices for CDSS design and implementation. As presented in [6], the identified design characteristics associated with the success of CDSS development are the following

- Computer-based decision support is more effective than manual processes.
- CDSS interventions that are presented automatically and fit into the workflow of the clinicians are more likely to be used.
- CDSS that recommends actions for the user to take are more effective than CDSS that simply provides assessments.
- CDSS interventions that provide information at the time and place of decision-making are more likely to have an impact.

Berner [6] states that attention must be given to CDSS implementation process in order to avoid negative affects in addition to quality assurance.

As pointed out in [2], introduction of CDSS is often met by opposition due to the flood of alerts, and most prescribers eventually ignore even crucial alerts ("alert fatigue"). To tackle the problem of alert fatigue, a multidisciplinary expert review committee silences or modifies alerts which are not significant, enhancing comprehensibility, and providing dosing instructions adjusted to the patient's renal function and recommendations for follow-up. But, the work does not establish guidelines for drug silencing.

The lesson learnt through analysis of open source clinical decision support systems in drug prescribing [17] includes essential attributes in renal and hepatic dosage adjustments, user interface requirements and how to design the interface, how to categorize drug-drug interactions, drug knowledgebase organization and prewritten medication orders. The limitations of this CDSS are that it is a standalone application and does not manage physiological contra-indications (renal failure, pregnancy, and lactation).

To summarize, best practices for CDSS design and implementation - how to tackle alert fatigue, CDSS being fitted to the clinical work flow and being available at the point of care, integration of CDSS with EMR and prewritten medication orders - are implemented in our system.

3. The Proposed Solution

The output of this work is a design and a prototype of Knowledge-Based Drug Prescription Clinical Decision Support System in the Ethiopian Context, which is shown to be effective in warning during drug prescribing errors - incorrect medication dosage and frequency, ignoring potentially significant drug-drug interactions, and inadequate dose adjustment for renal or hepatic function. To make it cost effective, knowledge and experience are exploited through analysis of open source CDSSs for drug prescribing and are employed in specifying the requirements, and designing and implementing the proposed system. Free Open Source (FOS) should be one of the least expensive and most effective solutions for technology and knowledge transfer to developing nations; this concept has diffused to several fields such as software, hardware, and content [14]. The advantages of open source software are that they are cheaper than commercially marketed products, are created by skillful and talented experts, are highly reliable, and freedom and flexibility (it gives people the freedom to use it, to share it, to modify it for their own needs, and to study it) [15].

In addition, the system is cost effective owing to the following factors:

i) As marked in [12], the cost of CDSS for Single User License is US $4650. This is expensive for most health care providers in Ethiopia; especially, public ones. As presented in [13], the total health spending in Ethiopia is still far from adequate to provide good health care. The per capital national health expenditure for the country was reported to be US$20.77 in 2011. This is very low compared

to the Sub-Saharan Africa average of US$93.65 during the same period.

ii) In addition to the cost of commercial CDSS, customization cost has to be taken into account. One of the biggest hidden expenses of commercial off-the-shelf (COTS) software is the cost of customization [9]. Any commercial off-the-shelf technology product should meet 80% of the needs [10]. In many cases, COTS software requires customization to correctly support the buyer's operations [11].

iii) For off-the-shelf solutions, the user will pay for an upgraded version, new licenses, and anytime that one needs support [8]. As presented in [1], the extensive quantity of clinical research being published on an ongoing basis must be incorporated into the CDSS in an accurate way; in a given year, tens of thousands of clinical trials are published. This means that maintenance rate is high and this in turn results in high maintenance cost for which the user pays. One concern of users who decide on a custom software solution is maintenance cost [8]. A custom solution includes access to and control over the source code and this means the owner can prioritize upgrades and create solutions on a chosen time-line [9]. Further, as pointed out in [9], if properly done, the development activities (analysis, design, implementing and testing) in custom software can dramatically reduce the up-front cost of custom software, while ensuring that it fits both the business and IT requirements of the owner.

iv) It saves foreign currency. The purchasing, maintenance, license and training costs of commercial CDSSs are paid in foreign currency. When it is developed by local experts, it will save foreign currency.

v) The experience and knowledge exploited through developing custom drug prescription CDSS can be utilized to develop CDSSs in other areas of applications, for instance, in diagnostic assistance CDSS, so that it will be able to add value in knowledge & technology transfer and the country will have lots of highly qualified medical and IT experts.

