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# M3DITRACK3R : A Design of an Automated Patient Tracking and Medicine Dispensing Mobile Robot for Senior Citizens

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***Abstract-*** **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, M3DITRACK3R, an automated medicine dispenser which keep tracks of the dosage and duration between each consumption would be beneficial for senior citizens living independently. Elderly patients that have ageing issues, such as dementia or Alzheimer's disease have difficulties to remember their responsibilities. Poor eyesight as one of the contributors for medicine consumption errors such as misdosage since the elderly finds it troublesome to read the instruction on the medicine case, and identifying the right dosage of the medicine. Physical disabilities such as arthritis makes it difficult for elderly patients to open the cap of a vacuum tight medicine bottle. Hence, this paper presents a robotic application referred as M3DITRACK3R that is able to track the location of patient using the infrared sensor and dispense medicine at the right dosage and at the right time. The hardware and software design are outlined based on critical reviews made over the existing systems. Performance test and user acceptance test have been conducted and satisfactory results are achieved.**

Keywords- Artificial Intelligence, Robotics, Social Robot, Medicine Dispenser

## I. 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 certainly are required to comply with the consumption of medication as has been prescribed.
United Nation statistics show that Malaysia is likely to reach ageing nation status, where the number of people above 60 years old make up at least 15% of the population by the year 2035 [1]. With this, independent living has become a commonplace for the elderly [2].

Medication adherence describes the patients' medicine taking behaviour and it is vitally responsible to ensure patients consume the right medicine at the right time which contributes to the effectiveness of the treatment. There are a few problems which have been identified with regards to this issue which are memory loss [3][4], poor eyesight [3] and physical ailment [3] especially among the senior citizens. Hence, he objective of this research is to develop a robotic application to automatically track and dispense the medicine for senior citizen patients against the traditional method.

During the investigation, the scope of the research has been scaled to study the characteristics of patients. In this context, the senior citizens are referred to the type of patients who can consume medicine that has been dispensed .They are also assumed to always be in the house. The next scope of research is the space for robot navigation. As this is only a prototype and a lab scaled size, the prototype house compound is assumed to be of 1.2mx0.6m with maximum size of obstacle fixed to size of a drink can. The type and method of medicine dispensing that will be considered for the prototype is to deal with only tablets and one capsule per dispense due to the limited number of ports of the LEGO Mindstorm Brick, which is only eight input and output ports. Due to the constraints of toolkit ability, it requires more ports on the EV3 brick to develop a complete prototype in the future.

## II. LITERATURE REVIEW

Adhering to medication refers to the extent to which a person follows the regime of their scheduled medicine. In reality what happens is that, due to other constraints, they get their prescribed medication but fail to follow their health care professional's instructions. Factors for poor compliance to medication can be classified into two groups, namely 'Intentionals' and 'Unintentionals' [5]. The first group-Intentional people, are those who rationally choose not to

take their medicine accordingly or even stop taking. On the other hand, the second group- Unintentional people refers to the group of people who want to consume their medicine but accidently fail to do so due to their physical and mental constraints.

### *A. Robotics Application*

Artificial Intelligence (AI) is the field of study where computational devices and models can be made to display and replicate intelligent behavior of human. Meanwhile, in recent years, robotics researches have steered increasingly towards the area of service robotics. This is due to the general aim of getting robots to meet the social needs of humans. Robotic applications has been studies and applied in many areas including medical, education, rehabilitation, and construction [6]. In relation to robotic applications for senior citizens, social robots have been developed to cater to their needs. Social robots can be categorized into three classes: humanoid; mechanoid; and zoomorphic [7]. In this paper, M3DITRACK3R will be a mechanoid robot.

### *B. Existing Medicine Tracking & Dispensing System*

A diverse range of devices has been developed to address this issue, which can be classified according to the nature of the device. Research was carried out on existing system to analyse the tracking and dispensing method of the devices. The literature is categorized as passive medication reminder [8,9], alarm-based medication reminder [10,11], software-based medicine tracker [12,13], and robotic- based medicine tracker and reminder [14].

The details and behavior of those existing systems are studied and compared. The findings are summarized in Table 1.

