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Pharmacy robotic dispensing and planogram analysis using association rule mining with prescription data

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ABSTRACT

Automation in pharmacies has achieved innovative levels of effectiveness and savings. In the present day, automated pharmacies are facing extremely large demands of prescription orders specifically at the central fill pharmacies that distribute drugs to retail pharmacies. As a result, improvements are necessary to the Robotic Prescription Dispensing System (RPDS) and RPDS planogram to increase the throughput of prescriptions. RPDS planogram defines where to allocate the dispensers inside the robotic unit and how to distribute them among the multiple robotic units. This research utilizes the pharmacy prescriptions database to extract useful knowledge to improve different strategies in pharmacy automation by using a data mining approach. In this study, a data mining tool is proposed to enhance pharmacy automation. Frequent Pattern Growth (FP-growth) approach, which is one of the algorithms of Association Rule Mining (ARM), is applied to an actual prescriptions database of a central fill pharmacy to study the associations within the prescribed drug regime. The FP-growth application in a prescriptions database is novel; thus, FP-growth is tested on both sequential mode, and parallel mode by using a distributed platform Hadoop and MapReduce paradigm. Two types of association rules are extracted: 1) associations among different drugs that involve their different dosage strengths and manufacturers; and 2) associations that include only information about different drug generic and brand names. The importance of the extracted association rules is evaluated by the use of different measures, including the support, confidence, lift and conviction. The discovered rules disclose strong associations among the purchased drugs that improve the allocation and distribution of dispensers among the robotic units, in addition to enhancements in other pharmacy managerial strategies.

1. Introduction

Automation in pharmacies has accomplished advanced levels of efficiency and savings. The aim of pharmacy automation is maximizing the throughput of prescriptions with reducing operational costs. Pharmacy automation helps pharmacists and technicians to avoid repetitive manual tasks that would otherwise waste time. Thus, they can enhance patient care quality by concentrating on clinical activities. Furthermore, pharmacists can spend more time in consultation and communication with patients which permits a better understanding of their cases, and thus providing the healthcare services they need (Khader & Yoon, 2014, 2015; Tan, Chua, Yong, & Wu, 2009).

In the present day, automated pharmacies are experiencing a significant increase in demand of prescription orders especially at the central fill pharmacies that allocate drugs to different retail pharmacies. With this rising demand, it is necessary to increase the throughput of prescriptions in automated pharmacies through improvements to the Robotic Prescription Dispensing System (RPDS) (Innovation Associates, 2007; Khader & Yoon, 2014; 2015).

Many pharmacies ignore the hidden patterns and the knowledge that can be extracted from the stored transactional database. This paper discovers knowledge from a pharmacy prescription database to improve the RPDS. This research involves the use of a FP-growth approach, which is one of the Association Rule Mining (ARM) algorithms, to examine possible associations within the prescribed drug regime for different patients. Prescription data mining helps to capture the most frequent itemsets for prescriptions. Frequent itemsets are groups of prescriptions that frequently appear in one transaction for different patients. Knowledge of frequent itemsets provides insight about the drugs that are more likely to

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be ordered together, and thus, dispensed together. The capture of those associations and the discovery of patterns in transactional prescription data significantly help in the RPDS planogram.

In addition to improving the automated dispensing of prescriptions, the extraction of the association rules provides new insights about customer purchasing behavior. Moreover, the extracted knowledge can lead to amplified sales by 1) assisting retailers to do selective marketing, 2) identifying useful advertising and marketing strategies, 3) managing the inventory, and 4) improving the replenishment criteria, as well as making the shelf space arrangement more efficient (Han et al., 2007; Hipp et al., 2000). This study is also beneficial in increasing the awareness of the importance of mining the transactional prescription database and its role in understanding the patterns and associations among the drugs. Consequently, to value the discovered knowledge from the stored unused pharmacy databases. Moreover, this paper contributes to studying the performance of FP-growth algorithm when applied to a pharmacy prescription database and that involves 1) applying and comparing the performance of sequential (conventional) and parallel FP-growth, and 2) testing the scalability of the algorithms.

The main contributions of this study can be summarized as follows:

- Discovering knowledge from pharmacy prescription database.
- Using data mining approach to improve pharmacy automation and other pharmacy strategies.
- Testing the performance and the scalability of conventional and parallel FP-growth on an actual pharmacy transactional database.
- Extracting important association rules among the drugs that involves the different dosage strengths and manufacturers.
- Illustrating improvement scenarios of pharmacy automation while incorporating the discovered knowledge.

