Jurnal Teknologi

Full paper

Automatic Human Guided Shopping Trolley with Smart Shopping System

Yen Leng Ng, Cheng Siong Lim*, Kumeresan A. Danapalasingam, Michael Loong Peng Tan, Chee Wei Tan

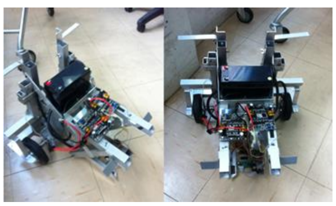
Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru Johor, Malaysia

*Corresponding author: limchengsiong@fke.utm.my

Article history

Received :15 August 2014
Received in revised form :
5 January 2015
Accepted :10 February 2015

Graphical abstract



Abstract

A shopping trolley is a necessary tool for shopping in supermarkets or grocery stores. However, there are shopping trolleys abandoned everywhere in supermarkets after being used. In addition, there are also shopping trolley safety issues such as sliding down from an escalator. It is known to be an inconvenience and time wasting for customers who are in rush to search for desired products in a supermarket. Therefore, an automatic human and line following shopping trolley with a smart shopping system is developed to solve these problems. A line following portable robot is installed under the trolley to lead the users to the items' location that they plan to purchase in the supermarket. This paper presents the hardware and software design of the portable robot. The result of the testing on the used sensors like ultrasonic and line sensors are presented. Lastly, the graphical user interface of Android application during the shopping trolley in operation is explained.

Keywords: Human following; Line following; Obstacle avoidance; Portable robot; Shopping trolley; Smart shopping system

1.0 INTRODUCTION

In recent years, robot technology has developed significantly. Most of the traditional robots are still commonly used for industrial applications, such as in car assembly factories [1]. Meanwhile, intelligent robots have become popular in daily life applications. Human-friendly robots are now used for taking care of the elderly [2-4]. The purpose of a human following robot is to improve the relationship between people and the robot [5]. For instance, the robot can carry heavy loads for people in hospitals, airports and shopping centers. The robot can provide services to humans as an assistant in different kinds of situations.

In robotic research, vision-based robots have gained growing interests for navigation, however, the tradition method of line following navigation still plays an important role in mobile robot technology. This is because a robot with line following capability requires a lower cost to build and has a simple design [6]. Besides, the application of Radio Frequency Identification (RFID) technology for robots nowadays has become popular, especially in the localization scheme. It is a non-touching recognition system that can tag and send tag data wirelessly at various distances [7].

In this project, a portable robot with human and line following functions is developed. In the next section, we highlight the research background on the problems related to shopping trolleys. In Section 3.0, we explain in detail both the hardware and software design for the developed portable robot. Results of the hardware and software testing are presented in Section 4.0. Discussion of the finding is presented in Section 5.0. Finally, Section 6.0 concludes the project.

2.0 RESEARCH BACKGROUND

Cases of losing shopping trolleys have caused grocery store owners a loss of $8,000 to $10,000 per year, which is equal to RM 25,696.00 to RM 32,120.00. Robin Webb, a manager of a big grocery store said that he loses 50 to 100 trolleys every six months. The shopping trolley loss happens because of theft [8]. In an Essex supermarket there is a weekly loss of shopping trolleys worth £3,000 (RM 16,218.35) [9]. It is also known that a supermarket or store will be fined £25, which is approximate to RM 135.15, if an abandoned shopping trolley is found [10]. Supermarkets or stores have to hire trolley collectors or obtain a contract with a trolley collector company to collect trolleys, which consequently increases operating cost. According to Fair Work Ombudsman (FWO), some companies have been fined for not paying trolley collectors such as an Adelaide Company that was fined $40,000 for underpaying six trolley collectors [11].

It was also found that shopping trolleys are always scattered around everywhere inside or outside supermarkets. Scattered trolleys can roll away from its position and collide with people, thus injuring them. A woman was killed by a runaway trolley when she exited the escalator [12]. There was another case where a loaded runaway trolley caused a woman to die from her injuries and injured her husband in a shopping center [13].

A portable robot with human and line following functions is developed to assist customers to carry a heavy load while shopping in the supermarket. Meanwhile, a smart shopping system is also developed in order to identify the location of each item in the supermarket, thus assists the customers to locate the desired items.

■3.0 SYSTEM DESIGN

The system design for both hardware and software for the development of the automatic human guided shopping trolley is described. The overall project system flow is presented as Unified Modelling Language (UML) in this chapter.

