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## A Preliminary Investigation of M3DITRACK3R : A Medicine Dispensing Mobile Robot for Senior Citizens

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### Abstract

Medicine adherence among patients is crucial to ensure the effectiveness of a given treatment. Failure to take a medication of the right dosage, at the right time causes minor healthcare problems to become worse. This is extremely problematic for the elderly patients who have difficulties in keeping track of their medicine. Therefore, to address this issue, M3DITRACK3R, an automated medicine dispenser which keeps track of the dosage and duration between each consumption, autonomously navigate to the patient and dispensing the medicines to the patient is proposed. This innovative prototype is able to detect its patient using sensing technology. Number of touch detected by the touch sensor is used to set the number of hours in each loop. M3DITRACK3R then navigates to find the patient using the infrared sensor to dispense the right dosage of medicine at the right time. It is a perfect solution for senior citizens living independently.

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### 1. Introduction

It is vitally important for anyone diagnosed with a medical condition to remember to take the correct amount of their prescribed medicine at the correct time. Failure to do so could, in some circumstances, have life-threatening consequences. Elderly people, in particular, may need to take several tablets each day and if they are living on their own they may not always remember. Despite their physical and mental challenges, they are required to comply with the consumption of medication as prescribed.

Malaysia currently has about 3 million senior citizens, and the number is rising. United Nation statistics show that Malaysia is likely to reach ageing nation status where the number of people above 60 makes up at least 15% of the population by 2035 [1]. According to the Department of Social Welfare, 11 government-run and 165 NGO- and privately-operated old folk's homes have been registered in Malaysia [1]. Despite the large number of the elderly in Malaysia, a research by Rahim et al. [8] found an interesting finding on the silence of the elderly in Malaysia. The research investigated the role of elderly in applying ICT to support their independent living. However, the outcome of the research concludes that ICT does not facilitate their life. These include the use of ICT gadget and smart phones for communication. Thus, it would be interesting for this research to attempt on getting ICT into the elderly but from a different angle i.e. a robotic application.

Adhering to medication refers to the extent to which a person follows the regime of their scheduled medicine. Factors for poor compliance to medication can be classified into two groups, namely *The Intentions* and *The Unintentionals* [2]. *Intentions* are those who rationally choose not to take their medicine or even decide to stop taking whereas *Unintentionals* want to consume their medicine but accidentally fail to do so due to their physical and mental constraints. There is a need for a robotic device to assist both groups of senior citizens. Research in the field of AI highlights the generation of algorithm with lesser requirement of human control when the device is being used. In relation to robotic application for senior citizens, social robots have been developed to cater to their needs and can be categorized into three classes: humanoid, mechanoid, and zoomorphic [3]. The medicine dispensing mobile robot for this investigation was mechanoid.

Existing robotic application related to medicine tracking and dispensing include fuzzy logic implemented by iMec, the intelligent medicine box to estimate the subsequent time to remind the patients of medicine consumption [4]. The inferencing considers the information received from the sensors to indicate the current situation of the patient and the sensors are activated by placement at specific areas in the house e.g. when the patient draws water from the kitchen tap. Suzuki et al.'s iMec ensures the consumption of the correct dosage by checking the medicine dispensed from the case and alerting of incorrect dosage by sending a message to an email address. Whilst Suzuki et al.'s device represents a significant improvement on adapted medicine bottles, it is too technically advanced for the majority of elderly people. Moreover, if the patient does not have a computer or email address, he or she is still dependant on a caretaker to monitor and dispense.

Using a social robot, a closed loop medication management supports patients by helping to reduce non intentional, non-compliance of medication [5]. The Healthbots project uses web programming and integrates a medication management module into the robot suite of software to collect essential data to track medicine adherence. This application is useful for those who would want to have a systematic management of their health care and medical issues. However it is not efficient especially when it comes to users who are not technologically savvy.

Robotic based device has been developed to aid elderly in taking medicines according to their prescribed time and dosage. An autonomous medicine and water delivery robot has been built to address the issue of poor medication adherence and dehydration for elderly living independently that lead to reduced quality of life [6]. This device is able to dispense medicine and water upon the prescribed time and prompt a message through smartphone asking for the current location of the elderly. Once the elderly has replied the message, the device will convert the text message into the corresponding IP address of the location, and move to the location as instructed. However, the major drawback of the robot is that it requires the patient to indicate their current location using a smartphone. This is not a suitable approach when it comes to aiding the elderly, especially those physically and mentally challenged to operate a smartphone. The research on existing systems is summarised in Table 1.1 below.

