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Robotic Technologies for Optimizing Dispensing Chronic Medication in South Africa Healthcare Center

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Abstract

In the last years special emphasis has been placed on the development of robots capable of helping humans to dispense chronic medication in the South African healthcare center (pharmacy). Human environments usually involve very large domains, where many unexpected situations can arise easily, and coding the behaviours to cope with every possible situation may result impractical. To provide a human teammate with the right assistance at the right time, a robot partner must be implemented. The robot will not only recognize what the person is doing (i.e., his observable actions) but also understand the intentions or goals being enacted. This style of human-robot cooperation strongly motivates the development of robots that can infer and reason about the mental states of others within the context of the interaction they share. Pharmacy leaders will need to begin looking beyond the traditional business models for their organizations to remain successful. Having the skills to provide entrepreneurial solutions will help continually improve the value the pharmacy brings to an organization. In this workshop, you will develop new pharmacy business strategies for continued success in this changing health care environment.

Keywords: Robotics; Human-Beings; Healthcare; E-Health

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1. Introduction

This Technological innovation in health care is an important driver of cost growth. Doctors and patients often embrace new modes of treatment before their merits and weaknesses are fully understood. These technologies can lead to increases in costs, either because they are simply more expensive than previous treatments or because their introduction leads to an expansion in the types and numbers of patients treated. In South Africa most healthcare are faced with challenges of dispensing chronic medication to the patients on time, these are as the results of patients unable to afford transport to the respective healthcare institution to collect their medication.

The use of modern communication technology as well as hardware and software is becoming more widespread and gains a key role for the evolution of the community pharmacy from both a professional and profitability perspective. Automation of the repetitive and labour-intensive manual parts of the dispensing process is one of the possibilities in this area. In this edition I'd like to take a short glance at the history of this technology and the current developments overseas as automated dispensing solutions are still quite new in Australia and the information and marketing on automated dispensing is scarce and sometimes misleading. Automated dispensing dates back to the mid-90s. The first automatic dispensers or 'robots' were developed in Germany in the mid-90s and were displayed for the first time by Rowa and Willach [1] at the Expopharm in Munich – the biggest pharmacy show in Europe.

For a healthcare to develop a strategy that can work and accommodates everyone is a challenge reason being privacy is a major concern of many citizens and the government has an important role in protecting the privacy of the citizen [2]. Therefore, the government has developed legislation to protect its citizens, who may make use of the legal facilities provided.

To facilitate the acceptance of electronic healthcare (e-health) services, it is necessary to develop the technology that help end-users to establish trust in healthcare service providers in terms of privacy, reliability, integrity of the data. Standard Internet security techniques provide authentication and encryption of the communication with a service provider. However, they do not provide the user with means to control or even know how a service provider will actually use their personal information. It is important to have mechanisms in place that allow users to make an informed decision to trust a service provider on the basis of facts, such as reputation and security attributes.

Mobile technology has provided an opportunity to revolutionise healthcare, especially in countries like South Africa that have the challenges of providing care in deep rural settings but also have a thriving telecommunications market [3]. South Africa's busiest HIV clinic sees more than 750 patients a day with more than 17 000 patients on ARVs. In response to lengthy patient queues and overworked pharmacist staff, the first robotically automated pharmacy has been introduced in a public health facility in South Africa. This innovation addresses the concerns of patients needing HIV and other chronic medicines.

2. Literature Review

Healthcare systems around the world are facing major challenges related to chronic diseases, demographic changes, nursing shortages, medical accidents and rising costs. For example in Europe, the proportion of people over 65 is expected to almost double by 2050 [4]. More elderly people will require prolonged medical care and assistance to ensure they live independently. Furthermore, chronic diseases are on the increase, as are their management costs. All these factors are starting to place additional strain on national healthcare systems.

Traditional healthcare institutions offer treatment mainly on the basis of disease symptoms. This approach is associated with high costs and a reduced quality of life for patients. Even though the advantages and benefits of preventive healthcare are widely recognized, current health systems in developing countries invest only a fraction of their expenditure in prevention of diseases. Moreover, most healthcare services are delivered inside medical premises. Despite being built for acute events, many hospitals allot a significant number of their beds to chronically ill patients, with considerable cost consequences. Efficient remote monitoring and care are thus required.