Table 1 : Summary of Existing Medicine Tracking and Dispensing System

| No | Existing System | Advantages | Disadvantages | Time tracking | Alarm triggering | Patient tracking | Dispensing |
|---|---|---|---|---|---|---|---|
| 1 | Medication Reminder System. [8] | • Keep tracks on the immediate next time for medicine intake | • Not adaptable for all bottle sizes<br>• Dispense manually from bottle<br>• No alarming mechanism | Yes | No | No | No |
| 2 | Add-On Medicine Dispenser Timer. [9] | • Fix device on existing bottle cap<br>• Avoid adaptability problem<br>• Displays time of next medicine | • Cannot be used for packets/strip pills<br>• No alarm<br>• User manually dispense from the bottle | Yes | No | No | No |
| 3 | MedCenter Pill Organizer [10] | • Tracks dosage intake for a month<br>• Has a separate talking alarm | • Dispense manually into the compartments<br>• 2 separate device-inefficient storing | Yes | Yes | No | No |
| 4 | Intelligent Medicine Case System [11] | • Can detect dose of dispensed medicine<br>• Promotes correct dosing and correct time | • Upon wrong dosing, email will be sent – No immediate warns<br>• Cannot differentiate types of medicine | Yes | Yes | No | No |
| 5 | Microsoft Healthvault. [12] | • Tracks medicine intake<br>• Monitores bp, and other parameters<br>• Stores medical history | • Internet : Not a suitable medium<br>• No alarm<br>• No immediate reminder | Yes | No | No | No |
| 6 | Closed Loop Medication System - RoboGen.[13] | • Supported by Hospital Information System (HIS)<br>• Mobile | • Medical information updated by caregiver<br>• Does not comply to independent living | Yes | Yes | No | No |
| 7 | Autonomous medicine and water delivery robot. [14] | • Enables dispensing of medicine<br>• Dispenses and delivers water | • Requires patient to send a text message through smartphone for the device to deliver water and medicine | Yes | No | Yes | Yes |

From the literature cited, the research proposed a robotic application called M3DITRACK3R that will adapt the features of time tracking and alarm triggering based on the alarm –based medication reminder [10],[11]. Additionally, the idea of patient tracking and dispensing will be adapted from the autonomous medicine and water delivery robot [14]. However, as compared to the existing system, M3DITRACKER tracks the patients autonomously using an infrared sensor, instead of using the mechanism of detecting the local IP address based on the location indicated by the patients via a smartphone. This is because, smartphone technology is not a suitable approach when it comes to aiding elderly, what more a physically and mentally challenged elderly. Therefore, M3DITRACK3R 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 due to some health constraints. Thus, M3DITRACK3R is developed overcome as an aid to assist the elderly by autonomously tracking the time and detecting the location of patients using sensors. The patient is attached with a beacon, a sensor that will 'communicate' with M3DITRACK3R in certain distance. In real world, the beacon can be attached in the form of a fixed bracelet to the elderly to avoid missing or misplaced.

## III. METHODOLOGY

The software architecture of the system is built after conducting research on a group of elderly who have to live independently. This system focused on supporting the independent living of the elderly. Therefore, the simplicity of the front end of the system is given priority during the construction of the robot architecture. The general flowchart of the robot functionality is shown in Figure 1.