3.1 Hardware Design

In the hardware design, Arduino Mega 2560 is used as the microcontroller for the portable robot. The hardware components comprise RFID reader, ultrasonic sensors, Bluetooth module, auto-calibrating line sensor and motor driver, which are connected to the Arduino Mega 2560. The RFID reader is used to read tag cards and send tag data to Android smartphone via Bluetooth module. Ultrasonic sensors are used for obstacle avoidance. The line sensor is used for the robot line following purpose. The motor driver is used to drive the electric scooter motor. There is a robot based mechanism installed under the shopping trolley. The microcontroller, RFID reader, Bluetooth module, auto-calibrating line sensor, motor driver and a 12V acid battery are put on the robot base in order to control the shopping trolley. The ultrasonic sensors are installed on each side of shopping trolley. Figure 1.1 illustrates the robot mechanism with attached hardware and components. Figure 1.2 depicts the robot mechanism that is attached to the shopping trolley. Table 1.1 summaries the specifications of the developed robot.

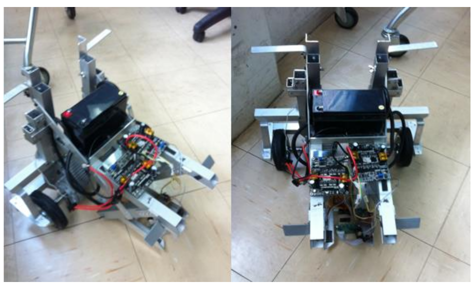


Figure 1.1 Side view and top view of the robot mechanism with the hardware and components attached

Figure 1.2 The mechanical structure of the portable robot is attached to the shopping trolley

Table 1.1 Robot specifications

Parameter	Specification
Features	• The robot is attachable to the shopping trolley. • The robot can follow lines and lead users. • The robot contains a database that is used to store data such as items' location. • The robot has 450 W electric scooter motors supporting maximum speed of 470 rpm with no load. • The dimensions of the robot are: 450.06 mm x 430 mm x 385.21 mm
Platform	Arduino Mega 2560 and Intel Atom DE2i-150
Actuator and driver	450 W electric scooter motor and MD30C motor driver.
Sensor	Ultrasonic sensor, HC-SR04 and RFID reader, RDM 6300
Communication technology	Wi-Fi Hotspot and Bluetooth
Algorithm	• Line following algorithm by using the PID control method. • Interrupt method is used for the line following algorithm. • The polling method is used for the RFID reader algorithm, Bluetooth connection algorithm and obstacle avoidance algorithm. • The differential wheeled drive method is applied in the robot mechanism.

3.1.1 Intel Board DE2I-150

An Intel board is used as the main platform in this project as a server database system. The operating system that it uses is Linux and acts as the central processing unit of the system. It uses an Intel® Atom™ Dual Core Processor N2600 (1M Cache, 1.6GHz) and is equipped with an Intel® NM10 Express Chipset, DIP package Bios flash, GD25Q16, 4 USB 2.0 Host ports and 1 USB Blaster as well as a Cyclone IV GXP4CGX150F31 FPGA device. The Intel Atom processor and the FPGA device are linked together via two high-speed PCIe lanes. There is a high communication speed between them. This board is placed in the supermarket and is connected with an Android smartphone using a WIFI hotspot.

3.1.2 Arduino Mega

The microcontroller board, Arduino Mega 2560, has 54 pins for digital input/output (I/O) and has 15 pins that can be used as pulse-width modulation (PWM) outputs. It also has 16 analog inputs, 4 hardware serial ports (UARTs), 1 USB connection port, 16 MHz crystal oscillator, a power jack, an ICSP header and a reset button. The ATmega 2560 can store code because it has 256 kB of flash memory, 8 kB is used by the boot loader, 8 kB is used by the SRAM and 4 kB is used by the EEPROM. In this project, Arduino Mega 2560 is used to interface with all of the hardware used in this project, such as the RFID reader, Bluetooth module, ultrasonic sensors, auto-calibrating line sensor and motor driver.

3.1.3 RFID Technology for Mobile Robot Localization

RFID technology is an identification system which relies on wireless frequency and small chips to transmit and process information in an environment without contact. At present, RFID technology has improved tremendously in mapping, navigation and localization. This is due to the uniqueness of the identification of each RFID tag. Therefore, the RFID reader, RDM6300, is used in this project in order to provide a specific coordinate for the robot to recognise its location.

The location of the robot and items are displayed on the shopping map on an Android smartphone screen. The frequency of the tag cards used must be set as the same frequency as that of the RFID reader. The RFID reader of RDM630 has two pins for Antenna 1 and Antenna 2, the TX pin to transmit data, the RX pin to receive data, two pins for 5 V Direct Current (DC), and two pins for ground. There is also one pin for LED. The RFID reader is attached under the robot so that it can read the RFID tag cards placed on the floor. When the RFID reader reads a tag card and identifies that the tag's data is the same as the selected item, tag data is sent to the Android application via Bluetooth. The data is processed and is matched with the coordinates of the item's location and hence the shopping trolley stops. The current location of the shopping trolley is displayed on the shopping map of the Android application. In this project, the RFID reader's TX pin is connected to the RX3 pin of Arduino Mega 2560 in order to receive data from the RFID reader. The LED is blinking when no RFID tag card detected. It is turned off when there is tag card detected.