Evidence suggests that every year hundreds of thousands of deaths worldwide are attributed to medical accidents, adverse drug effects and preventable injuries. The majority of these deaths are due to communication difficulties in the healthcare process and lack of information on patients' medical history. In the USA, it is claimed that more deaths are attributed to inappropriate medical decisions than to motor vehicle accidents, breast cancer or AIDS (To Err is Human: Building a Safer Health System, Washington DC, Institute of Medicine, [5]. Experts consider that the figures are likely to be of a similar magnitude throughout Europe.)

2.1. Robots at work

In the final decades of the 20th century, automated medication dispensing systems were introduced in hospital pharmacies to minimize medication dispensing errors and to save time and personnel. Several studies showed a moderate decrease in both medication dispensing errors and time [6] & [7]. In other studies, automated point-of-use distribution systems in hospitals were tested on their effect on medication administration errors [2] & [8].

A robot is really just a computer, but researchers are beginning to understand that human-robot interactions are much different than human-computer interactions. While the metrics used to evaluate the human-computer interaction (usability of the software interface in terms of time, accuracy and user satisfaction) may also be appropriate for human-robot interactions, we need to determine if additional metrics should be considered.

Automated dispensing devices can be used to hold drugs at a location and dispense them only to a specific patient. As Such devices, especially if linked with bar coding and interfaced with hospital information systems, can decrease medication error rates substantially [2]. Ensuring safety in the use of automated medication dispensing systems. Automation may also reduce error rates in filling prescriptions. Robots have been used for this in some large hospitals for some time, and more recently in smaller hospitals, and they are increasingly being used in the outpatient setting. No published data are available, but in one unpublished study a robot decreased the dispensing error rate from 2.9% to 0.6% [9].

2.2. Human versus Robots

Nowadays, robots are found in the most technologically advanced societies such as search and rescue, military battle, mine and bomb detection, scientific exploration, law enforcement, entertainment and hospital care. According to [10] entertainment robotics, social assistive robotics and robot assisted therapy are widely used as human interaction partners. Normally when people age, they require some sort of assistance because they are unable to perform some activities. Assistive robots make it possible the elderly effectively in everyday tasks such as communication with the external world to provide medicine and health check reminders in a hands-on manner [11]. Other kinds of medications if they are missed, they no longer work. For example, if the TB or HIV treatment is missed they build resistance and they fail to treat patients. Therefore, these assistive robots become handy in assisting human beings regardless of age.

The concept of closeness is to be taken in its full meaning, robots and humans share the workspace but also share goals in terms of task achievement. In the automobile industry, robots work with human beings when assembling cars. In recent studies about human-guided machine learning it is revealed that a simulated robot can learn a simple sequential task, such as a cleaning up a virtual kitchen, given feedback from a human tutor [12]. Therefore, social robots need a set of social skills in order to successfully encourage a user's social behavior, which might require the ability to use social cues and gestures to motivate users to interact with it and keep them motivated to interact with the robot beyond the first few moments of 'novelty' [10].

Robots process things faster and more accurate than humans. For example, the medication dispensary robots in the pharmacy, they pack medication and dispense them with no error. Humans when they are tired tend to commit unintentional errors. Humans can also be easily distracted. Therefore, the combination of humans and robots simplifies day to day tasks. According to [13] people rely on others (both other people and machines) when those others have capabilities that they, themselves, do not have.

Robotic dispensing machines have been available for more than 10 years as an alternative storage system to conventional pull-out drawers in community pharmacies. This system is an electronically controlled automated storage system that offers the capacity of a distinctly larger, conventional storage, while taking up only a minimum of space [2]. The robotic dispensing machines are bound for community pharmacies with a wide range of goods. The warehouse in German community pharmacies contains 8,000 to 10,000 different products [8].

A system within organisations can be both technical and non-technical. Non-technical interaction could refer to interaction that does not involve any form equipment, hardware or software. Interaction with a technical system, such as with computers, can be referred to as human-computer-interaction (HCI) [15]. The authors in [16] further explains that HCI is "concerned with the ways humans interact with information, technologies and tasks, especially in business, managerial, organisational and cultural contexts".

Thus, enhancing computer usability and receptiveness of the user's needs is indicated to improve interactions between users and computers [17].

