

AN RFID-BASED DRUG MANAGEMENT SYSTEM

A case in Medical Organization

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Abstract: Drug safety has attracted considerable public concern and press attention in recent years. Many precautions have been suggested to ensure the accuracy of drug distribution to patients but the results are not yet fully satisfactory. Enhancement of drug management is undoubtedly a trend to ensure no medication error happen in the healthcare industry, but there is still plenty of room for improvement in this situation. Drug Management System (DMS) is proposed as a platform for the hospital and clinics to explore the drug safety and patient safety. This paper will present the details about DMS for assisting the medical workers in drug replenishing and dispensing process. Also, problems existing in drug safety and benefits bring from DMS are presented.

1 INTRODUCTION

Medicine is regarded as a tool to heal people with sickness, but it is a weapon that can kill people. If humans take in wrong medicine, they will have side effects or eventually die. To avoid such mishaps, effective drug management is very important to healthcare industry.

Drug management involves two processes, namely Drug Quality and Replenishing Process (DQRP), and Drug Dispensing Process (DDP). To enhance safety in these two processes, improving human inspection is one of the common methods applied in medical organizations. Despite enhancements of inspection and quality of standards, numerous poor drug management incidents have been reported frequently in recent years. This situation is particularly much more serious in clinics compared with hospitals. This can be attributed to the lack of monitoring system in drug management adopted at clinics. As a result, medication errors happened inevitably. In 2008, the Department of Health reported that misidentifying medicines is a common mistake (Department of Health, 2008). Four clinics in Hong Kong have 442 medication error events in two months with an average of seven events a day. 260 medication error events were related to wrong packaging (Tam et al., 2008). Some medication errors brought serious impact to humans. For example, in 2006, the clinic of a private general

practitioner in Hong Knog mistakenly mixed up the syrup medicine for treating running nose with Isopropyl alcohol in which it involves poison that is normally used for wood processing. Another example happened in last year: wrong drugs in packs of medicine were found by mixing up diabetes tablets with drugs for controlling high blood pressure. About 60 patients were affected and they were nearly killed because of drug allergy.

These medication error incidents have a common characteristic – all the mistakes occurred and were detected in the drug management processes, i.e. DQRP and DDP. These processes involve the knowledge of pharmacy. Drugs with similar shapes and colors may have very different properties. For example, Gasteel and Isodil, shown in Figure 1, have similar shapes and colors but they are different on the back side. The current practice of drug identification mainly relies on visual inspection performed by humans to determine the drugs. Unlike the case in hospitals, clinics usually do not have resident pharmacists. Instead, nurses usually play an important role in the drug management processes. With lesser medicinal knowledge and experience compared with pharmacists, nurses are easier to make mistakes in the drug management processes. In short, if such processes contain errors, adverse drug incidents will continue to happen even though correct medications have been prescribed to patients.

In response to the above mentioned issue, a new

Drug Management System (DMS) is designed to deal with the problems of medication errors. This needs to modify the clinic operation by implementing an RFID-based solution (Huang and Ku, 2009; Ting et al., 2009; Fanberg, 2004). With the automatic identification capability enabled by RFID technology, the processes of drug identification, drug distribution and drug processing will be greatly improved. Moreover, the proposed system can even detect whether the drugs are put in the correct place or container, check the compatibility of drugs for adverse interaction, and deliver real time expiry date alert automatically.

In order to study the feasibility of our proposed DMS, a Hong Kong medical organization is chosen as case study. It specializes in providing health care for ambulatory patients treated by several general practitioners and medical professionals. Same as many clinics around Hong Kong, its drug management is a major challenge in its daily operation. It would like to seek an effective and accurate method to prevent medication errors.



Figure 1: Gasteel and Isodil – drugs that look alike at one side.

2 MOTIVATION AND OBJECTIVES

Four critical issues and challenges encountered in current drug management practices are attempted to address in this project:

- **Mixing Up of Drugs**
In typical medical organizations, doctors and nurses have to differentiate the drugs frequently. It is because they need to replenish the drugs when they are below the safety stock level and dispensing drugs to patient when electronic report is received. However, concerning the shapes and colours of drugs are

similar (i.e. an example is shown in Figure 1); it increases the challenges to distinguish the drugs for human. Most of the errors occurred because one drug is mixed up with another drug. With the eyes and perception, the mistakes of mixing up in the drugs management cannot be tackled easily. Therefore, it is necessary to apply technology to facilitate the medical staff in drug identification.

