DEVELOPMENT OF A SIMPLE MOBILE ROBOT FOR HUMAN-ROBOT INTERACTION IN HEALTH CARE ENVIRONMENT

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ABSTRACT: Human-robot interaction (HRI) field investigates how humans interact with robots. This project develops a simple robot with HRI features to solve the waiting problem of hospital patients and visitors to get attention from nurses. Interactive features of the robot include a LCD touchscreen mounted on a line-following mobile platform and a wireless remote call button. SolidWorks 2013 software was utilized to design the outlook of the HRI robot. The best conceptual design with safe and user-friendly features was fabricated. Using Proteus, the electrical circuit was simulated and the Nextion Editor created the Graphical User Interface (GUI) for the LCD display. Programming for Arduino Mega controller involved infrared sensor, DC motors, ultrasonic sensor and RF module. The completer robot has features including line following, obstacle avoidance, remote call button and carries bottled drinking water. Its LCD boost a GUI system and a cartoon game. Reliability tests were conducted to establish the robot's viability and functionality. Usability test at the ward in UTeM Health Center showed that the patient volunteers could communicate with and able to request for services provided by the robot. This indicates that the simple robot with HRI features was able to interact with patients in real hospital environment.

KEYWORDS: *Human-Robot Interaction; Mobile Robot; Healthcare Robot; Touchscreen Interface*

1.0 INTRODUCTION

The term ‘robot’ was coined from a Czech word ‘robota’ meaning ‘forced labor’. In that Czech playwright, robots eventually overthrow their human creators. Essentially, this brings forward the idea on the extent of the capabilities of robots. A robot can be categorized as a machine that accumulates data about its surroundings and utilizes the data taken as a guideline to do work. Today's robots are a fusion of numerous sensors and they can utilize this data to carry on autonomously. Now, robots perform exactness surgery, space investigation, ocean exploration and rescue missions in hazardous zones [1]. This study aims to develop a simple mobile robot with human-robot interaction (HRI) features to be used in hospital environment in Malaysia. To date, there is a paucity of studies on developing HRI robots for health care applications in this country. Robots for application in hospitals need to have a ‘user-friendly’ look and loaded with HRI features. Also, these robots need to work in an environment filled with humans and equipment. Thus, the safety of hospital staffs and patients is vital. Besides that, other common problems at hospital wards are:

i. Patients at hospital wards need to call for nurses for their every need, including simple help like to get a drink of water. Nurses, especially in government hospitals are very busy and need to tend to many patients at one time
ii. Patient’s visitors face the problem when they need to leave the ward for a few minutes; they cannot leave the patient unattended.

2.0 LITERATURE REVIEW

Study of robots in the HRI field covers a very wide chapter, as robots are now advanced and perform variety of tasks to fulfil their missions. Human-robot cooperation (HRI) is the investigation of collaborations amongst people and robots. To date, there are four main types of robots used for HRI purposes: animal robot, cartoonish robot, humanoid robot and mobile robot. Each of these robots has different interfaces and is used in applications that suit their physical shapes. Therefore, to suit the purpose of developing a simple robot to suit applicability in hospital wards, a mobile robot mounted with LCD was chosen for the robot’s shape. Previous studies show that mobile robots in HRI are not just mechanical robots which are autonomous or operated by humans. HRI features have been added to these robots to enhance its capabilities. These mobile robots have been used for children in schools, security and rescue applications, rehabilitation and medical or domestic services [2]. Looking at studies specific to the medical field, autonomous mobile robots have been used in radiotherapy applications and also remote investigation at locations with of high temperature and radiation [3].

2.1 Mobile Robots

Automated Guided Vehicles (AGVs) are a type of mobile robots that can perform desired tasks in unstructured environments without continuous human guide. There are many categories of mobile robots; such as manual remote or tele-operated, guarded tele-operated, line-following robot, autonomously randomized robot, autonomously guided robot and sliding autonomy [4].

Human following mobile robot can be described as a mobile robotic framework for following and tracking after moving obstacles. Such a system gives essential abilities to human robot collaboration and help to people in different settings. This is the reason why path following mobile robots has been a dynamic research region with frameworks grew, for example, for exhibition hall direction, doctor's facility help, or person on foot tracking. A large portion of these systems are intended to work inside outside situations and at constrained robot speed. Such ability is essential for robots support humans in difficult situations. Common applications include rescue missions or military mules carrying gear and support troopers [5].