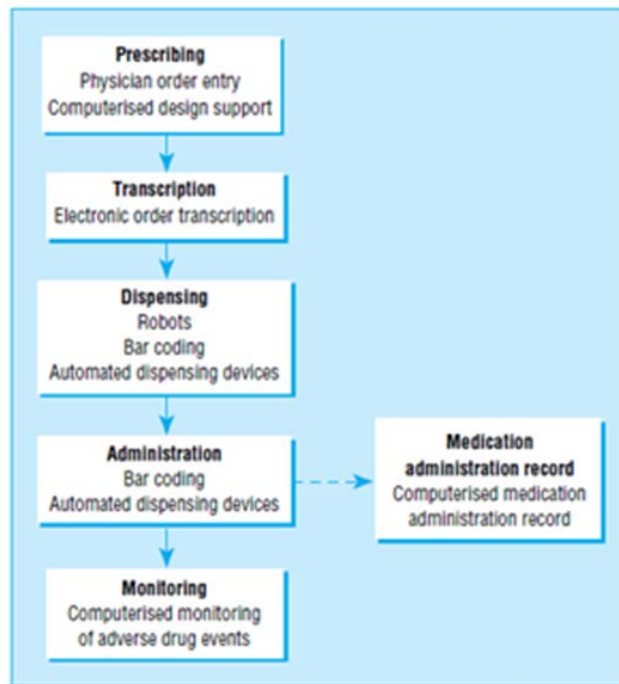


Fig 1:Role of automation by stage in the medication process. Sourced from Cook, Render and Woods, [14]

Telematics infrastructure constitutes an essential link in any e-health application. E-health demands a high degree of telecommunications network security, availability, adequate transmission capacity and reliability. For practical and economic reasons, security and reliability of telecommunications networks is a decisive factor in introducing e-health applications. The technical infrastructure may vary greatly depending on the resources available to any program. Guaranteeing the integrity, confidentiality and security of sensitive patient data is essential if patients and clinicians are to have confidence in the application of IT in health care as a whole, as well as the implementation of EHCR's (Electronic Health Care Records) in particular.

2.3. Strength of Robots

Robots, unlike many software agents, operate under real-world, real-time constraints where sensors and effectors with specific physical characteristics need to be controlled. To facilitate research in autonomous robotics and help architecture designers in managing the complexity of embodied agents, several robot development environments (RDEs) have been developed that support various aspects of the agent development process, ranging from the design of an agent architecture, to its implementation on robot hardware, to executing it on the robot. Much of the current work in human-robot interaction is thus aptly labelled given that the robot (or team of robots) is often viewed as an intelligent tool capable of some autonomy that a human operator commands, perhaps using speech or gesture as a natural interface [18] & [19].

In today's world, First point robots are used in many different fields. They work in factories, such as the automobile industry and the computer industry. Also, robots are used to explore space and underwater. For example, robots have been placed on Mars to explore and send feedback to NASA. Another aspect of robots is that they will go to places that are dangerous for humans, such as volcanoes and polluted areas. Lastly, robots

have been used in the medical field. We have used them to do more accurate procedures on humans and to do microscopic surgery.

The future of robots is unlimited because the possibilities are endless. They can assist the disabled because they are available whenever the person wants. Possibly, robots may replace humans in the workforce. Humans may be out of the factories, but they will need to tell the robots what to do. Perhaps, robots will have feelings and know what people want. Finally, robots may look like androids. An android is a robot that has human characteristics. The creation of robots have simplified humans job. Robots have enabled people to explore places where nobody dares to go. There are various pros and cons associated with robots. An important advantage is that they make our life much easier. An important disadvantage is that they take away the jobs from us.

2.4. Section headings

According to Siegwart&Nourbakhsh [20]; the greatest single shortcoming in conventional mobile robotics is, without doubt, perception: mobile robots can travel across much of earth's man-made surfaces, but they cannot perceive the world nearly as well as humans and other animals. Controlling autonomous mobile robots is hard for three fundamental reasons. First, the time available to decide what to do is limited.