- **No Checking Expiry Date**
As shown in Figure 2, the expiry date of drugs is often printed on the original package of drugs. After the packages of the drugs are opened, the drugs of expiry date cannot be tracked easily. Syrup will be found easily if the drugs are deteriorated due to expired date. This is because there are turbidities in syrup. However, tablets will not have any appearance changes after expiry date. Therefore, there is no way to enhance the expiry date management for the drugs.



Figure 2: Original Package of Drug with Expiry Date Shown.

- **Lack of Drug-Drug Interaction**
Some drugs cannot be prescribed to patients at the same time as they will interact with each other. In addition to the clinical knowledge and experiences of physicians, a proper prescription is also relied on the physicians' understanding of medicine properties, functions and ingredients. With more and more new drugs are available in the marketplace, medicine relation becomes more complex. In this sense, doctors may find difficult to recognize all these relations and thus drug-drug interaction may easily occur. In order to confront drugs adverse interaction, technology can be used to facilitate the physicians.

Based on the problem statements, the three major objectives are:

- To develop an effective and trusted drug processing method to avoid the drugs mixing up problems;
- To provide a dynamic and evaluation platform to assist the medical workers to check the expiry date and drugs interaction of drugs; and
- To facilitate collaborative and interactive drugs replenishing and dispensing processes between medical workers and patient.

3 ARCHITECTURAL FRAMEWORK, STANDARDS AND FUNCTIONS OF THE RFID-BASED DRUG MANAGEMENT SYSTEM (DMS)

Figure 3 shows the system architecture of DMS. Simply stated, the system is divided into 4-tiers namely: Presentation Tier, Logic Tier, Data Exchange Tier and Data Tier. The Presentation Tier is used to deliver the response to the users; while the Logic Tier processes and fuses the information scanned by the RFID reader; then the collected raw data is transforming into standard information by the Data Exchange Tier and the Data Tier stores the processed information (RFID tag information) for further analysis.

3.1 Details of the System Architecture

The Presentation Tier represents the communication media that enable users to receive essential information in appropriate form, and to acquire information based on the various authorities. Generally, it includes input or output devices such as UI Engine (like Personal Computers (PC) and Personal Digital Assistants (PDA)) and Report Engine (like Printer). Through a secure authentication by user logon with Logic Tier, users can enquire the system and obtain the information like drug information, expiry date, and so on.

The Logic Tier is the brain of the whole system since most of the work is performed here. It consists of three major applications: Information Retrieval, Real Time Alert and Data Verification. These applications are useful in recording and retrieving data in an intelligent and logical way. So that the system can send out alert for enquiries after any successful match between Logic Tier and Data Tier. Moreover, these applications support difference

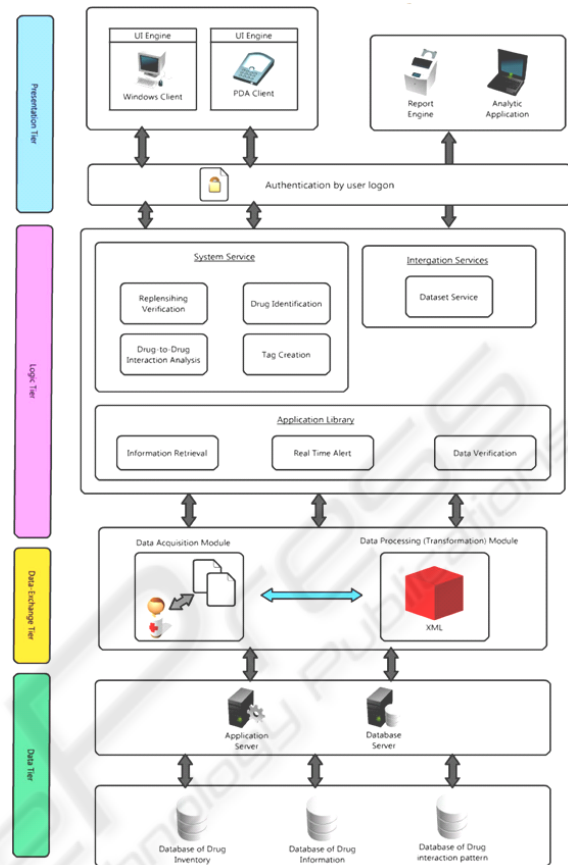


Figure 3: System Architecture of Drug Management System (DMS).

services and can be classified into two categories: System Service and Integration Service. The details of the services are demonstrated as follow:

- **System Service**
The System Service consists of 4 modules which are Replenishing Verification, Drug Identification, Drug-to-Drug Interaction Analysis and Tag Creation. The Replenishing Verification module responds for ensuring the correctness between the two replenished package and container; while the Drug Identification module responds for retrieving all the information of particular drug from drug database; and the Drug-to-Drug Interaction Analysis module responds for checking the interaction; and finally, the Tag Creation module responds for creating the tag once drugs are received from manufacturers.
- **Integration Service**
The Integration Service is mainly responsible for report generation. That means useful information can be extracted from suitable database(s) by the Dataset Service module and

they will be presented by the Report Engine in the Presentation Tier.

