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Abstract. In this paper, we focus on the problem of determining the feasibility of medication assignment in an automated dispensing cabinet. Indeed, a cabinet is made up of several drawers. Each drawer is subdivided into compartments, each capable of receiving one medication type. There are medications which should not be placed in neighbouring compartments because of the risk of confusion, according to medication similarity (look-alike/sound-alike drugs) or the pharmacological incompatibility which may lead to errors in dispensing. Then, the problem consists in determining the boundary conditions necessary for the allocation of medications to the different compartments without similar/incompatible medications in close proximity to one another. First, we developed an algebraic model that calculates the upper limit (not to exceed) of appearances of a medication in all pairs of incompatible medications. Then we formulated an efficient mixed-integer linear program that checks the existence of an acceptable solution to the assignment problem.

Keywords: automated dispensing cabinet, dispensing errors, optimal allocation, boundary conditions, algebraic model.

1 Introduction

The three main phases of the medication-use process are prescription, dispensing and administration. The prescription phase corresponds to the writing and the entry of the prescription with the update of the patient record. The second dispensing phase corresponds to the validation of the prescription, the preparation and the delivery of medications. The administration phase consists of the preparation and administration of the medication to the patient. Different errors can occur throughout the three phases. In this study, we will focus on the errors that occur during the dispensing phase, in an attempt to minimize them.

When properly used, automated dispensing cabinets can greatly reduce medication selection errors when compared to manual dispensing. However, errors may occur during the filling of the cabinet, and improper placement of a product in the cabinet increases the likelihood that the patient will receive a wrong medication (Hyland et al., 2007).

Consequently, decisions about the quantities of stored medications and their locations are the key of the reliability and safety of an automated cabinet.

To prevent the dispensing errors, it would be necessary to eliminate the causes that produce them. For example, confusing drug names due to the similarities between brand names (e.g.Sumial® and Luminal®) is a frequent cause of medication errors (Hoffman and Proulx, 2003).Indeed, for human factors such as lack of attention, errors of dispensing can occur from mis-selection of drugs with sound-alike/look-alike (similar-looking or similar sounding names or similar-looking packaging). Some solutions and best practices are presented in (Emmerton and Rizk, 2012).

Several techniques exist to reduce administration errors. One can mention the use of capital letters in the drug names writing (López et al., 2011), as in Hydroxyzine and Hydralazine written HydrOXYzine and HydrALAzine to mark the difference. The barcode utilization to identify drugs is another means of preventing errors of administration (Hassink et al., 2012) (Poon et al, 2010) (Morriss et al, 2009).

Several research studies have investigated the impact of the introduction of automated dispensing systems in pharmacies.

In a study led by Oswald and Caldwell (2007), the authors estimated error rate of filling and distribution before and after the implementation of an automated carousel system in Stanford's university hospital of 613 beds. They were able to notice the drastic reduction of the error rate. In another study (Serrano et al., 2012), the authors analyzed the impact of the automated dispensing system "Pyxis MedStation®" in the intensive care unit (ICU) both financially and in terms of human resources. By creating a list of drugs and using the management software 'Sinfohspharmacy', they showed that the monthly cost per patient with the Pyxis MedStation® system was reduced by 20.3%. The number of drugs in stock increased by 11.4%. In addition, less space was needed for storage while staff needed less time to carry out dispensing operations; reduction of 2 hours on average per day. Some researchers have studied the economic impact of the introduction of automated dispensing systems (Chapuis et al., 2015). Concerning automated dispensing cabinets, Pazour et al., (2012) addressed the problem of locating medications inside the drawers of ADCs in order to minimize human selection errors. They have developed a quadratic optimization model, allowing determining the best storage locations and avoiding putting two similar drugs side by side to reduce picking errors. However, solving real-sized problems is not practical; the authors note that the solving of a problem of twelve medication and two drawers using CPLEX10.1 fails in finding an optimal solution due to memory limitations. Therefore, they proposed a heuristic solution approach. Hachemi and Alla (2013) addressed the problem of assigning medications in an ADC by modelling the cabinet by a Petri net. Their goal was to synthesize, with a focus on control issues, a controller that prevented placing two incompatible medications side-by-side, whereas the problem considered in this paper is the prediction of the existence of an assignment solution according to the dimensions of a cabinet drawer.

A 2011 survey by the American Society of Health-System Pharmacists (ASHP) concerning the evaluation of the practices and the technologies related to drug distribution and administration and which concerned 1401 hospitals in the United States, has concludes that the adoption of the new technology changes the philosophy of drug distribution, and health information is rapidly becoming electronic. Indeed, health information, including patient medication profiles, is more and more electronic, allowing easy access to patient information by all nursing staff and pharmacists. In addition, the distribution of drugs is increasingly decentralized with drugs kept close to patients (Pedersen et al., 2012). This study noted that 89% of hospitals used automated dispensing cabinets.

The same survey conducted in 2014 found that 97% of hospitals surveyed used automated ADCs cabinets (Pedersen et al., 2015), confirming the trend towards decentralized drug delivery systems that have the advantage of reducing delays by getting medications closer to the point of care.

A recent study has further highlighted the role of ADCs in reducing dispensing errors (Fanning, 2015) by ensuring the physical separation of similar drugs, the use of alerts and light guidance technology, using Light-Emitting Diode (LED) to guide the operator to the correct compartment.

In this paper, we address the problem of determining the feasibility of medication assignment in an automated drug dispensing cabinet ADC. The problem is to determine the boundary conditions necessary for the allocation of medication to the different compartments of a cabinet, knowing that there are medications which should not be placed in neighbouring compartments because of the risk of confusion that could lead to errors in dispensing. In this paper we refer by "Incompatible medications" to medications having a very similar appearance, nomenclature, packaging, dosage form, demand frequency, risk level, and dosage concentration, like mentioned in (Pazour and Meller, 2012).

Comment: An extended version of this paper will be published in ISTE book.

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