Table 1.1: Summary of Existing Robotic Systems for Medication Purposes

No	Existing Device	Advantages	Disadvantages	Time tracking ability	Alarm triggering ability	Patient tracking ability	Dispensing ability
1	Intelligent Medicine Case System. [4]	<ul style="list-style-type: none"> <li>RFID embedded in the medicine case can detect dose of dispensed medicine</li> <li>Promotes correct dosing and correct time</li> </ul>	<ul style="list-style-type: none"> <li>Upon wrong dosing, email will be sent – Inefficient approach for non tech-savvy (elderly)</li> <li>No immediate warning</li> <li>Cannot differentiate types of medicine</li> </ul>	Yes	Yes	No	No
2	Microsoft Healthvault.	<ul style="list-style-type: none"> <li>Tracks medicine intake</li> <li>Monitors bp, and other parameters</li> <li>Stores medical history</li> </ul>	<ul style="list-style-type: none"> <li>Internet : Not a suitable medium for elderly</li> <li>No alarm</li> <li>No immediate reminder</li> </ul>	Yes	No	No	No
3	Closed Loop Medication System - RoboGen. [5]	<ul style="list-style-type: none"> <li>Supported by Hospital Information System (HIS)</li> <li>Interpersonal elements supports elderly</li> <li>Mobile</li> </ul>	<ul style="list-style-type: none"> <li>Medical information updated by caregiver</li> <li>Does not comply to independent living</li> </ul>	Yes	Yes	No	No
4	Autonomous medicine and water delivery robot. [6]	<ul style="list-style-type: none"> <li>Enables dispensing of medicine</li> <li>Dispenses and delivers water</li> <li>Enables delivery of medicine and water to patient</li> </ul>	<ul style="list-style-type: none"> <li>Requires patient to send a text message through smartphone for the device to deliver water and medicine</li> </ul>	Yes	No	Yes	Yes

From the literature cited, the research proposed a robotic application called M3DITRACK3R that will adapt the ability to keep track of the time of each medicine. When the time has arrived, it will track the location of the patient in the compound of the house. Upon the detection of patients, M3DITRACK3R dispenses the medication into a container. It has the ability of tracking time, tracking patient, and dispensing medicine for the patient. The target users for M3DITRACK3R are the mobile senior citizen patients who have the inability to keep track their prescriptions.

## 2. Preliminary Studies

A visit to an old folks' home in Perak, Malaysia was made to gather information on the current practice of taking medicine, and the problems faced by the senior citizens complying with their prescribed medicine. Respondents in the old folks' home comprises of five male elderly and two female elderly ranging in age from 58 to 83 years. Health problems requiring regular medication were heart disease, rheumatoid arthritis, mental illness, diabetes mellitus, and high blood pressure. Nearly all i.e. six remembered to take their medication whereas the elderly lady aged 63 years sometimes needed the caretaker's assistance. Although six of the elderly adhere to the right dosage as prescribed one is less likely to follow the right dosage. One of the reasons these old folks find it difficult to comply with the time is because they have to know how many times they should take their medicine and how many hours there are between each consumption. For example, if the medicine is prescribed as three times per day, the right time to consume this medication would be once every eight hours. However most of the elderly could not keep track of the exact eight hours, resulting in the consumption of their medications after taking each of their meals, whether breakfast, lunch or dinner, incorrectly assuming the interval of each meal is evenly distributed. This is not the correct way of taking the medicine.

Six of the senior citizens admitted having difficulties reading the instruction prescriptions on their medication. However, Lai mentioned that clear information, although important, is not sufficient to ensure a person follows their medication regime [7]. The problem that some of them face is due to physical constraints of finding it difficult to take the medicine out of the bottle.

