An RFID Warehouse Robot

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Abstract- **RFID is one of the latest trend in the industry. Its potential application can range from warehouse to library management. This project is aimed to build an autonomous robot with RFID application. The project integrates RFID reader and PIC microcontroller as the main components. The movement control comprises servo-motor with infrared sensors for the line follower. The whole programming operation was carried out by assembly language using MPLab 7.3. The robot has the ability to identify the items by reading the tag on the items. The robot will pick up the item and navigate to prescribed destination using line follower module to store the item at the appropriate place and location. A small white platform with black line is built for demonstration and testing.**

Keyword: ***RFID, robot, line follower, sensors, reader, servo motor.***

I. INTRODUCTION

A. Overview of the project

Nowadays Radio Frequency IDentification (RFID) has become solution in the markets including livestock identification and automated vehicle identification (AVI) systems. This is not a new technology but has been in the public domain for at least 10 years.

RFID is a form of data collection system. The data is stored and remotely retrieved using devices called RFID tags or transponders. RFID is suitable for identifying both products and assets within the supply chain environment. RFID solutions consist of four basic components: tags, readers, antenna and software.

The combination of RFID and autonomous robot will provide an incredible solution for warehouse. This robot is suitable for industry where they need to maintain a huge warehouse.

The RFID robot will serve the purpose to arrange and allocate the goods in the warehouse.

B. Aim

Design and construct an RFID autonomous robot.

C. Objectives

The main objectives of implementing the RFID robot included but are not limited to the following:

1. Construct an autonomous robot.
2. Integrate RFID technology in the robot.
3. Develop an application for RFID robot in warehouse.

D. Scopes

The scope of RFID robot is limited as following:

1. Circuit designs including controller board, motor driver and interface for RFID reader module.
2. Software development for autonomous robot involving microcontroller programming.
3. Application of RFID tag in identifying goods and its location.

II. RELATED WORK

A.. Case Study 1

Svetlana Domnitcheva [1] from Institute for Pervasive Computing, Swiss Federal Institute of Technology (ETH) Zurich, Switzerland develops smart vacuum cleaner –an autonomous location-aware cleaning device. He develops a prototype of an autonomous mobile cleaning robot which implements an opposite, self-positioning approach. The robot is enhanced with an RFID antenna. This device learns its present location by detecting small RFID tags spread on the floor and adjusts its behavior according to this information. The specification of the project is listed in Table 2.1

Table 2.1: Summary for Case Study 1

Features	Descriptions
Robot hardware	• Lego Mindstorms Robotic Invention kit
RFID hardware	• Hitachi's μ-Chip RFID antenna
CPU	• BTnode
Software	• Not Quite C

B. Case Study 2

Chaitanya Gharpure, Vladimir Kulyukin and Aliasgar Kutiyanawala [2] from Utah State University, Utah built RoboCart, a robotic shopping assistant for the visually impaired. They did their experiment at Lee's MarketPlace, a supermarket in Logan, Utah. They limit their scope to the robot-assisted navigation of a supermarket and on the product retrieval from the shelves. RoboCart uses RFID-based localization. They build a global map of the supermarket's grocery section (the lobby, 10 aisles, and 5 cash registers) and tested the robot by randomly selecting various destinations in the store.

Table 2.2: Summary for Case Study 2

Features	Descriptions
Robot hardware	• Pioneer 2DX robotic platform • SICK laser range finder • Logitech camera
RFID hardware	• TI-Series 2000 RFID reader • 200mm x 200mm antenna
CPU	• Dell TM Ultralight X300
Software	• ActivMedia's Laser Mapping and Navigation software.

C. Case Study 3

Tomohiro UMETANI, Tatsuo ARAI, Yasushi MAE, Kenji INOUE, and Jun-ichiro MAEDA [3] from Osaka University, Japan develop parts and packets unification for construction automation and robots. The project is about simplification in motion planning of the construction robots using information attached to components and reconfiguration of data structure for process of construction tasks using RFID tag.

Table 2.3: Summary for Case Study 3

Features	Descriptions
Robot hardware	• hybrid arm
RFID hardware	• OMRON V700-D13P2 • OMRON V700-H01

D. Summary of Case Study

From the above case studies, RFID can be implemented in many ways and benefits our life. These three cases have one thing in common that is accuracy. In case study 1, the smart vacuum cleaner needs to find the correct location while RoboCart in case study 2 need to lead the customer to the correct location. As for the case study 3 the robot need to identify the part correctly before assemble. This is similar to my project where I use RFID to identify the goods and place it at correct location.