After the information processed by the Logic Tier, it will then be transferred to the Data Exchange Tier which is responsible for collecting raw data and transforming them into standard information. The Data Exchange Tier is constituted of 2 modules: Data Acquisition Module and Data Processing (Transforming) Module. For Data Acquisition Module, it acquires raw data to the system. Each RFID tag, on the package of drugs, containing tag ID and drug information will be used to represent each category of drug. When we use RFID reader to detect them and once the reader received the returned signal, the tag can be read. For Data Processing Module, those collected data will be transformed and normalize into a common format – eXtensible Markup Language (XML). XML is a common information format which can be used on the Internet, Intranets and elsewhere. Upon the completion of transformation process, the standard information will be transferred to the Data Tier to store the information.

The Data Tier consists of several databases include Drug Inventory, Drug Information and Drug Interaction Pattern that contain all the information of the system. When a raw data is captured, it will be first under processing in Logic Tier. Then it will be converted to meaningful information and pass through the Application Server or the Database Server. Finally, the information will be stored in a suitable database in Data Tier. When any enquiry is made, the information will be selected from the related database in Data Tier. The Data Tier is acting as an information repository of the system.

3.2 RFID Technology Standards

In normal practice of medical organizations, there are mainly eight types of medicine, including capsules, tab, syrup, power, lozenges, gel, cream and drops or lotion.

To standardize the numbering schema in the DMS, Electronic Product Code (EPC) is adopted (Kwok et al., 2008). EPC is a global unique serial number that identifies products in item level (EPCglobal Inc., 2005). As shown in Figure 4, EPC consists of four components. Generally, it enables users to store 96-bit data, which categories into version, manager code, object class and serial number. In order to store detail information of medicine and enable medical staff to identify drugs in item level, some critical information will be given specific number as differentiation. The schema is

described as follow:

- **Version Section**
It stores a 2-digit figure which can indicate types of medicine from 01-08 (i.e. the typical eight categories).
- **Manager Code and Object Class**
They store 7-digit and 6 digit code respectively. They record the other relevant information like types of package and manufacturing company for identification.
- **Serial Number**
It stores a 9-digit code that represents the assigned unique number for item identification.

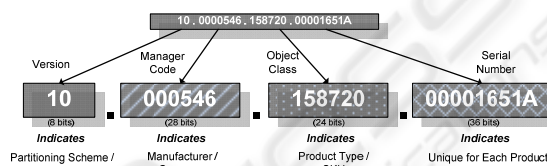


Figure 4: Format of EPC Number (96-bit version).

There are various package combinations of different types of medicines such as boxes or bottles. If the exact volume can be identified, large packages of drugs can be stored systematically. By assigning an EPC numbering system in the clinic, exact package or bottle of drugs can be easily identified or found. Once the RFID reader detects an RFID tags, the DMS can efficiently show related information such as drugs' name and quantity to the medical staff.

3.3 System Functions

The proposed system performs 5 functions: Tag Creation Function, Drug Identification Function, Replenishing Verification Function, Expiry Date Alerting Function and Drug-to-drug Interaction Checking Function, they are described as Table 1.

4 CASE STUDY: APPLICATION OF DMS IN A HONG KONG MEDICAL ORGANIZATION

In order to study the feasibility of our proposed Drug Management System, a Hong Kong medical organization is chosen as case study. Traditional workflow analysis is discussed first to illustrate the problems encountered in drug management in the organization, and hence the second part demonstrates how the proposed methodology can enhance the current situation and challenges.

Table 1: System Functions of RFID-based DMS.

Function	Description
Tag Creation	To create the tags and input relevant drugs information
Drug Identification	To review the drug details
Replenishing Verification	To confirm the drugs being replenished correctly
Expiry Date Alerting	To determines whether the drug is expired or not
Drug-to-drug Interaction Checking	To determine whether the medicines dispensed to the patient have interaction or not

4.1 Traditional Workflow Analysis

Figure 5 shows the existing working process of drug management. Generally, drug management can be divided into two processes, Drug Quality and Replenishment Process (DQRP) and Drug Dispensing Process (DDP).