3.1.4 Ultrasonic Sensor

The ultrasonic module, HC-SR04, is chosen for the project. It has 4 pins, which are 5V pin, ground pin, trigger pin and echo pin. The ultrasonic sensor has an ultrasonic transmitter and ultrasonic receiver. Its center frequency is 40 kHz with 1 kHz tolerance. The ranging distance is from 2 cm to 400 cm and the resolution is up to 0.3 cm. The effectual angle of this sensor module is less than 15 degrees and its measuring angle is 30 degrees. The trigger input pulse width is 10 µs.

In this project, six distance sensors are used for obstacle avoidance. Both front and rear parts of the shopping trolley are installed with one ultrasonic sensor. While, the left and right sides of shopping trolley are installed with two ultrasonic sensors. These sensors are connected to Arduino Mega 2560. The shopping trolley stops when an obstacle is sensed within 10 cm.

3.1.5 Bluetooth Module

The Bluetooth module, HC-06, is used in the project to provide wireless data transmission between Arduino Mega 2560 and Android smartphones. Its maximum sensitivity is 80 dBm. It has Enhanced Data Rate modulation and the change range of the modulation depth is 2 Mbps to 3 Mbps. Besides, there is a built-in 2.4 GHz antenna with external 8 Mbit flash memory. The Bluetooth module can work at low voltage of 3.1 V to 4.2 V. It is interfaced with Arduino Mega 2560 through the UART port, which are the TX and RX pins. In this project, the Bluetooth module TX pin is connected to the RX1 pin and the Bluetooth module RX pin is connected to the TX1 pin in Arduino Mega 2560 for two way data transfer.

3.1.6 Auto-Calibrating Line Sensor

The auto-calibrating line sensor, LSS05, is used to detect and follow a line. It consists of five Infrared-Red (IR) transmitter and receiver pairs. It can function to follow any colour as long as the brightness is distinct and suitable for LSS05. LSS05 allows the IR transmitter to be switched off after a certain idle period in order to minimize the current consumption. It has five digital outputs to indicate the position of the detected line. There is a PIC16F819 microcontroller that is used for data processing, power indicator LED, power and output signal connectors. The maximum input power is 5 V. It has five sensors and they are independent of each other. The refreshing rates of the sensors are more than 100 Hz. The sensing distance is 4 cm. This line sensor is connected to Arduino Mega 2560 and installed on the portable robot to detect and follow black lines in the supermarket.

3.1.7 Motor Driver

The motor driver is used to drive the motor in this project. By controlling the PWM speed, the motor speed can be controlled. The model of motor driver used is MD30C. It is designed to drive a medium to high powered brushed DC motor. Its current capacity is up to 80 Amperes (A) for 1 second when at its peak, although it has a continuous capacity of 30 A. Its PWM generator enables it to operate without a host controller. This motor driver has bidirectional control for 1 brushed DC motor and the voltage of the motor is 5 V to 25 V. Its logic level input is 3.3 V and 5 V. It has better efficiency due to its full NMOS H-Bridge and there is no heat sink needed. The PWM frequency of speed control can go up to 20 kHz.

3.1.8 Electric Scooter Motor with Gear

This electric scooter motor is used to drive the shopping trolley. It is a 450 W scooter motor and its DC voltage is 24 V with 11 Nm torque. It has a speed of 395 rpm and a maximum current of 26.5 A.

3.2 Software Design

The software design approach in this project involves Intel board DE2i-150 as a database server and Java programming language based Android application as a client. The Intel board running Linux operating system provides a communication platform that receives data from the clients and acts as a central processing unit that processes the data. The Android application provides a user interface to the users in order to create the desired shopping list, send and receive information from the server as well as from the Arduino Mega 2560 board.

The main algorithm of the software design for the client is to utilize the Android application because the user interface has to organize the shopping list and to show the grocery items in the respective locations on the shopping map. First, users would connect to the hotspot available in the supermarket where it allows the users to access the database. The Android application as a client is then being connected to the server of the supermarket. The users are able to search for the items and its locations in the supermarket easily. With the user interface on the Android application, users are able to choose the items from the buy list. When an item is selected, its data is sent to the server hosted on Intel board. The server then processes the data and sends the coordinates of the selected items to the Android application. All the selected items' locations are displayed on the shopping map, thus helping users to organize their shopping journey better.

In general, the server stores data and listens to the client for an active connection. When there are clients connected, it waits to receive the shopping items from the users. The server processes the data received from a buy list which is set by users, then identifies the coordinates of the selected items and informs the users by displaying a mark on the shopping map. When a shopping map user interface is open, a dialogue message pops up to allow the user to activate the shopping trolley to start moving.