A visit to the Jeffrey Cheah School of Medicine and Health Sciences (JCMHS), Monash University Malaysia was done in April 2014 for informal interviews with medical students completing their final year at the Clinical School in Johor Bahru. A total of 21 students were asked about the common medical problems faced by senior citizens above 60 years old. Their responses stated that the common medical problems faced by the senior citizens are diabetes, hypertension, cardiovascular diseases, dementia, Alzheimers, osteoporosis and osteoarthritis, kidney problems and Parkinsonism as shown in Figure 2.1. One of the common symptoms of dementia is memory loss, and this strongly affects the ability to comply to medication schedules. Therefore, most of these elderly people require assistance to remind them of their medication times. The medical students also mentioned one of the major reasons of non compliance is due to lack of awareness and understanding of the importance of taking the medication. In addition, as shown in Figure 2.2, some elderly patients are tied to polypharmacy i.e. the use of multiple medications from different health care units, which can be more confusing and even more difficult to keep track of.

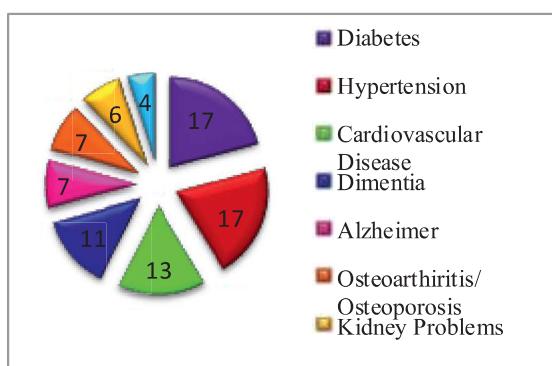


Figure 2.1: Common Health Problems Faced by Senior Citizens

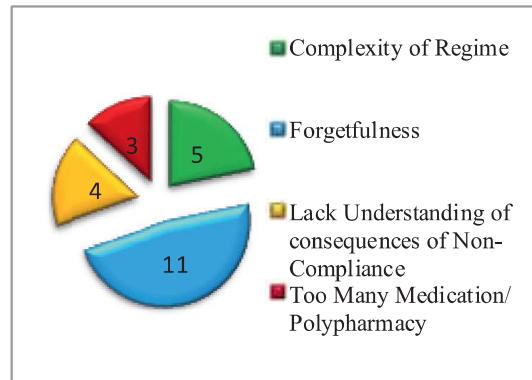


Figure 2.2: Major Causes of Non-Compliance to Medications by Senior Citizens

The medical students were asked for their opinions about the need and acceptance of having M3DITRACK3R to dispense pills on a regular, prescribed basis. Thirteen considered it helpful to ensure consumption of the right dosage of medicine at the right time. However, when asked if senior citizens would be likely to accept this device, most of them were unsure. Klamer alleges hedonic factors such as satisfaction and playfulness are important factors for the acceptance of a robot by senior citizens [3]. The ability of the robot to move towards the elderly could increase their interest and make medicine time a more pleasurable and interactive experience. Given Klamer's comment, one recommendation for M3DITRACK3R is that it could be used to brighten up the care of terminally ill children in a hospital ward. Further studies could investigate the effectiveness of M3DITRACK3R for this age group.

### 3. Proposed Design

M3DITRACK3R was developed in a few designs to analyse the optimum robotic model for senior citizens. The proposed model uses the Lego Mindstorm EV3 kit to prove the concept through a lab-scaled prototype. Lego Mindstorm EV3 provides robotics tool set that has been commercialised. This programmable kit provides a uniform platform to be used which enables future improvement over this robot. It provides a programmable kit with sensors and hardware tools which can be further purchased individually when needed. The prototype has to be equipped with a medicine slot, which enables the patients to insert their medicine. This is then followed by a touch sensor, determining the duration of the medicine. If one touch is detected, the timer will be set to 12 hours, whereas two touches indicate 8 hours. The chosen model of M3DITRACK3R is proposed as in Figure 3.1.