When several large packages of drugs have been first delivered to the clinic, medical workers (i.e. usually nurses may take this role) may record the relevant drugs information such as expiry date and quantity in a logbook. In usual practice, large packages of drugs are replenished into small containers for stocking. After checking the existing stock level of drugs, if the existing stock level is lower than the safety stock level, large packages of drugs are refilled into small containers. While refilling drugs, nurses are required to match drugs and small containers largely based on drugs' appearance and their experiences. In a large extent, human errors are made since there is not much difference between drugs' appearance and medical staff may mistake small container and transfer pills to an incorrect small container. Moreover, some relevant information like expiry date of drugs needs large human involvement to check from the logbook. With the demanding services of clinic, it is time consuming to realize the date first before any replenishment is conducted. Once the refilling process completed, the containers are stored back to the shelf.

Another process is about drug dispensing which regulates the procedure of dispensing drugs to patients. Figure 6 shows the workflow of DDP. In existing clinic operation, an Electronic Medical Record (EMR) system is used to notice staff that specific kinds of medicines should be distributed to an exact patient (McInnes et al., 2006). After receiving the record, nurses may pick up particular small containers of drugs from the shelf and

distribute certain amount of drugs into small package and finally distribute to patient.

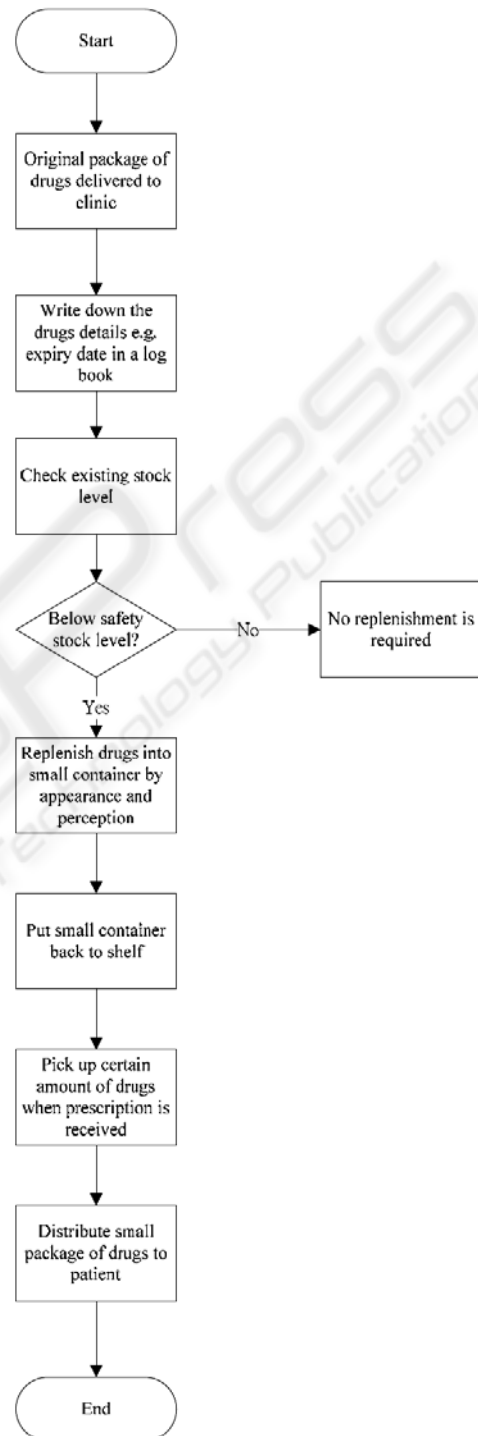


Figure 5: Existing Workflow of DQRP.

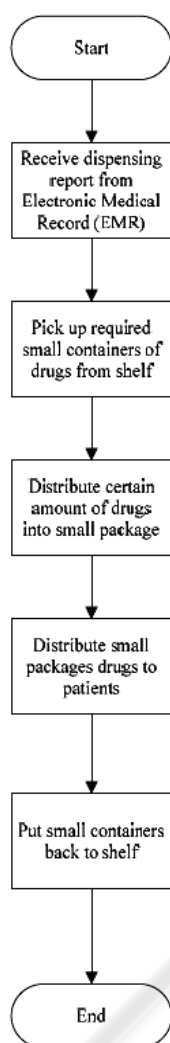


Figure 6: Existing Workflow of DDP.