2.2 Research on Mobile Robot with HRI Features

HRI features represent the interaction criteria that occur between human and robot. There are few ways on how these interactions occur, for example: gestures, voice recognition and interaction through typing or touches to define what we want. When these features are added to a mobile robot, a complete HRI featured robot is formed.

Mobile robot with HRI features are advancing into human possessed environments, for example; at home and at work, for amusement, or helping incapacitated individuals in personal care or essential exercises to enhance their independence [6]. In this study, gestures and interaction through LCD monitor are the essential types of interaction added to the mobile robot features.

3.0 METHODOLOGY

This section describes the proposed methodology of this research covering the design, development and testing stages.

3.1 Conceptual and Detailed Design

Simple conceptual designs were made in the form of sketches before 3D drawings were developed to decide the first look of the robot. Figure 1 shows a sketch of the chosen design during the conceptual design stage. This design concept was selected based on its stability to compromise bigger weight and space to carry more loads. This robot is required to carry small water bottles. Larger space can occupy more water bottles. However, this consumes more weight which could slower down the robot or affect the support system. Thus these aspects need to be balanced in the detailed design stage.

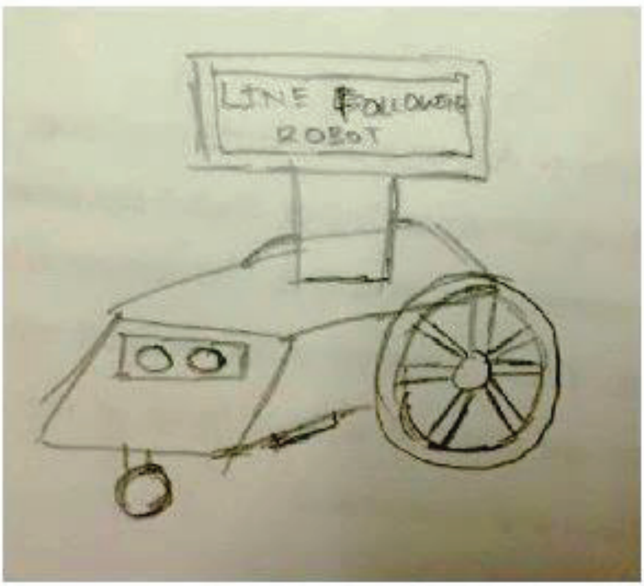
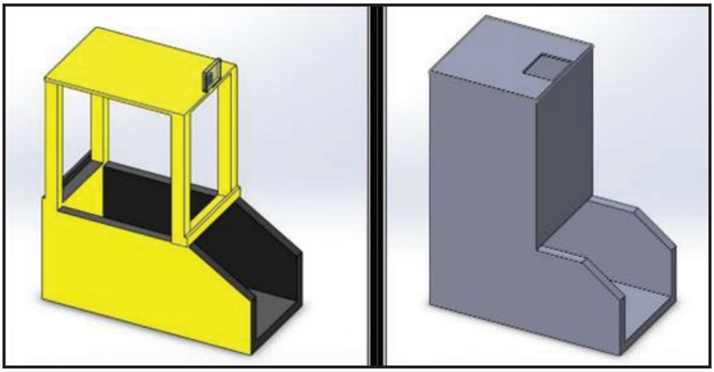


Figure 1: The conceptual design chosen for the mobile robot

In the detailed design stage, two different types of designs were developed based on the robot's outlook in Figure 1. To construct the 3D drawings, SolidWorks 2013 software was used. The designs are shown in Figure 2 (a) and (b). Both designs incorporate the box-like look. Design 1 was proposed with stainless steel material to build the mainframe while Design 2 used wood.


(a) (b)
Figure 2: Two detailed designs (a) Design 1 and (b) Design 2

Design 1 was not chosen because the space between the robot base and head will compromise the electrical wires. Also, the material proposed to be used for the base and structure is from stainless steel which is not safe for use in public environment such as hospitals. Thus, the best final design for the robot was Design 2 where whole space for the wires and controllers were covered to create a safe and user-friendly look. The base material was made from wood which is light but strong.