A mobile robot must operate at the pace of its environment. (Elevator doors and oncoming trucks wait for no theorem prover.) Second, many aspects of the world are unpredictable, making it infeasible to plan a complete course of action in advance. Third, sensors cannot provide complete and accurate information about the environment. These are fundamental problems because they cannot ever be engineered away. No matter how powerful a computer we build, a finite amount of time will allow only a finite amount of computation. No matter how good a sensor we may build there is always information that it cannot deliver because the relevant situation is hidden behind a wall or across town. No matter how good our domain theory may be, many important aspects of the world simply cannot be predicted reliably.

The mobile robot is also limited by dynamics; for instance, a high center of gravity limits the practical turning radius of a fast, car-like robot because of the danger of rolling. But a mobile robot is a self-contained automaton that can wholly move with respect to its environment. There is no direct way to measure a mobile robot's position instantaneously. Instead, one must integrate the motion of the robot over time [20].

When collaborating with a human partner, much new functionality comes into play. For instance, within a collaborative design the task can be divided between the participants, the collaborator's actions need to be taken into account when deciding what to do next, training must be provided in cases of one participant's inability to perform a certain action, and a clear channel of communication must be used to automate and maintain usability for qualification and actions.

Robotics engineers can design robots which can do tasks such as fitting small parts of watches and to the hazardous tasks such as fuelling the chambers of nuclear reactors. Robots are thought to be super-machines but they have limitations. Despite the great advancements in the field of robotics and continuous efforts to make

robots more and more sophisticated to match the capabilities of human beings and even surpass them, still, from a very scientific and logical point of view, robots developed up till these days are no way closer to human beings. Whole lot of things, ranging from delicate and precision

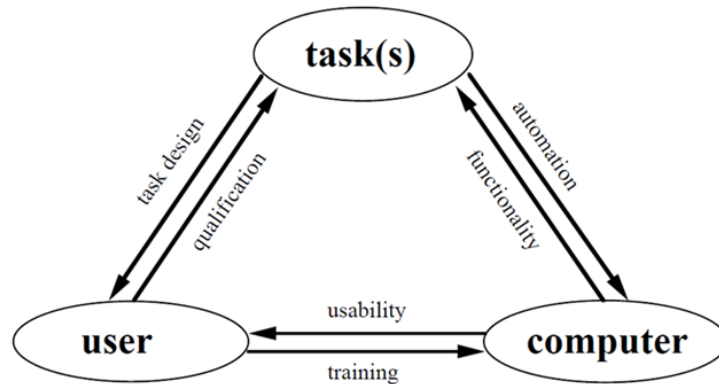


Fig 2: Performing Tasks with Humans

When executing a task, goals as preconditions and until conditions of actions or sub-tasks manage the flow of decision-making throughout the task execution process. Additionally, overall task goals are evaluated separately from their constituent action goals. This top-level evaluation approach is not only more efficient than having to poll each of the constituent action goals, but is also conceptually in line with a goal-oriented hierarchical architecture. For example, consider a task with two actions. The first action makes some change in the world (and has a state change goal), and the second action reverses that change (also a state-change goal). The overall task goal has no net state change and becomes a just-do-it goal even though its constituent actions both have state-change goals.

3. Author Artwork

The automation system demonstrates the latest technologies in pharmacy dispensing and the Clinic has seen patient waiting times in the pharmacy drop from over four hours to 18 minutes. The system has also eliminated the loss of stock due to drug expiry which will save the Department of Health millions of rands. Doctors in the clinic write electronic scripts which then link directly into a patient management system in the pharmacy using cloud technology systems. Medicines are then automatically dispensed and are available for handover by pharmacy staff shortly after the patient arrives at the pharmacy.

Four Phase were implemented in order to have a Robotic Technologies for Optimizing Dispensing Chronic Medication:

Phase 1- saw clinicians prescribing medication by entering the prescription into Decision support system (DSS), printing and signing the prescription printout. The printed prescription remains in the patient file and is the original prescription.

Phase 2 - New pharmacy system and the automated dispensing machine (Rowa). To address long waiting times for patients, automation of the pharmacy included a pharmacy dispensing system and an automated dispensing machine that stores medication in the pharmacy area. The pharmacy system was implemented. Using patient demographic data from DSS imported into the pharmacy system, pharmacists entered patient prescription data from the signed prescription brought to the pharmacy by the patient. The pharmacy system dispenses and prints medication labels and sends electronic prescription messages to the Rowa machine. The Rowa machine picks medication and delivers it via a chute for the pharmacist to collect and hand to the patient.