E. RFID

RFID is a system of storing and remotely retrieves data using wireless technology operating with the 50 kHz to 2.5 GHz frequency range RFID technology comprises three basic elements: the RFID tag, the RFID reader/writer and the host line of business system

RFID does not require line-of-sight to operate for communications between a tagged object which could be almost anything including a car, merchandise, package, etc. and a reader which is an electronic device used to capture the RFID signal. Data encoded on the RFID tag can contain a variety of information about the object including item description through the use of an electronic product code (EPC). The EPC is an electronic representation of a product, which can include information about the product, manufacturer, and uniquely identify the product.

F. RFID tag

RFID tag has a chip and an antenna. A chip can store a unique serial number or other information based on the tag's type of memory, which can be read-only, read-write, or write-once read-many. The antenna, which is attached to the microchip, transmits information from the chip to the reader.

There are theree types of RFID tags: Passive, Active and Semi passive. Passive RFID tags do not have their own power source, such as a battery, nor can they initiate communication with a reader Active RFID tags on the other hand contain an internal battery and are typically read/write devices. Semi passive RFID tags are equipped with a power soured such as battery to provide power for the integrated circuits, but do not actively transmit a signal to the reader.

G. RFID Reader

A reader uses its own antenna to communicate with the tag. When a reader broadcasts radio waves, all tags designated to respond to that frequency and within range will respond. A reader also has the capability to communicate with the tag without a direct line of sight, depending on the radio frequency and the type of tag (active, passive, or semi passive) used.

Readers can process multiple items at once, allowing for increased read processing times. They can be mobile, such as handheld devices that scan objects like pallets and cases, or stationary, such as point-of-sale devices used in supermarkets. Readers are differentiated by their storage capacity, processing capability, and the frequencies they can read.

III. Methodology

A. Hardware System Overview

The RFID robot is designed according to forklift which used in warehouse. The chassis is built from aluminum structure and drive motors and sensors. The IR sensors are placed at bottom of front of the robot for quick response of robot during line tracking. Figure 1 shows the structure of RFID robot from side view and top view. All dimensions in Figure 3.1 are in millimeters.

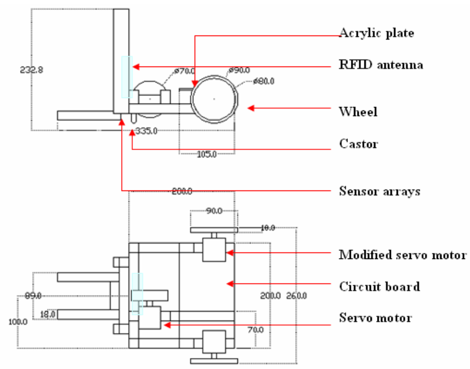


Figure 3.1: The structure of RFID robot from side view and top view

B. Control System Overview

RFID robot consists of one MCU as the main brain of the control system. Two channel of inputs which user input and sensors for line follower module. The system has one channel of half duplex communication with the RFID reader and three channels of output. One channel of output is to motor driver for locomotion and one channel of output to servo motor act as the mast of the forklift for lifting the block. One channel of output is connected to indicator. Figure 3.2 shows the block diagram of the overall working system of RFID robot.

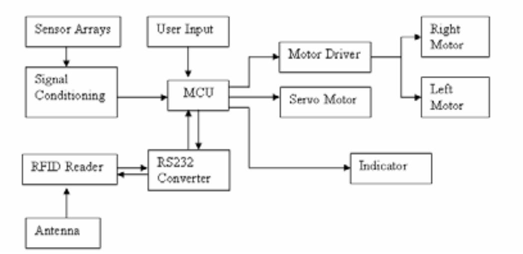


Figure 3.2: RFID Robot control system block diagram

C. Simulation of RFID Robot

For simulation of the function of RFID robot, a small white platform is built with black line on it for line tracking purpose. The layout of platform is shown in Figure 3.3. The conceptual of the simulation is detection, navigation and locomotion. The robot and RFID tag are programmed for movement, navigation and identification tasks. The RFID robot will move from starting zone to loading area follow the shortest possible track based on the pre-loaded program into the microcontroller that controls and navigates the robot movement. It will then lift up the sample block. During lifting the robot will read the ID of the tag on the block. After identification of the block, the robot will move the block to destination of the loading block using line follower module. Three 13cmx12cmx10cm blocks are built as sample in the simulation. Figure 3.5 show the blocks for the simulation and Figure 3.4 show the flow of the simulation