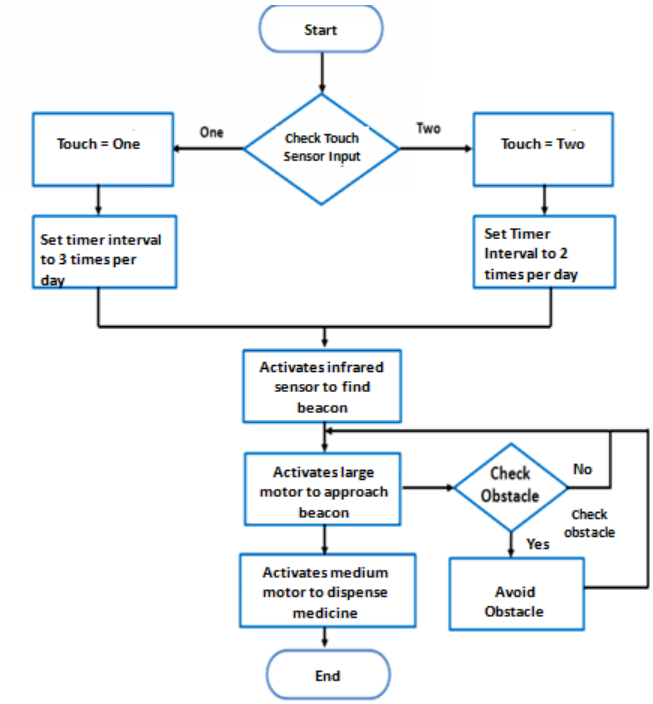


Figure 1 : Flowchart of M3DITRACK3R

M3DITRACK3R starts upon receiving input from the touch sensor. Patients or caretaker need to fill medicine in one medicine slot with one type of medicine followed by distinguishing how many times this medicine is to be taken. Upon detection of the touch sensor, the robot will begin the loop of its timer where the duration will be based on the number of touches being detected which has been previously pre-programmed. Prior to every medicine delivery, M3DITRACK3R will navigate and locate the patient using an infrared sensor finding for its corresponding beacon which will be attached to the patient in the form of a bracelet or chain. After navigating to the patient, M3DITRACK3R will then dispense the medicine into a container, and prompt a text message to the caretaker after each dispense. This is to ensure the caretakers are being notified on the updates of M3DITRACK3R. For safety and stability purposes, an ultrasonic sensor is used to detect and avoid any other object or obstacle in front of M3DITRACK3R. The lab scaled prototype is developed using the commercialized LEGO Mindstorm EV3 tool kit. This highly programmable kit provides a uniform platform to be used which enables future improvement over this robot. The hardware configuration and details of each port of M3DITRACK3R is shown in Figure 2 and Table 2 respectively below.

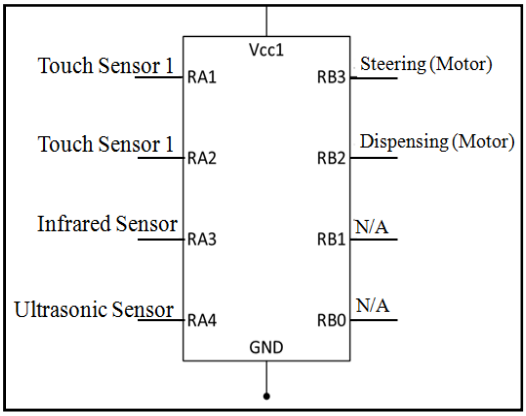


Figure 2 : PIC Chip pin diagram of M3DITRACK3R

Table 2 : Description of M3DITRACK3R ports

| Port | Input / Output | Description |
|---|---|---|
| RA1 | Touch Sensor 1 | The Touch Sensor is an analog sensor that can detect when the sensor's red button has been pressed and the number of presses where the time interval for type 1 of medicine is read. |
| RA2 | Touch Sensor 2 | The Touch Sensor is an analog sensor that can detect when the sensor's red button has been pressed and the number of presses where the time interval for type 2 medicine is read. |
| RA3 | Infrared Sensor | The Infrared Seeking Sensor detects the beacon heading which will be attached to patient, enabling the tracking and moving to the direction of the patient. |
| RA4 | Ultrasonic Sensor | Digital Ultrasonic Sensor detects proximity of obstacle enabling avoidance of collision |
| RB3 | Steering (Large Motor) | Control the steering movement to navigate the robot towards the patient. |
| RB2 | Dispenser (Medium Motor) | Control the dispensing of medicine using medium sized motor. |

The touch sensor is responsible to sense input from elderly. Once the input has been received, it will be sent to the Lego Mindstorm EV3 brick, which processes the input and starts the timer. After the completion of a cycle on the timer, output is sent to the motor, to move the robot using the wheels to approach the elderly.

M3DITRACK3R's structure is proposed in a few designs to analyse the best robotic system to cater to the identified problem . The designs are shown in Figure 3.

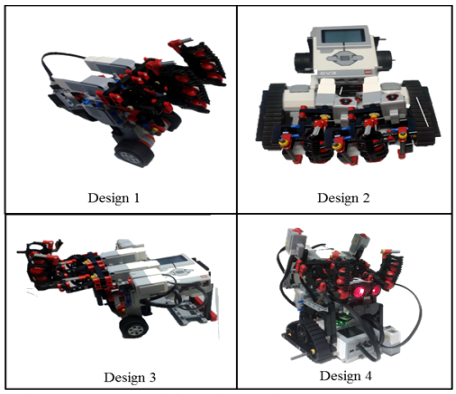

Figure 3 : Potential Designs of M3DITRACK3R

Each designs of M3DITRACK3R has its advantages and disadvantages. The emphasis is placed mainly on stability, consumption of space, and ability to add medicine slots. The details are mapped with the information in Table 3.