When the RFID reader detects a tag card with tag data (each tag data is deemed as a different coordinate in the Android application) which is the same as the coordinates of the selected items, the trolley stops. Subsequently, a dialogue message pops up to ask the user if he or she wants to continue to move the shopping trolley (i.e. continue shopping). When the RFID reader detected the last selected item's location, the shopping trolley stops until the user presses the button from the dialog message to allow the shopping trolley to move to a payment counter, thus automatically ending the shopping journey. Figure 1.3 shows the Unified Modelling Language of the overall system process.

4.0 RESULTS

4.1 Hardware Development

The ultrasonic sensor is connected with the Arduino Mega 2560 board. There are six ultrasonic sensors used in the project. Figure 1.4 shows a snapshot of the output of the six ultrasonic sensors using Arduino IDE serial monitor.

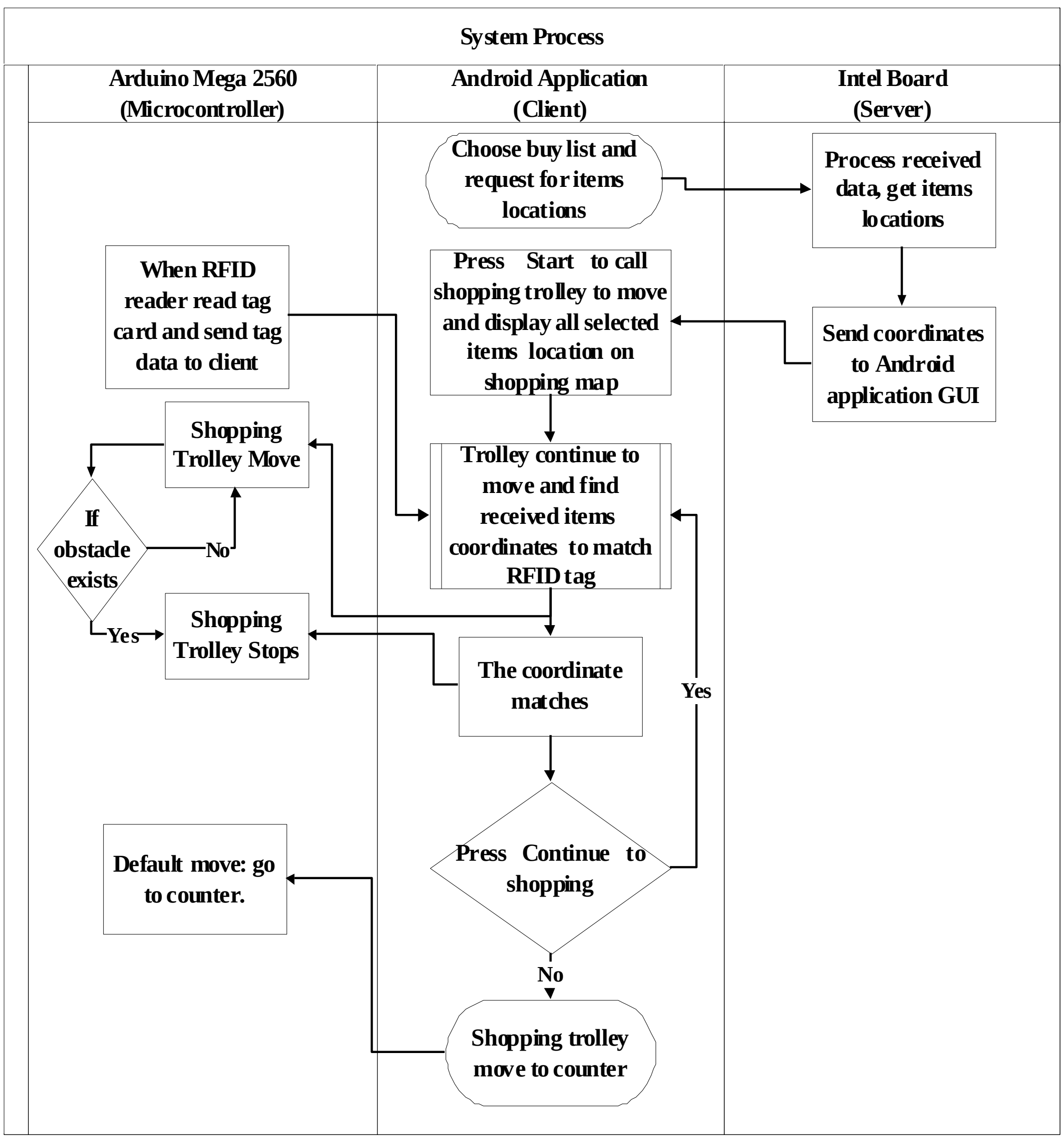


Figure 1.3 UML of communication flow between arduino board, intel board and android application