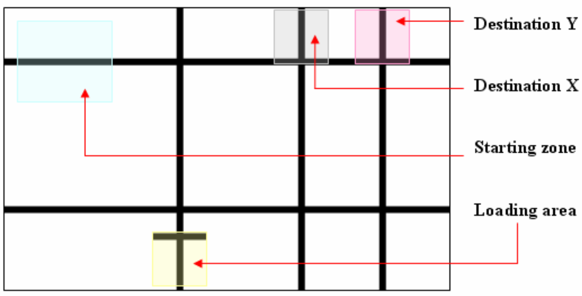


Figure 3.3: Layout of the platform

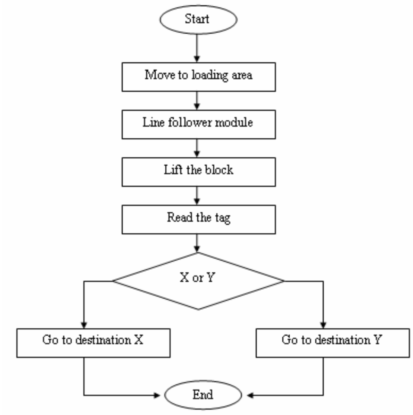


Figure 3.4: The flow of the simulation

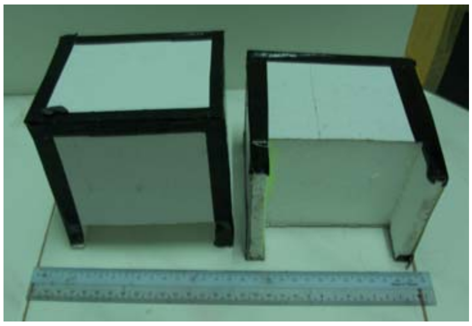


Figure 3.5: Blocks for the simulation

D. Robot Locomotion Principles

The motor driver functions to control the left and right motor. RFID robot uses L293D as motor driver. L293D is a 4.5 to 36V quad push-pull or dual H-bridge driver. The L293D has built in clamp diodes and can supply 600mA per channel. Two motors are mounted at both left and right of the RFID robot for driving and steering the robot purpose. The direction of the motor will determine the direction of the robot. The robot will move forward or backward if the both motors are turning at same speed and same direction. Meanwhile the robot wills self turn either left or right if the motors turn at different direction. The robot will move to the left if the right motor rotates forward while the left motor stop.

E. Sensors and Navigation

The RFID robot uses line follower concept for navigation. Three infra-red sensors are used for line follower. The line follower is one of the self operating robot that follows a line that drawn on the floor. The basic operations of the line following is to detect line position using infra red sensors mounted at front end of the robot. Figure 3.6 shows the detection of the sensors and figure 3.7 shows the actual infra-red for the RFID robot. Table 3.2 shows the movement of the robot regarding the value of the sensors. When the sensors sense a black line, 0 will be sent to MCU. LM324 is used for signal conditioning for infra-red sensors. LM324 is low powered quad operational amplifiers. If positive input is higher than the negative input the output will set high or 5V otherwise low or 0V. These outputs are connected to MCU processing and LED for indicator during debugging.

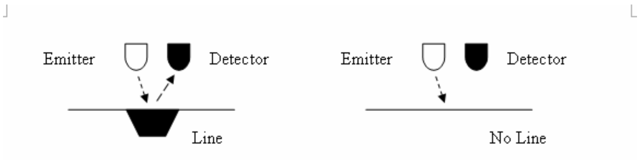


Figure 3.7: Detection of the Line Using Infra Red Sensor

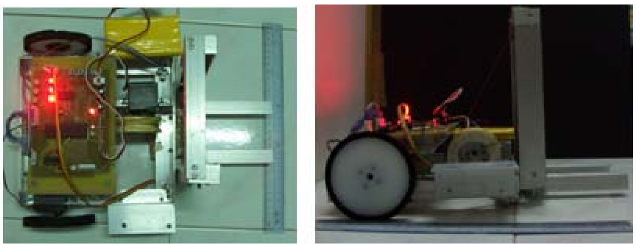
F. Firmware Overview

The firmware for PIC microcontroller was written in assembly language using MPLab 7.3. The finished firmware was simulated and debugged using MPLab SIM and SIM Uart1 to determine the problem before downloading the machine codes into the PIC microcontroller. The machine codes were burned into the PIC microcontroller using a low cost commercial PIC programmer from Cytron Enterprise. The software used to load the firmware to the PIC microcontroller is WinPic800

IV. ANALYSIS AND RESULT

A. Robot Structure

RFID robot is assembled using L-bar aluminum. Rivets, screws and nuts are used to hold the joint between two bars or more. Figure 4.2 shows the final version of RFID robot.