3.2 Robot Development

The development of the robot was separated into two parts: mechanical assembly and electrical components assembly. Mechanical assembly involved building the design hardware for the robot, while electrical components assembly deals with connecting all the electronic hardware with wires and giving them correct amount of power supply to each component to work properly. Using Proteus 8.0 Professional Software, the circuit electrical connectivity was simulated to ensure there are no short circuits and misconnections. Hardware design for the electronic and mechanical parts was based on the functionalities required. In general, the mobile robot requires a pair of wheel (mounted on DC motors) to move to a target point from an initial point. It also requires LCD display for interaction purpose. These elements were connected to Arduino Mega microcontroller which acts as the brain of the robot (Figure 3).

Nextion Editor, the development software for visual building of GUIs was used to create the user interface for the LCD display.

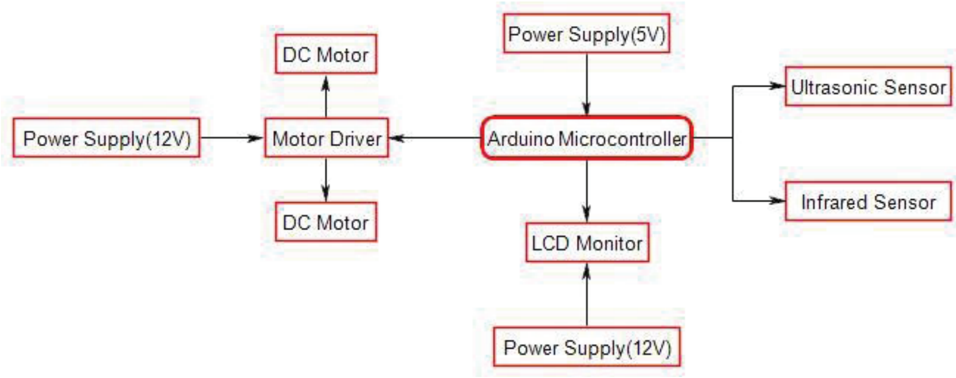


Figure 3: Different elements connected to the arduino controller

3.3 Robot Programming, Prototype and Operation

Programs in Arduino IDE environment were divided into few parts; LCD display, infrared (IR) sensor, DC motor, ultrasonic sensor and RF module. The robot operation begins with the signal transmitted from the remote call button. Once the robot receives signal, it will start to analyze any obstacles on its path during its line following task. If the robot detects any obstacles in its path, it will immediately stop moving and will only continue moving after the obstacle is removed as shown in the sample coding in Figure 4. The distance to be detected is 0.1 meter.

```
{
 if (distance> 5)
 {
  line_sensor();
 }


 if (distance< 5)
 {
 digitalWrite(in1, LOW);
 digitalWrite(in2, LOW);
 analogWrite(enA, 0);
 digitalWrite(in3, LOW);
 digitalWrite(in4, LOW);
 analogWrite(enB, 0);
 }
}
}
```

Figure 4: Sample codes in Arduino IDE for obstacle avoidance function

Preliminary design of the prototype comes with a non-adjustable direction on the user's eye level with respect to LCD display (Figure 5 (a)). Users must adjust their position themselves to be able to see the LCD display clearly. Thus, the prototype was modified to solve this problem and to provide more comfort to users. What differentiate both are the degrees of freedom provided by the LCD display and a small adjustment by enhancing remote call system to a wireless system. The final version as in Figure 5 (b) enables the user to adjust the LCD according to their preferred angle of view.

(a) (b)

Figure 5: The robot during prototype stage with (a) static LCD display angle and (b) the robot's final look adjustable LCD. The final dimensions are 29 cm x 50 cm x 80 cm

Figure 6 shows the operating flow chart of the mobile robot which is set to work at a medical ward. The robot starts to operate once the signal is triggered by the patient or visitor using the remote call button. The robot will capture the point where the signal is triggered as the goal to be reached. If by chance an obstacle is detected during the travel distance between the robot initial position and goal point, a new command will be postponed until the obstacle is removed. Thus, it is recommended for an operator to monitor the robot's line track from time to time for a smooth progress of operation.