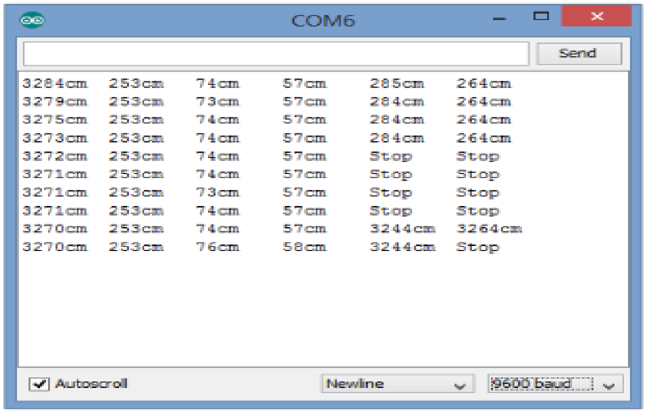


Figure 1.4 Data collected from six ultrasonic sensors. The results are displayed in a tabular format using the serial monitor of Arduino IDE

The line sensor is tested for its line following function. Figure 1.5 shows a line sensor that has detected a black line, which has resulted in the related sensors to light up and the result is displayed in the serial monitor.

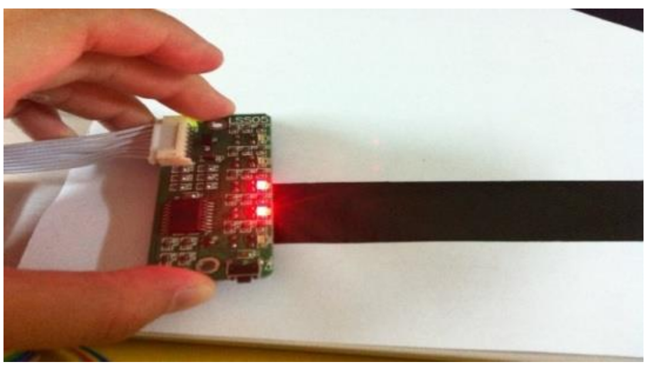


Figure 1.5 The line sensor detects the black line on a white background. The LEDs for the corresponding sensors that detected the black line are lit up

The RDIF Reader, RDM6300, is tested and the result is shown in Figure 1.6. The Bluetooth module is also tested. The received tag number is sent to the Android application and displayed in the GUI via Bluetooth. The Android application is also used to send data to the Arduino Mega 2560 via Bluetooth in order to control the motion of the motor.

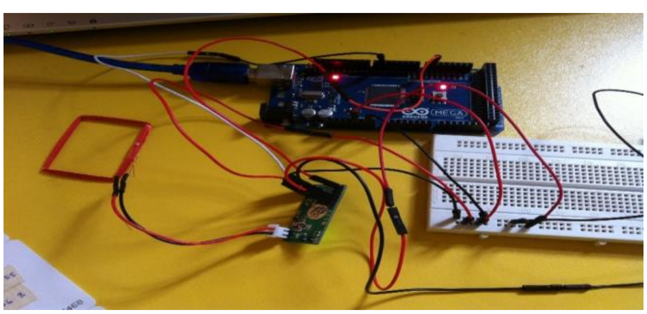


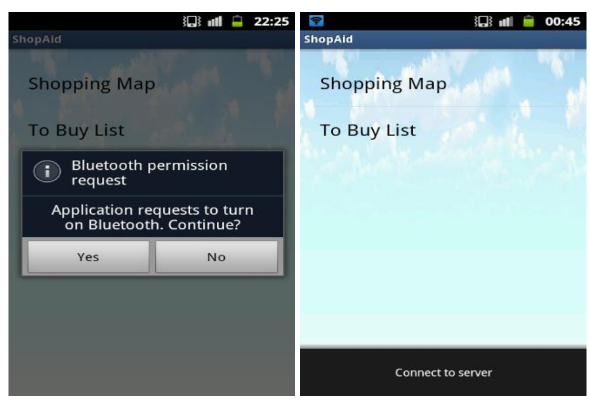
Figure 1.6 The RFID reader is connected to Arduino Mega 2560. The TX pin of the RFID reader is connected to pin RX of the Arduino Mega board

All of the hardware and components are programmed in the main microcontroller. Two ultrasonic sensors are put on the front of the shopping trolley in order to avoid obstacles in front of it. RFID tag cards that act as location indicator are placed on the cardboard along the black line. The communication between smartphone and robot is via Bluetooth connection. The movement of the shopping trolley is controlled by using a smartphone. Figure 1.7 shows that the performance test of the project is carried out in an indoor environment.