The rest of this paper is organized as follows: Section 2 provides a background about the RPDS and its planogram process, data mining, and ARM and FP-growth algorithm; The data description and preprocessing, as well as the applied methodology are described in Section 3; The experimental results are shown in Section 4; Section 5 discusses the outcomes of this research; In Section 6 the conclusions and future work of this research are presented.

2. Literature review

2.1. RPDS

The RPDS consists of drug dispensers that reside in a hexagonal robotic unit, a main conveyor system, and a pneumatic vial and cap delivery system. Drug dispenser stores, counts, and releases different capsule and tablet types all under computer control (Bergeron, Dolores, Potepalov, & Williams, 1999). The conveyor system transfers totes are those assigned to hold patient prescriptions among the different stations, and that is based on the routing criteria and the type of order. The pneumatic vial and cap delivery system loads and transports empty vials and caps to the robots (Khader & Yoon, 2014). RPDS used at a central fill pharmacy has more than one robotic unit to handle the large demand of prescriptions, which makes the distribution and assignment of drug dispensers to these robotic units a difficult problem. Efficient distribution and assignment of drug dispensers among and within these robotic units has a major role in running a smooth dispensing system and in improving the throughput of prescription orders (Innovation Associates, 2007; Khader & Yoon, 2014, 2015).

The process of assigning the locations of the drug dispensers and distributing them among and within the robotic units, along with determining the number of dispensers of each drug to be

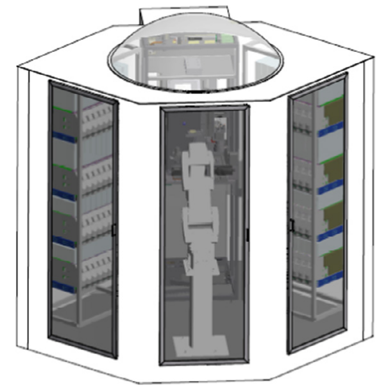

Fig. 1. Hexagonal robotic unit.

placed in each unit, is called the RPDS planogram process. A proper planogram significantly improves pharmacy throughput of prescription orders. Moreover, the pharmacy is better equipped to meet the demand of its patients in a shorter time. Ultimately, the pharmacy is able to maintain a high customer satisfaction level and to increase its revenues (Khader & Yoon, 2014, 2015).

The RPDS system does not consist only of the robotic units, but it also consists of 1) the manual station for filling certain prescriptions manually, such as creams and shampoos, and 2) the packaging and verification station for packaging the prescriptions and verifying patient's information, respectively. Thus, the cycle time of completing one order of prescriptions is the time elapsed from when an order enters the system until it is verified. Integrating the discovered associations and patterns in the process of the RPDS planogram significantly decreases the time of autofilling, which consequently decreases the overall cycle time of completing an order of prescriptions. That results in increasing the pharmacy throughput because the RPDS is able to fulfill more prescription orders.

2.2. RPDS planogram

A planogram identifies where and how much of each item should be physically placed on a shelving unit in order to maximize sales. A planogram is a diagram or a model that shows where and how to place the specific retail products on shelves to increase the throughput and improve the financial performance. This process is challenging and time consuming. It is considered as a NP-hard problem, which is difficult to solve (Bai & Kendall, 2005). In the RPDS, a planogram identifies where to allocate the dispensers inside the robotic unit and how to distribute them among the multiple robotic units along with the determination of how many dispensers of each drug should be physically placed inside the robotic unit.

There is a complete lack of literature in this domain. Thus, the study aims to optimize the planogram process of the RPDS by finding the associations among the different drugs. Fig. 1 shows the robotic unit, which consists of the robotic arm and the dispensers that are allocated in the automated bins. The number of the dispensers that are assigned to each drug is based on the demand of the drug; thus, it is possible to have more than one dispenser assigned to a certain drug in a specific robotic unit.

The planogram process of the RPDS is illustrated in Fig. 2. This process is mainly followed by the RPDS provider. The first task involves receiving the historical transactional dataset from the pharmacy that requests the RPDS.

The transactional dataset should cover a large time frame of transactions and it should include all the necessary information such as 1) the pharmacy rules of the system design, 2) the