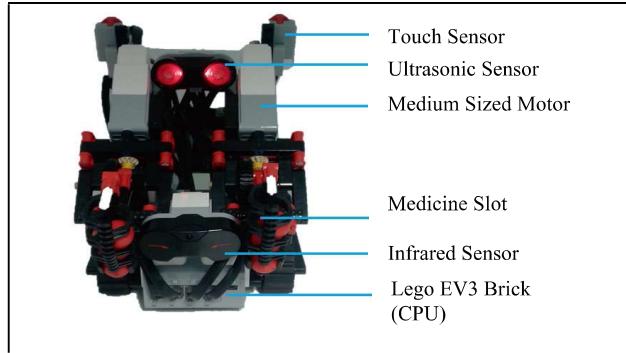


Figure 3.1: Proposed Design of M3DITRACK3R

This design is the most suitable design for M3DITRACK3R because one of the important features of M3DITRACKER is the ability to keep track of all the patient's medicines. Therefore, a design that keeps the number of medicine slots rigid is unsuitable due to the large number of medicines prescribed. Stability plays an important role when it comes to tracking the patients because the robot will have to move around the programmed track to find the patient and an unstable robot will collapse while tracking the patient. Table 3.1 below shows the description of Lego Mindstrom EV3 components.

Table 3.1: Components of M3DITRACK3R

Components	Description
Lego Mindstorm EV3 Brick 	<ul style="list-style-type: none"> <li>The brain of the Lego Mindstorm EV3</li> <li>Control all the other parts as programmed</li> <li>The program from Lego Mindstorm software is transferred into the brick via Bluetooth or USB cable.</li> </ul>
Motor 	<ul style="list-style-type: none"> <li>Enables wheels to rotate and move.</li> <li>Motor is also able to turn a system of gears.</li> <li>M3DITRACK3R uses the motor to move the wheels in order to track and deliver medicine to the elderly</li> </ul>
Touch Sensor 	<ul style="list-style-type: none"> <li>Used to identify the duration / interval of medicine</li> <li>Able to distinguish one or two presses</li> <li>M3DITRACK3R timer will begin when the number of touches is detected</li> </ul>
Infrared Sensor 	<ul style="list-style-type: none"> <li>Tracks and finds the location of its beacon</li> <li>Locates the patients which has been attached with beacon</li> </ul>
Ultrasonic Sensor 	<ul style="list-style-type: none"> <li>Used to detect and avoid any obstacle before M3DITRACK3R</li> </ul>

The architecture of the system is built after conducting research on the elderly. This system focuses on helping the elderly in living independently. Therefore, the simplicity the front end of the system is given priority during the construction of the robot architecture. The flow of the system is shown in the activity diagram in Figure 3.2 below.

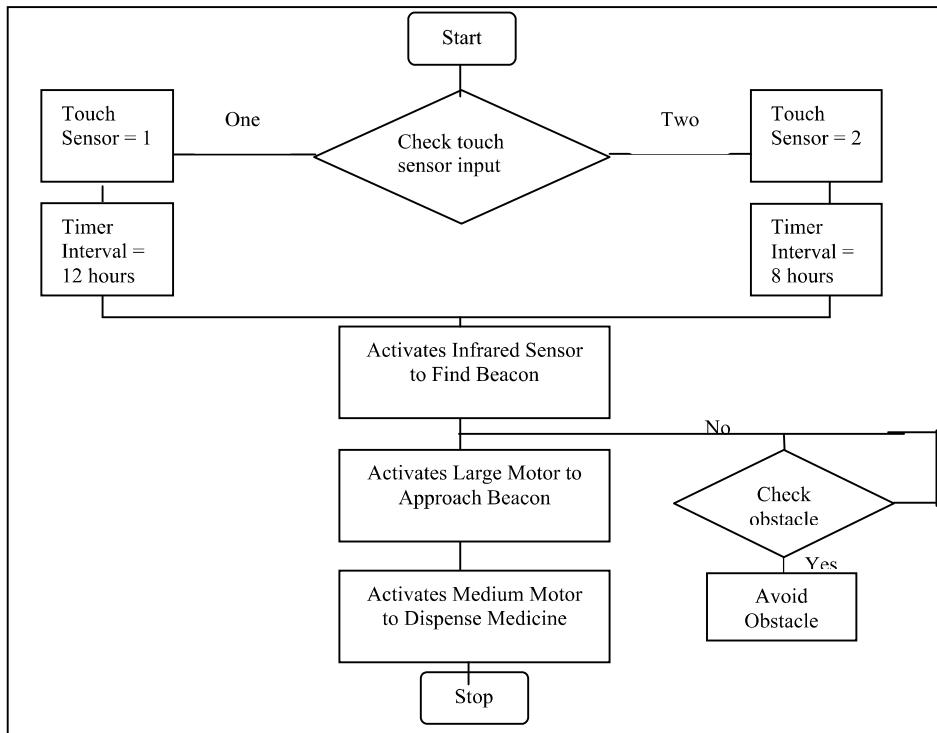


Figure 3.2: Flowchart of M3DITRACK3R functions.