4.2 Proposed Methodology

In order to tackle the problems that involved in the DQRP, a DMS is introduced to the company. It is an RFID-enabled system to manage the flow of drugs throughout the chain. As large packages of drugs have been delivered to the clinic, each package of drugs is given a RFID tag with relevant information stored in EPC standard. Since drugs are split into different categories, the categories indicator is stored as a part of identity according to EPC standard. By then, after creating a unique RFID identity to each package of drugs, drugs are refilled into small containers if the existing stock level is lower than the safety stock level. In order to ensure a correct small container is picked, nurses are required to place both large package of drug and small container

on an RFID reader for authentication. This is an important step to make sure the right medicine will be replenished into the right small bottle. Prior to DMS, human errors are happened frequently since the authentication process is highly depends on worker's perception and identification of drugs' appearance.

If package of drugs can match with a small container, nurses can start to replenish medicine into small bottles. After refilling all medicines, small containers are placed back to shelf.

For the proposed working procedure of DDP, after receiving drugs dispensing report from EMR system, nurses pick the right small containers from shelf and place onto an RFID reader to ensure the right bottles are selected. Meanwhile, expiry date can be double examined and to prevent from distributing expire medicine to patients. If drugs are expired, they should be disposed immediately. Moreover, the DMS enables users to detect whether there is drugs interaction. If drugs are not interacted, they can be distributed to patients.

4.3 System Functions

The proposed system performs 5 functions: Tag Creation Function, Drug Identification Function, Replenishing Verification Function, Expiry Date Alerting Function and Drug-to-drug Interaction Checking Function, they are described as follow:

- **Tag Creation Function**
As shown in Figure 7, this function is in charge of creating the tags and input relevant drugs information once drugs received from manufacturers.
- **Drug Identification Function**
As shown in Figure 8, this function retrieves all relevant information of particular drug from databases so that the medical workers can review the drug details and make sure the replenished and dispensed drugs are correct.
- **Replenishing Verification Function**
This function deals with confirming relevant drugs mainly. It examines the tags on two packages of drugs first, and then come to use replenishing verification function. If the two RFID tags are matched, a Green Tick will be shown (Figure 9a); otherwise, a Red Cross will be shown (Figure 9b). After the steps completed, the medical workers are admitted to transfer the drugs from one package to the other.

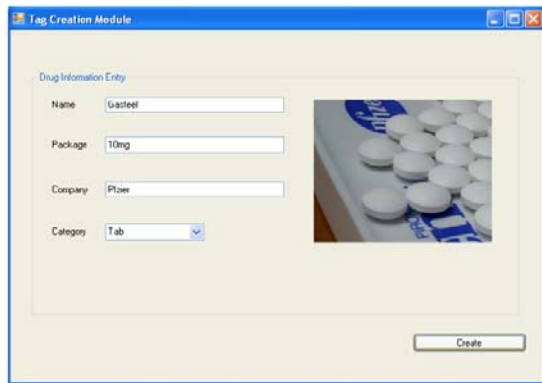


Figure 7: Screen Capture of Tag Creation Function.

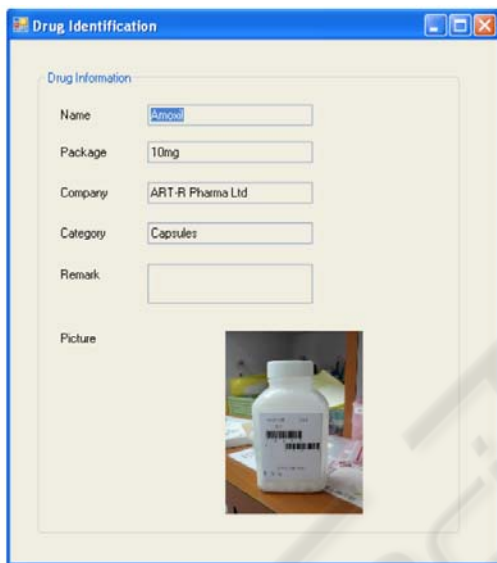


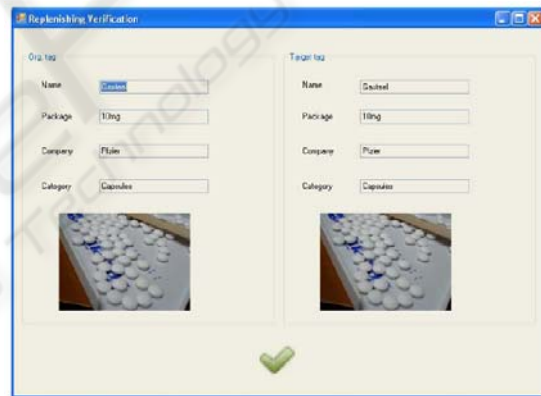
Figure 8: Screen Capture of Drug Identification Function.