Figure 1.7 The robot that is attached to the shopping trolley is tested on a black line with a white background. The movement of the robot is controlled by using a smartphone

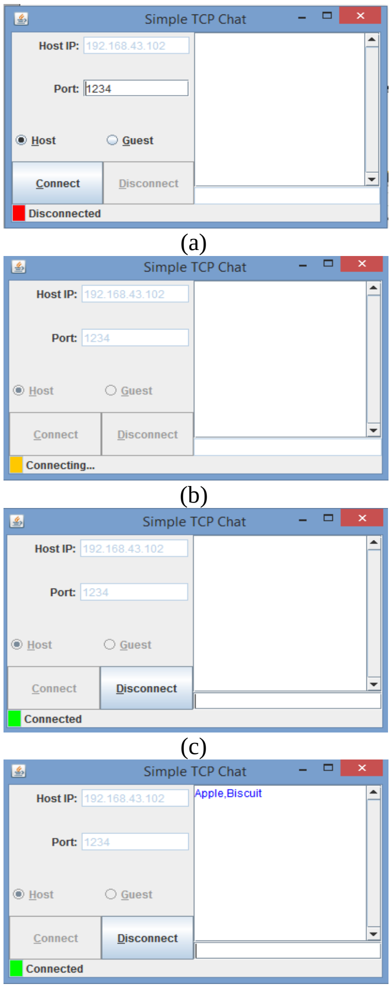
4.2 Software Development

In software development, GUI of the Android application and server system is developed using Java programming language. Software eclipse is used to develop both systems. The results of both communication systems are shown in Figures 1.8 till 1.12.



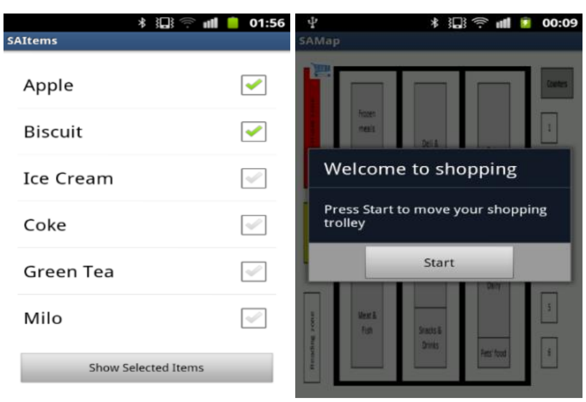
(a) (b)

Figure 1.8 Screenshot (a) shows the dialogue message of the Bluetooth permission request. The dialogue pops out once the Android application is launched without turning on the Bluetooth connection on the Android smartphone. Screenshot (b) shows that the user can click on the menu button to connect the Android application to the server system after the Wi-Fi hotspot is turned on



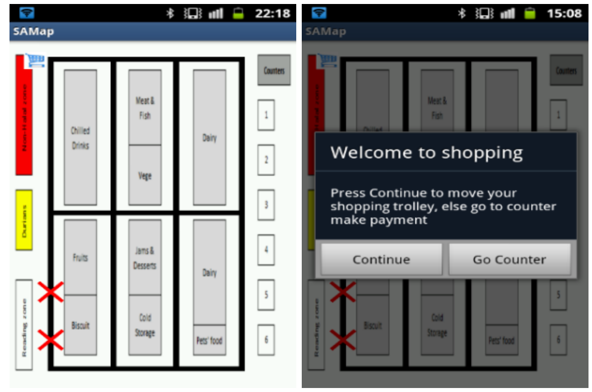
(a) (b) (c) (d)

Figure 1.9 Screenshot (a) shows the server GUI is in disconnect state. Screenshot (b) shows the server is waiting for the client's connection. Screenshot (c) shows the server is connected to a client. Screenshot (d) shows the server has received the selected items from the Android application and it has sent the locations of items, in term of coordinates, to the Android application GUI automatically after being processed



(a) (b)

Figure 1.10 Screenshot (a) shows the GUI of the Android application with two selected items from the buy list. Screenshot (b) shows that the dialog message pops up once the shopping map is open. The received coordinates from the server are marked on the shopping map



(a) (b)

Figure 1.11 Screenshot (a) shows the GUI of the shopping map on the Android smartphone with the marked items' location of the selected items in the To-Buy-List. Screenshot (b) shows a dialogue message that has popped up when the shopping trolley reaches and stops at the selected item's location. Users can press "Continue" to allow the shopping trolley to move to the next item's location, or press "Go Counter" after they have collected all of the selected items

Figure 1.12 The screenshot picture shows the menu buttons where a user can manually stop or enable the shopping trolley to continue moving

5.0 DISCUSSION

Arduino mega 2560 is used as the main microcontroller to interface with all hardware used in this project. Tag card data is used as a location indicator in order to let the user know the locations of the shopping trolley and selected items. The locations are displayed on the GUI of an Android application. A Bluetooth module is used to transfer and receive data the between Arduino Mega 2560 board and an Android smartphone. The line following sensor allows the shopping trolley to move according to the detected black line. Thus, the shopping trolley can lead users during shopping. In order to prevent the shopping trolley colliding with other shopping trolleys or people in the supermarket, ultrasonic sensors are used to avoid collision.