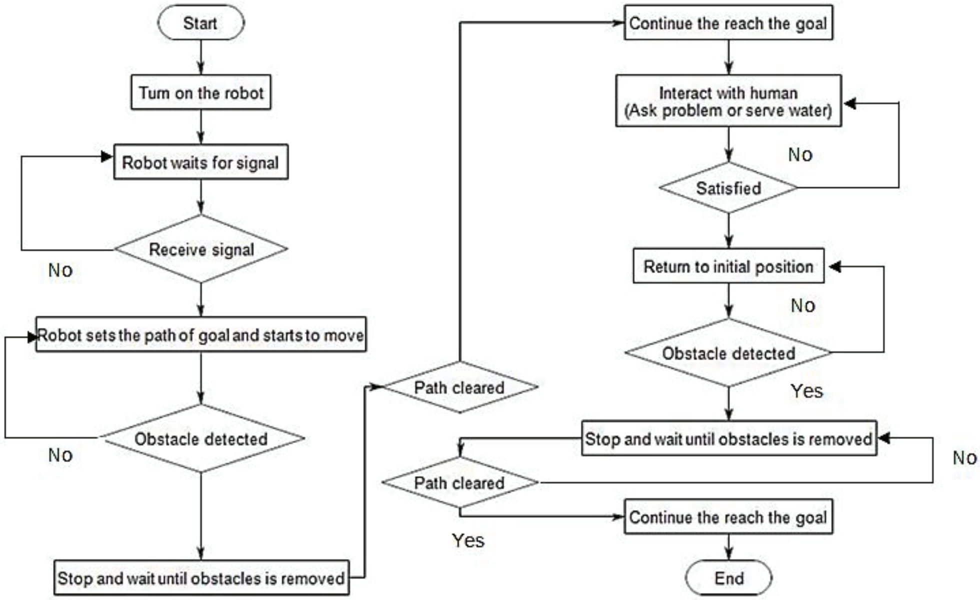


Figure 6: Operation flow chart of the mobile robot which is set to work at a medical ward

4.0 RESULT AND DISCUSSION

Reliability and usability tests were conducted to test the robustness of the navigation algorithms (line following and obstacle avoidance) and capabilities of the complete robot to interact with humans.

4.1 Reliability Test

Several testing were carried out to verify the reliability of the robot to meet certain conditions and able to follow the given tasks. Testing includes for line-following, obstacles avoidance and remote call button.

For the line following test, if any of the five sensors on the robot's IR sensor detects the black line, it will start to move according to the given instructions. Line-following test was done five times to ensure the reliability of the sensor and the robot. Line following conditions are the move forward task, move right, move sharply to the right, move left, move sharply to the left, reverse and stop. Based on the result obtained, the probability of success for line-following tasks is high, with 31 successes out of 35 attempts (88.6% success). The cause for the 11.4% of failure at first time test was identified and the codes were improved.

For the obstacle avoidance test, the robot was 100% successful at all stopping distances set for it and the test was repeated for five times for each distance. Remote call button for the robot was set for reliability testing to identify distance it is being able to respond to call. Testing was done by placing the receiver module on the robot and transmitter module on the call button. Both the receiver and transmitter was then separated and tested to find out the best distance to be chosen to place the robot (from 1 meter to 20 meter of distance). From the results, the selected distance to place the robot was 5.0 meter between transmitter (at the patient's bed) and receiver (on the robot). Robot was then tested again to ensure the reliability of the chosen distance. Results showed 100% success rate.

4.2 Usability Test

The usability test was conducted to investigate the capability of the robot to interact with humans. Subjects were two volunteer staffs from UTeM Health Center (User A and User B), who played the role as patients. Both subjects were males. A list of short instructions was given to each of them. The testing was carried out according to the given instructions as the testing procedures. UTeM Health Center was selected as the test location was because it represents a hospital environment on a smaller scale. Figure 7 shows the direction of the robot pathways inside the UTeM Health Center's ward. Navigation is important in a mobile transport robot working in the ward environment where there are hallways and unexpected obstacles [7].