3.1 Architecture of the System

The proposed system has three tier client/server architecture. The architecture of the system as shown in Figure 2 consists of client tier, business tier and data tier. At the client tier, there is PC client which provides an interface for the respective users to log and manage users and drugs, prescribe medicine using appropriate web forms. The business tier contains the core part of the drug prescription clinical decision support application, i.e., the web server and application logic. Data tier is the database that stores application data - user data and drug knowledgebase.

3.2 Implementation

For development of the proposed system, we used object oriented software engineering because it makes the system easier to extend and build without affecting other functionalities of the system.

To attain the research project’s objectives, different tools are employed in different phases of the project. Microsoft Visio 2010 and Microsoft Word 2007 are used in the modeling and designing phases. Active Server Pages (ASP).NET, C-sharp (C#), (ActiveX Data Object) ADO.NET and Java Script (open source) in Visual Studio 2012 and SQL Server 2008 R2 are used while developing the prototype.

The developed system is capable of showing different screens depending on the role of the user. The home page and Prescriber Main Window Page are described briefly as follows. The snapshot in Figure 3 shows the home page of the developed system and contains input fields in which users need to fill so as to login into the system.

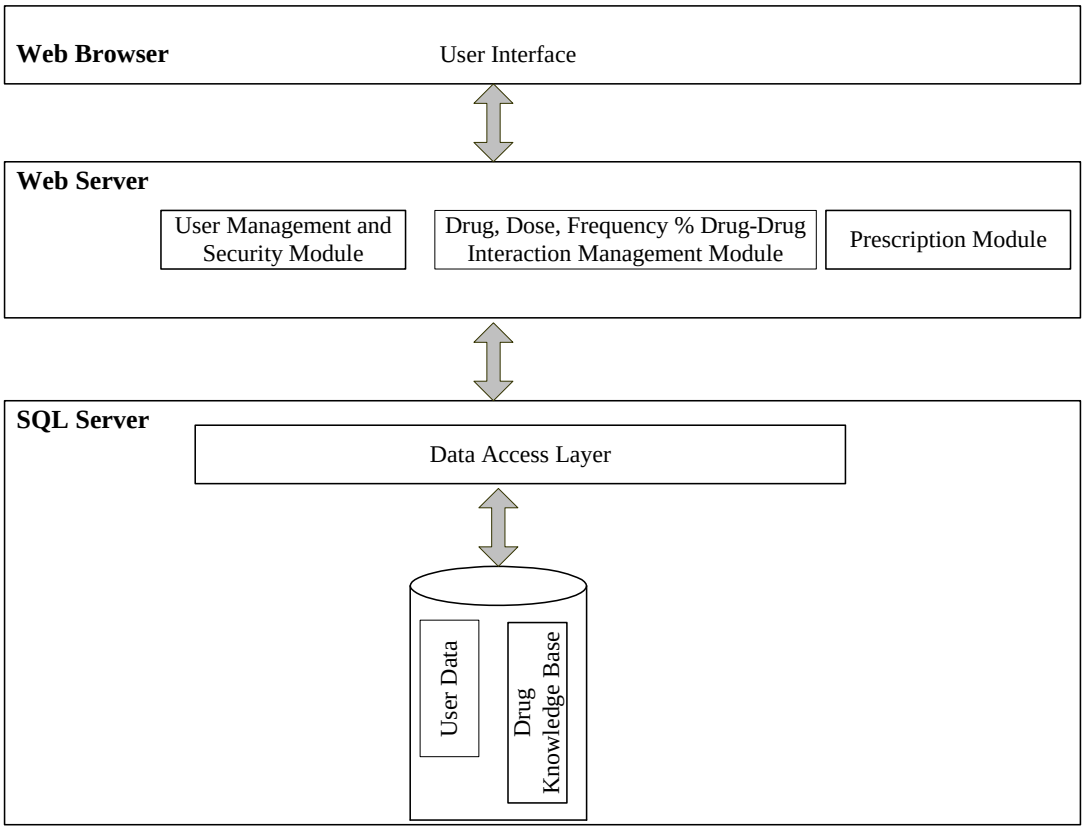

Figure 2: The Architecture of the Drug Prescription CDSS

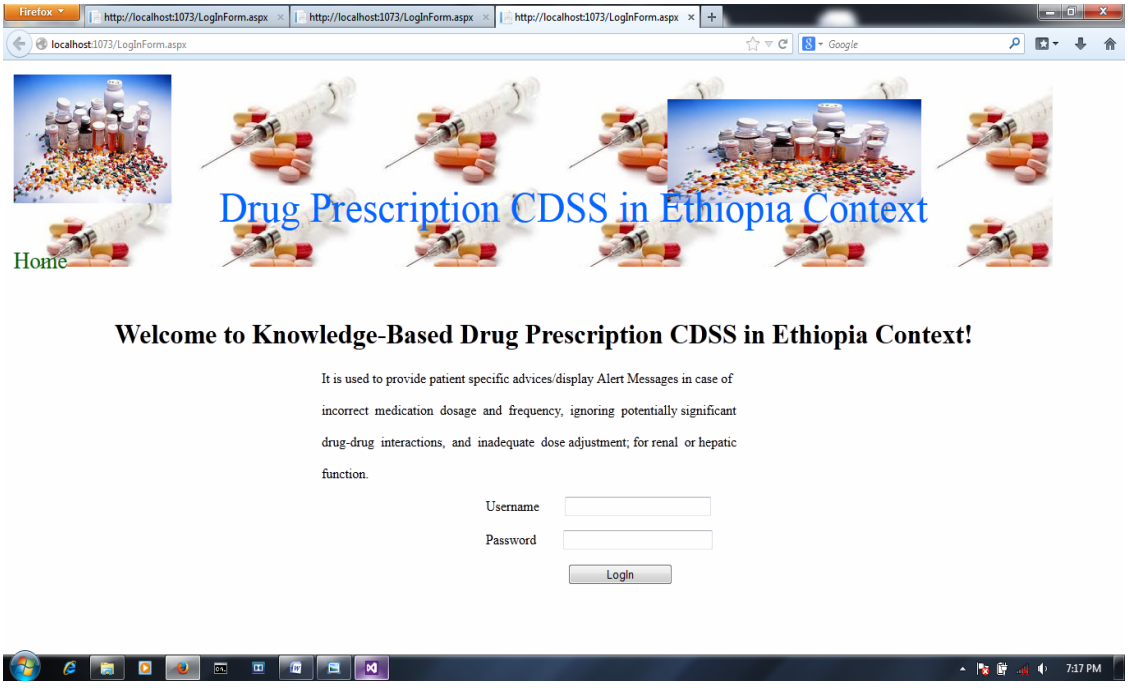

Figure 3: Home Page Snapshot

The snapshot in Figure 4 shows Prescriber Main Window page and it is used by a prescriber to view and update patient medication profile, to create & validate prescription and to have explanation in case of drug-drug interaction.