The problem encountered in hardware development is that all possibilities of hardware installations must be taken into consideration when designing the portable robot base. When testing with the RDIF reader, it is found that the distance between the tag card and the RFID reader must not exceed 4.5 cm. Also, the movement of the RFID reader to pass by the tag card must be slow enough to ensure the readability of the tag card. Furthermore, the UART port communication must be fully understood before use. For both the connections of the RFID reader and the Bluetooth module with the Arduino board's serial port, TX pin is used to transfer data out while RX pin is for receiving data. Therefore, the RFID reader TX pin must be connected to RX pin of Arduino board so that the Arduino board can read the data sent from RFID reader. Since the Bluetooth module is used for two-way communication, the TX and RX pins of the Bluetooth module must be connected to the RX and TX pins of Arduino board respectively.

The gap between line sensor and black line must be within 1.5 cm, in order to get a more accurate detection. When the gap is wider, other IR sensors light up and thus cause the direction error. Furthermore, after making sure each piece of hardware can function properly, all the algorithms in the programs are integrated. In general, the whole system is tested. At this stage, it is found that the line following robot and RFID reader cannot function properly due to the polling method. The microcontroller is continuously checking the given device status. The device only performs the service from the microcontroller when the status condition is met. It is less efficient as the line following robot keeps running and the RFID reader needs to scan the RFID tag card at the same time. Therefore, the interrupt method is preferred in the programming, where each device can perform based on the priority assigned by the microcontroller. This is much more efficient when compared to the polling method.

In software development, to set up Java environment, Java Development Kit (JDK) and Java Runtime Environment (JRE) are installed for Java program development purposes and to run Java program in run time. The Integrated Development Environment (IDE) used is Eclipse. Java programming language is used as the main programming language in the Android application and Java application programming. Eclipse provides a very resourceful Software Development Kit (SDK) which is available from Android 1.5 up to the current Android 4.4.2.

In this project, the minimum Application Programming Interface (API) level is 8, and any Android devices with Android version of 2.2 (Froyo) and above are able to run this software. One of the communication methods is Bluetooth where it sends the selected items to the server. The Bluetooth connection in Android requires a declaration of BLUETOOTH and BLUETOOTH_ADMIN permission in AndroidManifest.xml in order to; request for a connection, accept a connection, enable data transmission, perform scanning and manipulate Bluetooth settings. Figure 1.13 shows the permission code declaration in the program.

```
<uses-permission android:name="android.permission.BLUETOOTH_ADMIN" />
<uses-permission android:name="android.permission.BLUETOOTH" />
```

Figure 1.13 Bluetooth Permission in Android Mnifest.xml must be declared in the program

Next, setting up Bluetooth using "BluetoothAdapter" from the Android Bluetooth activity class is needed to enable the Bluetooth function. Devices with a discoverable state provide their device name, class and unique MAC address. Getting the MAC address of the Bluetooth module HC-06 is necessary in this case. This is because the paired device is different from the connected device. Pairing means the two devices get to know each other, meanwhile connected means the devices are able to communicate and exchange data as Radio Frequency Communication (RFCOMM) channel is shared. With the Media Access Control (MAC) address pre-defined in the "MainActivity" of the Android application, the communication is directed to the HC-06 module when the application is activated. Figure 1.14 shows the MAC address of Bluetooth Module declaration.

```
// MAC-address of Bluetooth module
public static String address = "00:14:01:15:30:34";  //Address of HC-06 Bluetooth Module
```

Figure 1.14 MAC address of Bluetooth module, HC-06 must be declared in the program

Furthermore, server and client systems are developed by using the communication channel. This is called socket method. There are three phases involved: open socket, receive and send socket, and close socket. Both server and client have specific socket addresses, called communication identifiers. Each socket consists of a port number and internet address. Figure 1.15 shows the socket declaration in the program.

```
public Socket socket;
public static final int SERVERPORT = 1234;
public static final String SERVER_IP = "192.168.43.102";
public ObjectInputStream input;
public Socket client;
```

Figure 1.15 Socket declaration, server port and server IP address set up in both server and client system

The server socket object is created to listen and accept connections from clients. The server socket object is constantly in the state of opening and listening mode until there is a message from the client. In order to receive a response from the server, "InputStreamReader" is created to read the received text lines, meanwhile "OutputStream" is created for sending information out. "PrintWriter" is a class that takes "OutputStream" and provides a simple way to print regular data types into a readable format on the stream. One of the most important elements for successful communication between the Java server and Android client is that, there must be a declaration for internet permission in Android Manifest.xml as shown in Figure 1.16.

```
<uses-permission android:name="android.permission.INTERNET" >
</uses-permission>
<uses-permission android:name="android.permission.ACCESS_NETWORK_STATE" >
</uses-permission>
```

Figure 1.16 Declaration of internet permission for socket connection

There is an issue encountered in the motor controlling programming. When the shopping map activity in the Android application is chosen to open, it took about 5 seconds to proceed, which is unusual. In addition, tag data would not be sent when the Android device failed to connect with the Bluetooth module HC-06. Nevertheless, the second attempt to reconnect would work fine. This might somehow be due to the signal disruptions that interrupt the connection between the Android device and the Bluetooth module from the shopping trolley.