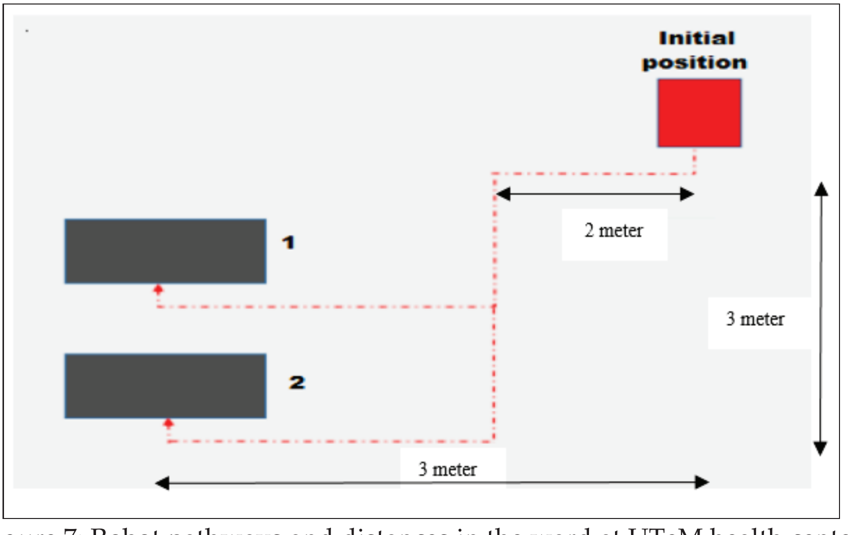
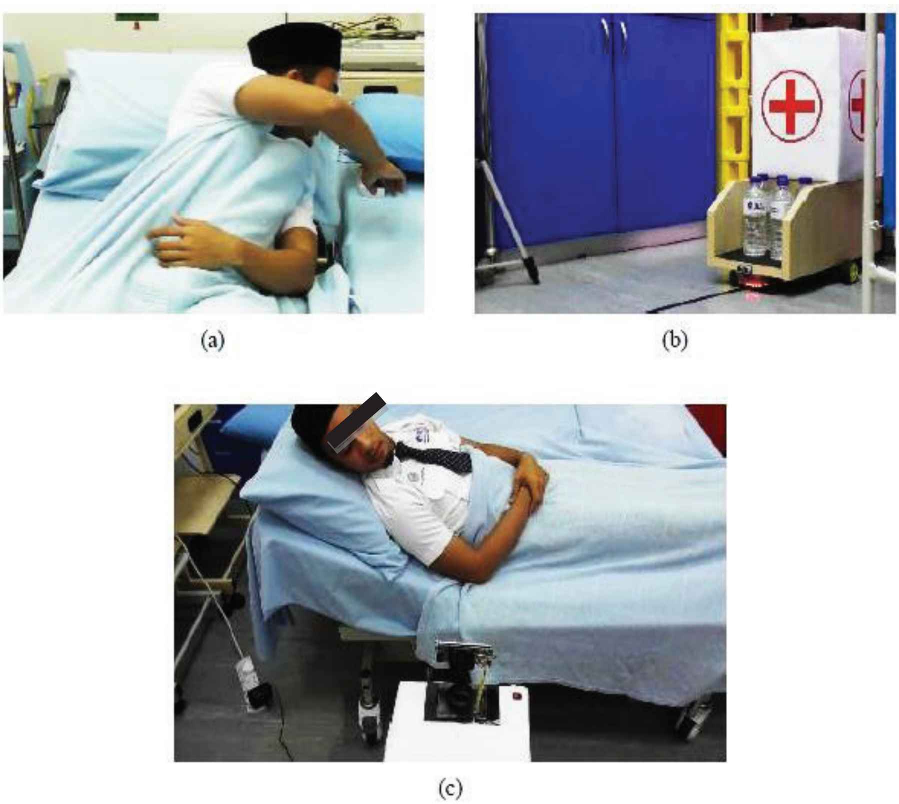


Figure 7: Robot pathways and distances in the ward at UTeM health center

The mobile robot was placed in the 'red box', where the robot was on standby mode and this is the initial position of the robot. Two patient beds are in the testing area (Bed 1 and Bed 2) and patient may call the robot from any one of the beds. Figure 8 shows the instruction flow for the patients (respondents) during the testing.

Once the signal is triggered from the call button by the patient (Figure 8 (a)), the robot shall move to the patient's location. Once the mobile robot reaches the patient's bed, it will interact with the patient through its LCD monitor. After the job is done, the robot will follow the final command which was to return to its initial set point.



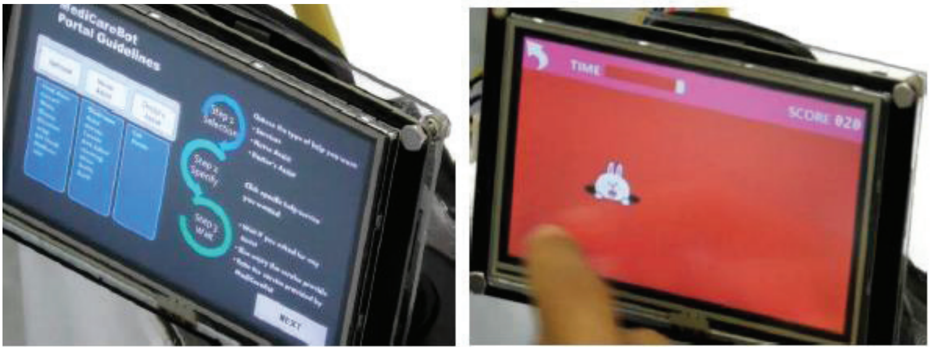
(a) (b)