(a) (b)

Figure 4.1: Final version of RFID robot.
(a) Top view
(b) Side view

B. PCB Layout

The quality of the PCB is good. The size of the board can be reduced and perfectly put on the robot because of double sided technique is used. The double sided technique can reduce the number of jumper. Large ground plane is distributed at bottom of the PCB. 0.1 Micro-farad bypass capacitors are connected to each supply and IC. The track of the layout is designed at 16mils and clearance 32 mils. Figure 4.2 shows the actual layout of the PCB.

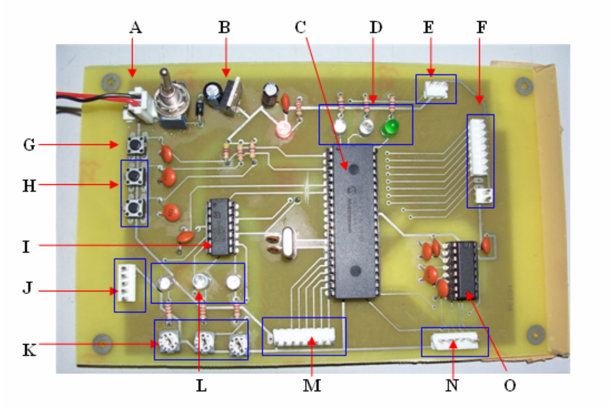
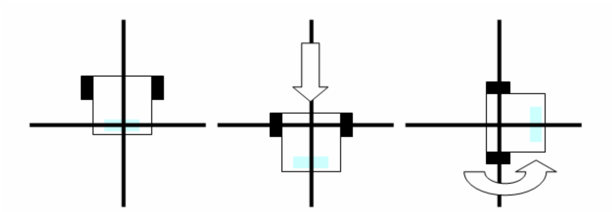


Figure 4.2: Actual layout of the PCB

Sensors are functioned when there is obstruction in front of the robot by distinguishing the its colour. It responds to the instruction written to the microcontroller. Figure 4.4 shows the flow of the robot when doing self turn.



(a) (b) (c)

Figure 4.4: The flow of the robot when doing self turn.

(a) robot found junction
(b) move forward for 1 second
(c) turn the right wheel forward and left wheel backward

The sensors can be determined whether it works or otherwise by using a digital camera. Digital camera is able to capture the signal of the emitter where the wavelength of the infra red is beyond the eyesight of human-being. The sensors indicators are 3 LEDs. The LED will turn on when the infra red detect a white surface and turn off when detect black surface. Figure 4.5 shows the picture of sensor indicator when the robot is on the track.

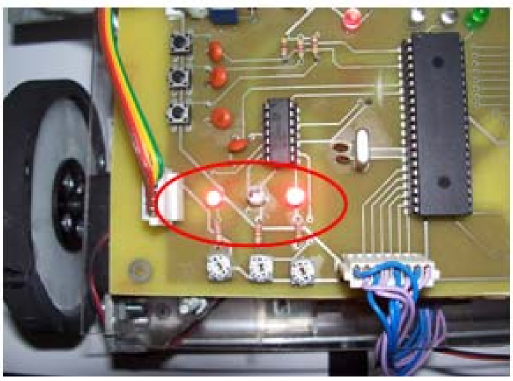


Figure 4.5: Picture of sensor indicator when the robot is on the track

C. Block Lifting

During the robot simulation, the RFID robot needs to lift the sample of blocks. A programmed RFID tag is attached to each block. It contains data among others are category, location, and rack. Once the data in the RFID tag is read by the tag-reader on the robot, it will activate the robot controller to navigate the robot to the proper place and location for storage. The two L-bar at the front of the robot act as the blade of the forklift and the servo motor will lift the blade up and down to lift the block. In order to generate PWM to the servo motor continuously, the function TMR0 Interrupt in PIC16F877A is used. The advantage of the TMR0 Interrupt is that; MCU can generate the PWM signal continuously without stopping the MCU task at that time. The TMR0 will overflow for every 100µs. In order to create a PWM with period 20ms, +5V will be generated by PIC16F877A at RE2 pin for every 200 cycles. RE2 will turn low to 0V after 15 cycles to create a 1.5ms pulse. The PWM signal is measured using an oscilloscope. Figure 4.6 shows the PWM signal generated by RE to turn the servo motor 0 degree, 90 degree and 180 degree. Figure 4.7 shows the block lifted by the blade at 4.5cm height when 90 degree rotation of the servo motor.