System improvements **phase 3** saw the implementation of a new pharmacy module in DSS in order to link ICD 10 coding to prescribed drugs and align drug databases in the two systems.

Phase 4 Interface between DSS and pharmacy system: an interface between DSS and the pharmacy system eliminates the need for the pharmacist to recapture prescription data. The design uses a generic message bus that is able to accommodate different health information systems and pharmacy systems, interacting with each other. The transfer of data is managed via HL7 messaging (an industry standard messaging system). This ensures up to-date flow of patient demographic and prescription data between the systems, each system receiving and sending information.

A major technical problem is communication between medical devices, since manufacturers have developed their commercial devices in isolation and in way that precludes communication both between themselves and with hospital computer and data management systems. In order to derive the expected clinical, administrative and research benefits from electronic communications in health care, need for technical standardization and the development of protocols that enable open and structured communication are paramount

An unfavourable working environment tends to increase dispensing error rates. The designated area for drug dispensing should have adequate space and appropriate lighting, temperature, and humidity for comfortable work.¹⁴ Drugs should be stored in a way that facilitates the workflow, and furniture should be ergonomically distributed. The most significant cause of dispensing errors in community and institutional pharmacies is work overload. Studies have demonstrated a direct relationship between errors and work overload. Stress caused by imposing a maximum time limit for dispensing the prescription is a significant factor. The most obvious solution for work overload is to have enough trained staff and to increase the time limit for dispensing the prescription.

The system holds all the medicine stock in a secure container and a robotic picking head is used to quickly dispense the medicines to the pharmacist. It was not just a machine that was installed, but systems and processes for stock control management and pharmacy dispensing that are aligned to a new way of work flow and responsibility within the pharmacy. "Patients now receive their drugs very quickly, which leaves more time for patient counselling from the pharmacy staff. Picking errors and have been reduced to zero and patient care has improved. Patients are now more compliant on their medicines as a result of not having to spend the whole day at the clinic."

With increased efficiencies, the staff requirement to run the pharmacy has been drastically reduced, allowing for pharmacy personnel to be used for supportive functions in the wards and throughout the clinic. The pharmacy used to close at 19h30, with staff working overtime. Now the pharmacy sees all patients by 15h00.

4. Conclusion

Ensuring that the e-health becomes a suitable, ubiquitous medium for delivering health care services is a challenging task. E-health must not only provide connectivity among the participants in clinical care transactions, but it must also ensure that such transactions do occur predictably, efficiently, and without endangering patient safety. The ability of e-health to empower consumers, support dynamic information exchanges among organizations, and "flatten" organizational hierarchies might result in need for new operational strategies, business models, service delivery modes, and management mechanisms. Organizations need to evaluate the potential and implications of e-health, anticipate health care needs and be prepared to adapt to local conditions, while minimizing the risks associated with e-health service delivery.

To summarise, when it comes to choosing the right automated dispensing solution for your pharmacy much will depend on the healthcare system of your country, which usually determines your type of market environment (slow or fast mover market). Just as important is a thorough analysis of the individual business model of your pharmacy and, last but not least, what you really want or need to achieve with an investment of this magnitude in the immediate and medium-term future.

As the above brief sketch of the history of automatic dispensers would suggest, there is no such thing as the 'best' machine. In reality, today the machines of most manufacturers will reliably pick and transport the medication to where it's needed, as technology has advanced and matured. Some vendors offer dispensers which not only pick but also store, label and even sell the medications automatically or semi-automatically. While channel machines are generally quicker in picking and replenishing, more compact and less complex to operate, chaotic dispensers are better suited to pharmacies with a wide range of medications, a lot of split-packs or the need/concept to keep almost all of their products inside the dispenser. However, pharmacists should be aware that there is no 'complete' automation of all the items in a dispensary – just think about items which are too heavy, bulky, dangerous or need cooling.

Today, most manufacturers have realised that they need to offer both types of systems – random and channel – in order to be compatible in both slow and fast mover markets and to suit different customer needs. In fact, most internationally active players have both types of machines in their portfolio, while more locally oriented players focus on the type of machine which is best suited to their core market.

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