(c)

Figure 8: Instruction flow for the robot: (a) Patient calling for robot, (b) Robot receives signal from patient and (c) Robot is ready to give assistant

Next, the instructions were given for each patient to operate the LCD display. Each patient was able to adjust the preference settings on the screen's brightness, to make sure the screen brightness was optimal for user to use and will not cause discomfort to the user's eyes.

Then, the patients were instructed to use the main portal using the LCD touch screen, which is called the 'MediCareBot Portal' (Figure 9 (a)). This portal is the main feature of the robot with facilities to help users. Each feature has its own advantages. 'Services' feature provides basic help and assist to the patient. Example of services provided includes the food menu and also a simple entertainment game (Figure 9 (b)). 'Games' can help to reduce patient's stress level, anxiety and boredom at the ward. Games conducted by a robot are fun and interactive at the same time [8]. However, a time limit was set for each person to play the game for not more than 15 minutes per round.



(a) (b)

Figure 9: (a) 'MediCareBot Portal' interface and (b) a simple interactive cartoon game for users

The portal on the LCD touch screen also offers information on medicines for users who wants to know about medications and information about doctors working in the health center. There was also a nurse-assist feature which includes options of: request for washroom assist, gloves/towels, bed adjustments, cleaning service and urine bottle refills. Once any buttons is pressed according to required assistance, request will be sent to the data server monitored by nurses at the counter. However, these feature was not fully developed as the monitoring counter at the UTeM Health Center does not have a monitoring server.

As for other available features, the robot also provides a quick guide menu to operate the 'MediCareBot Portal'. This feature is to help new users. In the guideline, steps to use and available features are defined. Users will be directed straight to guideline once they open the portal and the guideline will still be available (as a small icon on the screen) even when using other applications on the LCD.

The robot is also a water supplier. It can be called whenever patients in the ward require water. The drinking water bottles are placed in front rack of the robot to make easier for users to reach out. Figure 10 demonstrates how the water bottles are places on the robot and how the bottles can easily be reached from the patient's bed.

(a)

(b)

Figure 10: (a) Water bottles placed in the front rack of the robot and (b) The bottles are easily accessible to the patients from the bed

Final feature designed on the robot is the option to continue or to end the interaction process between the user and the robot. If the patient no longer requires services from the robot, it will return back to its initial position.

4.3 Survey on User Experience in using the Robot

After the usability tests, both users (User A and User B) were asked to answer a simple survey. From the survey responses, both users agreed that they were satisfied with the line-following capabilities of the robot and the LCD interaction between each user and the robot. Both were also congruent that settings menu was useful and important as the brightness setup help to reduce eye glare when staring at the LCD.

User A acknowledged the use of 'MediCareBot Portal'. He found that food menu feature is a very important application as it helps to identify the menu provided for the day. He also suggested for features such as direction/maps of hospital are added, because it helps to find out the emergency escape route for future emergencies. User B confessed his interest in features such as games. Overall, both users were happy with the simple HRI robot and they agreed that the robot was usable in the ward environment. These findings show that a mobile robot manufactured with basic components at a low price has good prospective to be manufactured and widely used [9] in small healthcare centers. Such robots that assist nurses; combined with HRI features, obstacle avoidance, line-following ability and able to transport water can be an essential part of the ward environment in Malaysia in the near future. This is not only help to solve problems on the shortage of nursing staff [10] but also make hospitals a more cheerful environment for convalescing patients.

5.0 CONCLUSION

Findings made in this study mark a step forward in the application of robots for human-robot interaction (HRI) in Malaysia. More similar studies are expected to flourish in the next years. The aim of this study which was to develop a simple robot with HRI features has been achieved. The robot was designed with a line-following capability using infrared sensor, and interaction capabilities through a LCD screen on its 'head'. The developed robot was then tested to prove the viability of its interaction properties. Reliability tests focused on the robot's line-following capabilities, wireless remote call button and obstacle avoidance. Usability tests with two subjects demonstrated the robot's working ability in real life environment at a medical ward.

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