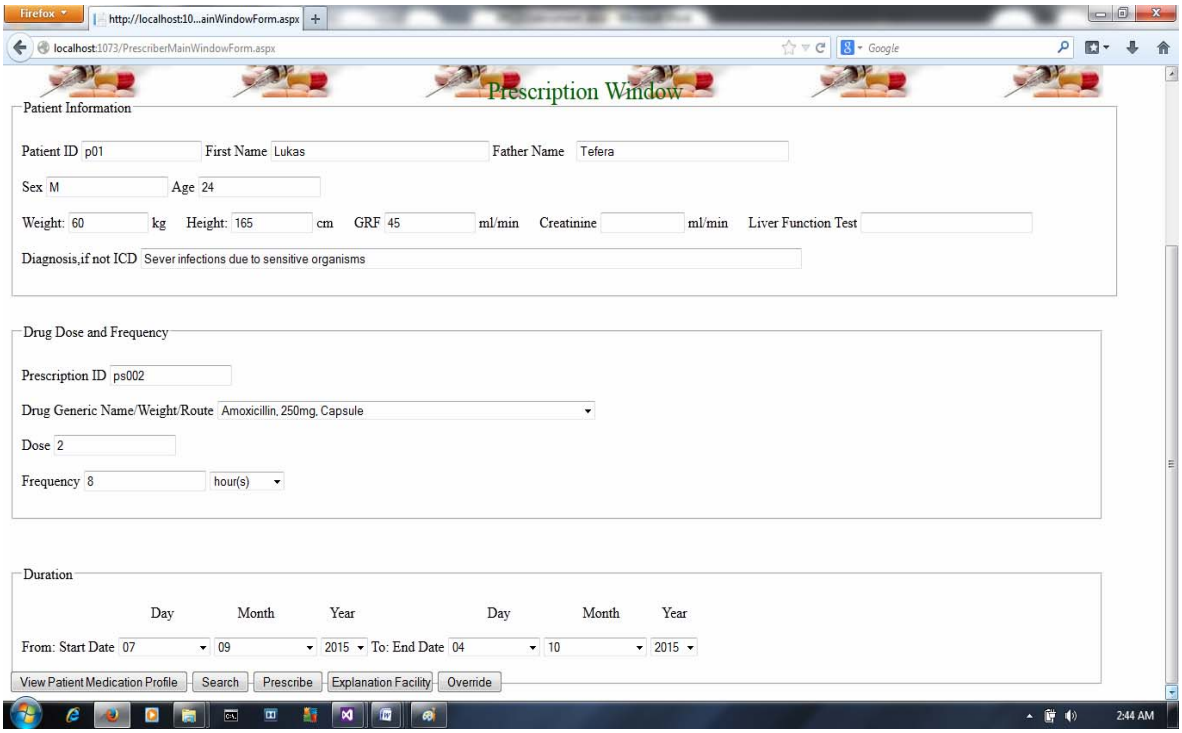

Figure 4: Prescriber Main Window Page Snapshot

4. Evaluation

Validation is a crucial component in the development of any CDSS. As discussed in the literature [7], a sound CDSS validation study contains the following fundamental components: enough clinical cases for validation, an appropriate validation design, knowledge base validation and inference engine validation.

In order to ensure that the core functionality of the system - prescription module - works well, test cases are created by medical doctors along with the developer based on medicines formularies [16]. This implies that these test cases validate drug knowledgebase and decision support algorithms (inference engine) working correctly. The test cases are executed and the test results show that the developed system is effective in validating prescription. It displays alert messages in case of potential prescription errors - wrong dose and wrong frequency, significant drug-drug interactions and inadequate dose adjustment for renal or hepatic function. The usability test is conducted by observing users using the system and by distributing PSSUQs among target users and the result is promising.

5. Conclusion and Future Work

Prescription errors are common in hospitalized patients and result in significant morbidity, mortality and costs. The prescription errors have been proved to exist in Ethiopia. In Ethiopia, the electronic medical record system called SmartCare is deployed currently and usage of EMR in some private hospitals open the door to usage of CDSS in drug prescribing because drug prescription CDSS integrates with patient history and provides patient specific advice so as to reduce prescription errors. Still, commercial CDSSs are expensive for most health care providers in Ethiopia, especially public health care providers. To overcome this problem, this system has been developed so as to reduce potential drug prescribing errors, which are incorrect medication dosage and frequency, ignoring potentially significant drug-drug interactions, and inadequate dose adjustment for renal or hepatic function.

The developed system has been tested and shown to be effective in displaying alert messages whenever the potential drug prescribing errors mentioned above occur.

In the future, we will extend the system to include drug interaction with pregnancy, lactation, disease, food, alcohol and to include all drugs in Ethiopia and anatomical therapeutic chemical (ATC) codes of these drugs and patient's known allergies.

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