- **Expiry Date Alerting Function**
As shown in Figure 10, this function determines whether the drug is expired or not. A large pop up alert message box is generated to warn the medical workers about the expiry date.
- **Drug-to-drug Interaction Checking Function**
As shown in Figure 11, this function determines whether the medicines dispensed to the patient have interaction or not. Similar to the Expiry Date Alerting Function, a large pop up alert message box is generated to warn the medical workers when interaction exists.

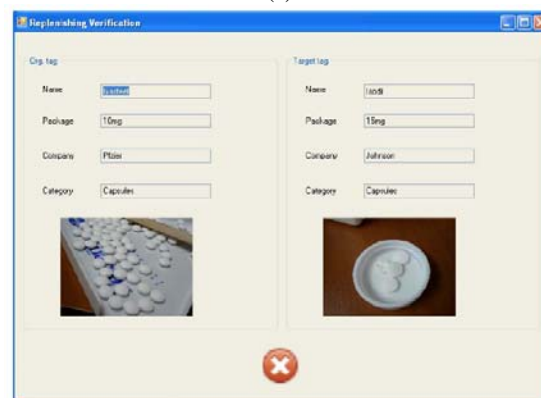
5 DISCUSSION AND CONCLUSIONS

DMS can enrich, enliven and add variety to traditional drug replenishing and dispensing processes by using RFID technology. The following are some of the significant impacts of DMS.

- **Originality, uniqueness and innovativeness**
DMS is path breaking. Although some research projects have investigated the feasibility of implementing RFID in the dispensing process (Lehmann and Kim, 2005), they overlook the importance of drugs replenishing process. Since the drugs replenishment process is the initial stage to process the incoming drugs, if mistakes are made in that process, medication errors will eventually take place even though the dispensing operation is correctly performed. Moreover, in order to enhance the innovativeness of DMS, special features like drug images and interaction alert are added to the DMS.



(a)



(b)

Figure 9: Screen Capture of Replenishing Verification Function with (a) Matched tags (b) Unmatched tags.

- Practicality, User-friendliness, Extensibility & Scalability

DMS provides users with information about drugs immediately. By using DMS, they can easily determine whether the drug has reached its expiry date and it will interact with other drugs. A real time alert (or pop up window) is used to warn the users of abnormalities and thus bring their awareness to the problematic medicines. Furthermore, with the user-friendly interface of DMS, users can easily distinguish between drugs that look alike by the checking system to avoid medication error. Furthermore, the DMS applies an international standard and a global unique serial number (i.e. EPC) to identify drugs at item level that can be adopted by different clinics or hospitals. When more and more clinics and hospitals adopt the DMS, it can be extended to pharmaceutical manufacturers so that the whole drug supply chain can be traced and tracked easily (ITU, 2005).



Figure 10: Screen Capture of Expiry Date Alerting Function.

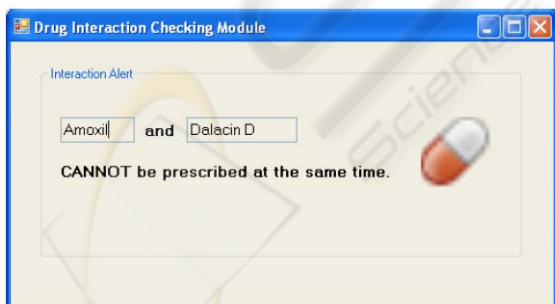


Figure 11: Screen Capture of Drug-Drug Interaction Checking Function.

- Social Responsibility

Traditionally, inspections are carried out only when patients are found to be sick after taking wrong medicine. However, with the help of RFID, DMS improves the efficiency and

effectiveness of drug management. All the problematic cases can be brought to the attention of the operator (such as the nurse) in real time. By adopting DMS, clinics can adequately address social and environmental concerns in their business operations. The proposed system will assure drug safety consistently. Thus, patient safety is enhanced by reducing medication errors. In addition, DMS speeds up the drug replenishing and dispensing processes that help to reduce operation expenses. This can drive the stakeholders to scale up change throughout their clinics.

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