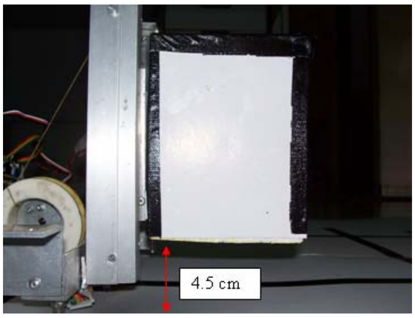
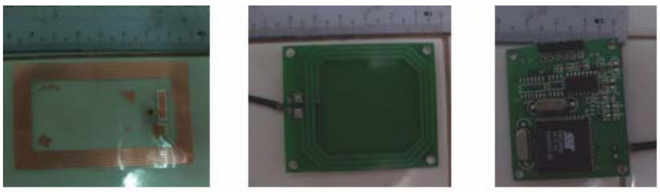


Figure 4.7: Block lifting at 4.5cm height

D. Communication with RFID Reader

The MCU communicate with the RFID reader via RS232. MAX232 is chosen as the RS232 converter. The MAX232 is a dual driver or receiver that includes a capacitive voltage generator to supply voltage levels from a single 5-V supply. Each receiver converts EIA-232-F inputs to 5-V TTL or CMOS levels. The PIC16F877A has a built in Universal Synchronous Asynchronous Receiver Transmitter (USART) function. This function is used to communicate half duplex with RFID reader. The communication is done at 115200 bps, 8 data bits, no parity bit, 1 stop bit. The RFID robot will read the ID of the RFID tag during loading the block. The RFID module is shown in Figure 4.8. Due to the size of the antenna, the maximum detection distance of RFID tag is 6 cm. Figure 4.9 shows the photo taken during testing the RFID reader.



(a) (b) (c)

Figure 4.8: RFID module

(a) RFID tag
(b) Antenna
(c) RFID reader

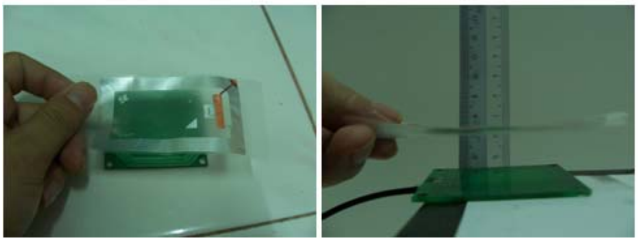


Figure 4.9: Testing RFID reader with the tag

The steps taken to communicate with RFID reader is listed below. The results of this communication are shown at figure 4.10.

- Put the RFID tag above the antenna not more than 6cm.
- Configure the PIC16F877A to serial communicate with RFID reader at 115200 baud rate, 8 data bits, no parity bit and 1 stop bit.
- Sending "AA00041006000012BB" in Hexadecimal format to gain the tag ID from the reader.
- Receive signal from the reader until "BB" is received.
- Save the signal at file register in the PIC16F877A.

Case 1: Found tag

- "AA000C00010000250E0A07000007E0CCBB" will be received by PIC16F877A where "250E0A07000007E0" is the ID of the tag.
- PIC16F877A will convert the 8 byte Hexadecimal ID into ASCII.
- Configure LCD.
- Send the ID in ASCII format to LCD display.

Case2: No tag found

- "AA0002018380BB" will be received by PIC16F877A. This means that no tag found.
- PIC16F877A will configure the LCD.
- "NO TAG FOUND" will be display at LCD.

(a)

(b)

Figure 4.11: LCD Display when reading RFID tag

(a) ID of the tag when tag is found
(b) RFID cannot find the tag

VII CONCLUSION

The main purpose of this project is to develop an autonomous robot with RFID application. The final version of the product is a prototype of RFID robot. The design of the robot is similar to forklift. RFID robot's locomotion system and navigation system was implemented using PIC microcontroller. RFID robot uses the line follower module for navigation and locomotion. RFID robot is able lift up the item at certain height by generating PWM signal to servo motor. Half duplex serial communication is done between PIC microcontroller and RFID reader. PIC microcontroller retrieves data from RFID reader and displays it at LCD.

Discussion

RFID robot could be configured to perform various applications. However in prototyping stage, RFID robot might not be able to accomplish all the tasks successfully. The application of RFID robot has good potential in warehouse management. It will replace the work and forklift to arrange and store the goods. The robot will manage the goods automatically according to the database programmed in the robot. This will save cost and time.

The application of the RFID robot is not limited only to warehouse management. It also has a good potential in hypermarket, building safety and manage and arrange books in the library.

Recommendations

In order to apply RFID robot in real live application, its must be upgraded. Some of the appropriate suggestions are listed below. These suggestions can be continued in future research to build a better design.

- Implement RFID robot with wireless communication to the host computer.
- Add a database in the host computer
- Develop a graphical user interface for controlling the robot.
- Implement GPS module into the RFID robot navigation system

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