■6.0 CONCLUSION

With the aid of automatic line following and human leading functions portable robot, supermarket owners need only to purchase the portable robot and can easily install it under shopping trolleys. Users can then enjoy shopping without pushing the shopping trolleys themselves. Meanwhile, the smart shopping system allows users to access the location of items that they plan to purchase in supermarket by using their Android application and call the shopping trolley to move automatically. Thus, the shopping trolley can lead the users to their desired location of items that they plan to buy. This system is called the server and client system. The location of the shopping trolley and items can be tracked easily by using the RFID technology localization scheme and Android application. Both communicate via the Bluetooth function.

There is some room for further improvement of project. Firstly, the mechanism of the robot should be enhanced and designed in a simpler way, to ease the installation under a shopping trolley. Secondly, a more advanced algorithm should be developed so that the shopping trolley is able to move in a crowded environment and follows the user automatically in any direction. Lastly, an improved Android application that can remind the users on the items they need to purchase when they are unintentionally passing by the goods location. In addition, it can also remind the users who have health problems about the nutrition of products. Besides that, the locations of shopping trolleys are tracked and can be displayed to allow supermarket staff and users know the shopping trolley current locations.

Acknowledgement

The authors would like to acknowledge the financial support from Fundamental Research Grant Scheme (vote no R.J130000.7823.4F314) of the Ministry of Higher Education (MOHE), and Research University Grant (vote on Q.J130000.2523.05H59) from Research Management Centre (RMC) of Universiti Teknologi Malaysia.

References

[1] Božek, P. 2014. Automated Detection Type Body and Shape Deformation for Robotic Welding Line. *Advances in Systems Science*. 229–240.

[2] Leroux, C., Lebec, O., Ben Ghezala, M. W., Mezouar, Y., Devillers, L., Chastagnol, C., Martin, J.-C. , Leynaert, V. and Fattal, C. 2013. ARMEN: Assistive Robotics to Maintain Elderly People In Natural Environment. *IRBM*. 34(2): 101–107.

[3] Bouakaz, S., Vacher, M., Bobillier Chaumon, M.-E., Aman, F., Bekkadja, S., Portet, F., Guillou, E., Rossato, S., Desserée, E., Traineau, P., Vimont, J.-P. and Chevalier, T. 2014. CIRDO: Smart Companion for Helping Elderly to Live at Home for Longer. *IRBM*. 35(2): 100–108.

[4] Wu, Y.-H., Wrobel, J., Cristancho-Lacroix, V., Kamali, L., Chetouani, M., Duhaut, D., Le Pevedic, B., Jost, C., Dupourque, V., Ghrissi, M. and Rigaud, A.-S. 2013. Designing an Assistive Robot for Older Adults: The ROBADOM Project. *IRBM.* 34(2): 119–123.

[5] Kazuyuki. M., Lee, J-H. and Hideki, H. 2004. Human-Following Mobile Robot in a Distributed Intelligent Sensor Network. *IEEE Transactions on Industrial Electronics*. 51(1): 229–237.

[6] Li, Y., Wu, X., Shin, D., Wang, W., Bai, J., He, Q., Luo, F. and Zheng, W. An Improved Line Following Optimization Algorithm for Mobile Robot. *Computing and Convergence Technology (ICCCT), 2012 7th International Conference on*. 3–5 Dec. Seoul, South Korea, 84–87.

[7] Han, S. S., Kim, D. K. and Lee, J. M. 2007. A New Tag Arrangement Pattern for a Differential Driving Mobile Robot Based on RFID System. *International Conference on Control, Automation and System*. 17–20 Oct. Seoul, South Korea, 1228–1233.

[8] Wilkinson, K. 1999, June 3-9. Wheels of Fortune. *Metroactive New & Issues*. Retrieved September 16, 2014, from http://www.metroactive.com.

[9] Tesco Tackles Trolley Thefts in Colchester. 2011, November 8. *BBC News*. Retrieved September 16, 2014, from http://www.bbc.co.uk.

[10] Stores Face Abandoned Trolley Fine in Carmarthenshire. 2011, February 2. *BBC News*. Retrieved September 16, 2014, from http://www.bbc.co.uk.

[11] Shopping Trolley Underpayment Cases to Proceed. 2013, September 1. *Australian Payroll Association*. Retrieved September 16, 2014, from http://www.austpayroll.com.au.

[12] Goldstein, S. 2013, June 24. Runaway Shopping Cart Kills Chinese Woman in Supermarket in Freak Accident. *Daily News*. Retrieved September 16, 2014, from http://www.nydailynews.com.

[13] Candice, M. Trolley Crushed Shopper. *ABC News*. Retrieved September 16, 2014, from http://www.abc.net.au.