Table 3 : Advantages and Disadvantages of Designs

| Design | Advantage(s) | Disadvantage(s) |
|---|---|---|
| 1 | - Small in size<br>- Less space consumption | - Low stability<br>- Slots not dynamic (fixed) |
| 2 | - Stable | - Slots not dynamic (fixed)<br>- Large and bulky in size |
| 3 | - Small in size | - Not stable<br>- Not dynamic |
| 4 | - Medicine slots can be increased<br>- Compact | - Not stable when surface is too rough |

One of the important features of M3DITRACKER is the ability to keep track of all the patient's medicines. Hence, a design that keeps the number of medicine slots rigid is not suitable due to the large number of medicines prescribed to the elderly. The robot will have to navigate to locate the patient. Therefore an unstable robot will collapse while tracking the patient. From the review, Design 4 in Figure 2 is the best design that tally to most of the required features in the Table 4.The details of the design is shown in Figure 4.

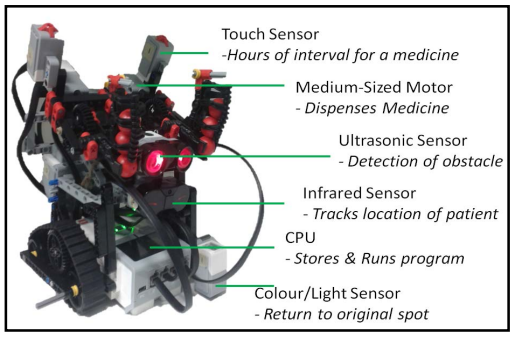

Figure 4: Detailed view of M3DITRACK3R

## IV. RESULTS AND DISCUSSIONS

We have conducted several tests to proof the proposed concepts. The tests are surveys and feedbacks, performance tests, user acceptance test.

### *A. Results of Survey and Feedbacks*

Two types of surveys were conducted. The first was a visit to an old folks' home in Perak, comprising of 7 residents 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. The following questions related to times and dosages. As Figure 5 shows, ime was more problematic than accurate dosage.

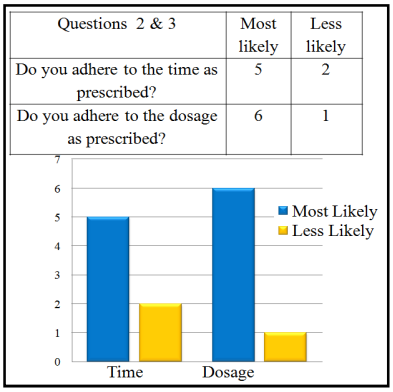

Figure 5 : Medicine taking Time and Dosage Compliance

Most of the elderly could not keep track of the exact 8 hours, resulting in the consumption of their medications after taking each of their meals- breakfast, lunch and dinner, whereby they assume the interval of each meal is evenly distributed. One of the common confusions that occurs is that the elderly patients face difficulties remembering whether they have actually consumed their pill or merely "intended" to consume the pill [8]. Figure 6, however, reveals almost half of the residents do not take their medication by choice.

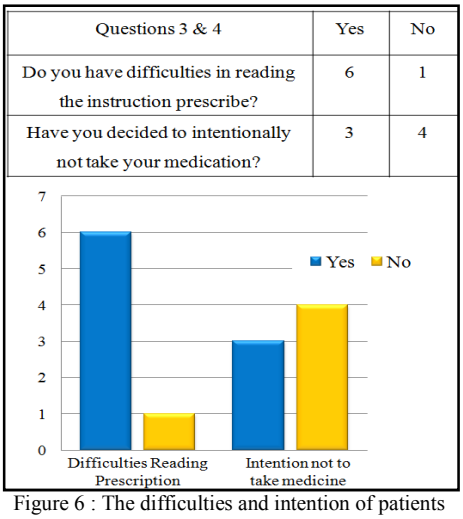

Figure 6 : The difficulties and intention of patients

Constraints such as difficulties in reading eventually affected the thinking of the elderly, influencing their non-compliance to the perceived troublesome schedule of the medication. Almost half of the respondents have inadvertently not adhered to their medication due to their mental and physical constraints.

The second survey was a visit to Monash University, Malaysia for an informal interview with medical students completing their final year. A total of 21 students were asked about the common medical problems faced by senior citizens above 60 years old as shown in Figure 7 below.

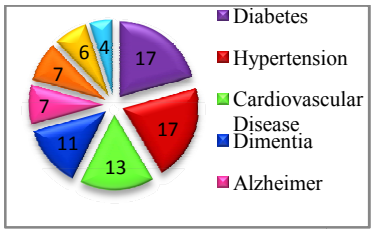


Figure 7: Common Health Problems faced by senior citizens

One of the common symptoms of dementia is memory loss[4], 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.