Obstacle avoidance is studied to ensure M3DITRACK3R reaches the elderly without the obstruction of physical environment. For this case, the infrared sensor and the ultrasonic sensors were studied. Due to the lab-scaled size of the prototype, the test area of is assumed to be of 1m x 1m, where the maximum size of the obstacle is fixed to the size of a drink can. The proposed prototype layout is shown in Figure 3.3 below.

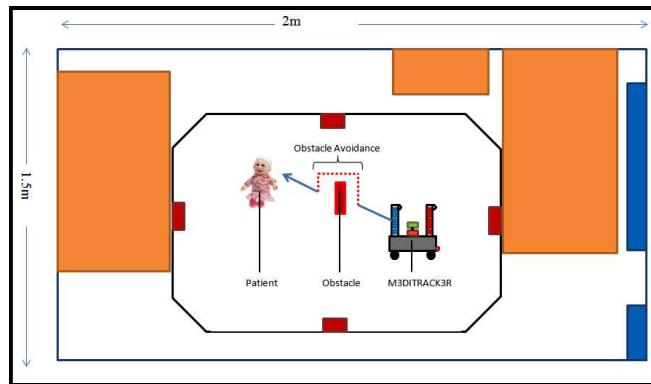


Figure 3.3: Proposed Prototype Layout for Patient Tracking

The track of the prototype layout will be programmed to a fixed pattern to allow M3DITRACK3R to track the patient along the prototype compound. The coding for the obstacle avoidance is pre-programmed because the main research of M3DITRACK3R is not for obstacle avoidance. Therefore, a fixed avoidance of obstacle with the maximum size of a drink will be programmed as in Figure 3.4.

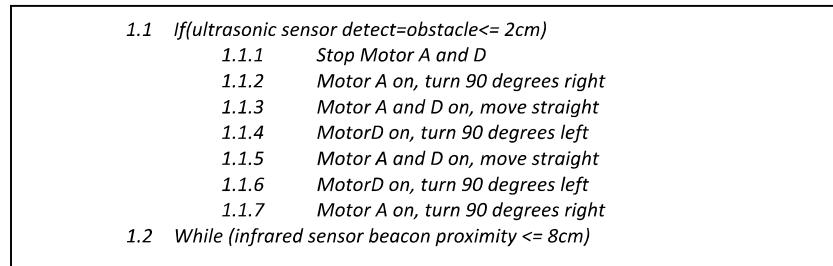


Figure 3.4: Proposed Obstacle Avoidance Algorithm

#### 4. Conclusion

Despite the importance of compliance to taking prescribed medication, failure to adhere to this regime is becoming common among the elderly. This phenomenon, can, in some circumstances, result in life threatening consequences. This project has focused on the problems faced by senior citizens concerning adherence to their prescribed medication. Various causes for the non-compliance of medications have been identified. Adding to this, the consequences of not being able to take medication at the right time and right dosage has also been recognized. In order to tackle this problem, studies on the existing devices have been done. However there were advantages and disadvantages on each of those devices, providing an opportunity to extract the useful features needed for the production of M3DITRACK3R, a medicine dispensing mobile robot. This robot is able to track the time of each medication, and tracks the senior citizen in order to dispense the right dosage.

#### 5. Future Works

Currently, the prototype is still under development. Upon completion, it will be tested at an identified old folks home. The aim is to test the acceptance of the elderly on the usage of a robotic device by carrying out a demonstration and asking for their feedback. The mechanism used in M3DITRACK3R can further be improved and developed for the usage of hospitals in a big scale. M3DITRACK3R can be programmed to monitor medicines of several patients, per robot. Therefore, this could reduce the workload of a nurse. However, safety issues and concerns certainly need to be considered as well.

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