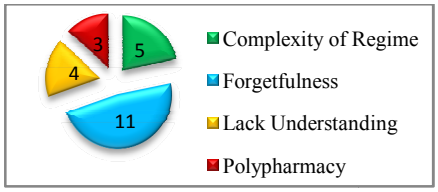


Figure 8: Major Causes of Non-Compliance to Medications

Therefore, dealing with the detrimental health complications, the elderly have to achieve a good control in practicing a strict medication regime. Majority of the respondents mentioned forgetfulness as the major cause of non compliance to medications. This can be classified into the unintentional non compliance where they have less power and are passive in decision making due to their physical and mental constraints[5], needing an external aid to overcome this constraints.

### *B. Results of Performance Test*

A few experiments are conducted on the prototype to test its ability in different environments. An obstacle avoidance test was carried out to test the two sensors that were studied, which are the infrared and ultrasonic sensor.

Table 4 : Obstacle Avoidance Test Results

| Type of Sensor | Maximum Distance Detected (cm) | Maximum Height Detected (cm) |
|---|---|---|
| Ultrasonic Sensor | 70cm | 15cm |
| Infrared Sensor | 250cm | 25 cm |

Based on the results in Table 4, the ultrasonic sensor will be used for the development of M3DITRACK3R because the range of distance an ultrasonic sensor is able to detect enables M3DITRACK3R to react and detect an obstacle earlier as compared to the infrared sensor. Next, a line test was carried out to test and compare the speed of M3DITRACK3R on straight and curvy line. The results of the test are shown in Table 5.

Table 5 : Line Test Results

| Type of Line | Distance (m) | Time taken (s) | Speed ($ms^{-1}$) |
|---|---|---|---|
| Straight | 1 | 8.4 | 0.1190 |
| Curvy | 1 | 7.9 | 0.1266 |

Based on the tabulated data, the speed of M3DITRACK3R on two types of line can be obtained. With an additional speed of $0.0076ms^{-1}$ , M3DITRACK3R moves faster in a curved line. Therefore, a curve has been created at the corner of the track. Finally, a surface test was conducted to evaluate and compare the speed of M3DITRACK3R on different surfaces of floor. The results of the test are shown in Table 6

Table 6 : Surface Test Results

| Type of Surface | Distance (m) | Time taken (s) | Speed (ms-1) |
|---|---|---|---|
| Corrugated Board | 1 | 8.4 | 0.1190 |
| Carpet | 1 | 9.2 | 0.1087 |

Therefore, the speed of M3DITRACK3R on a smooth surface enables it to navigate faster as compared to a rough surface. The difference produced for a 1m straight track was $0.0103\ ms^{-1}$ . As a result based on the three tests conducted, M3DITRACK3R uses the ultrasonic sensor to detect obstacle due to the ability of detecting the object much earlier. Curvy line is used to direct the robot to return to its original position in a faster way compared to a straight line. The prototype will be using a corrugated board due to the smooth surface resulting in a higher speed of M3DITRACK3R navigation.

### *C. Results of User Acceptance Test*

A user acceptance test was conducted on 7th August 2014 at Rumah Orang –Orang Tua Seri Payung as shown in Figure 9.

Figure 9 : Demonstration at old folks home

The objective of this test was to get feedback on the acceptance of the elderly towards the unusual way of medicine taking and using a technology i.e a robot. Each respondent including their caretaker were explained about the function of the robot followed by a demonstration. They were then interviewed on their acceptance of M3DITRACK3R in assisting them to comply to medication. Table 7 shows their feedback on advantages and disadvantages of M3DITRACK3R .

Table 7 : Advantages and Disadvantages of M3DITRACK3R

| Advantages | Disadvantages |
|---|---|
| • Stable<br>• Helpful to remind on medication<br>• Love the presence of a robot<br>• Medicine taking time becomes fun | • Costly<br>• Need caretaker to configure<br>• Afraid of new technology |

## V. 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. It not only aids the elderly who live independently but also the caretakers of the elderly by reminding and dispensing the right amount of medicine at the right time.M3DITRACK3R is able to track the time of each medication, and tracks the senior citizen in order to dispense the right dosage. This ensures the elderly patient consumes the right dosage of medication at the right time, provided he or she accepts this new, unusual method of medication.

Our objectives, has been achieved where the problems faced by senior citizens in adhering to their medication is identified through interviewing the residents of Rumah Orang-Orang Tua Seri Payung and surveying medical students. Comparative studies were carried out on existing devices, providing an opportunity to extract the useful features needed for the production of M3DITRACK3R, a patient tracking and medicine dispensing mobile robot. A robotic application is then built according to the features followed by the performance and acceptance testing.

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