February 8, 2010
Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 440 Functional Specification for the Robotic Item Retrieval System

Dear Dr. Rawicz,

Attached is a document from Freedom Innovation Research describing the functional specification for the Robotic Item Retrieval System. We are designing and implementing an automated system that can help disabled people to retrieve item at home.

This document provides detailed functional specifications for the entire system. The requirements are analyzed for general functionality, reliability, and the usability. We will follow the requirement as goals during the product design and will have functionality testing for each component. These requirements will guide us to the success of our project.

Freedom Innovation Research (FIR) consists of five motivated and innovative people: Steven Choi, John Ogawa, Jason Tsai, Kenta Yuan, and Richard Zhang. We are all fifth-year engineering students with at least one year of industrial work experience. If you have any question or comment about our project, please feel free to contact us at ensc-440-2010sp-fir@sfu.ca.

Sincerely,

John Ogawa
Chief Executive Officer
Freedom Innovation Research

Enclosure: *Functional Specification for the Robotic Item Retrieval System*

Functional Specification for the Robotic Item Retrieval System

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Submitted to:

- Dr. Andrew Rawicz – ENSC440
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Issued Date:

- February 8, 2010

Executive summary

Robotic technology is becoming more and more popular in the industry, however, not many robotic devices have been built for home services. The purpose of our project is to create an automated household robot that could actually benefit average people, especially those with disabilities. The Robotic Item Retrieval System we are developing is capable of retrieving item for people with restricted mobility. Some of the key functionalities of our product include automated indoor navigation, item location and item retrieval.

The Robotic Item Retrieval System will be developed in three phases: the proof-of-concept phase, the integration phase and the final production phase. In the proof-of-concept phase we will focus on the development of the following sub-systems:

- Drive Train – The base of the robot that drives the robot movement.
- Navigation – Guide robot to follow the path to the item.
- Robotic arm and Platform – The way for the Robot to retrieve item.
- Wireless Communication – Establish communication between the robot and host computer
- User Interface – Consist of Computer Graphical User Interface and Robotic User Interface

This document listed the overall system requirements as well as the functional requirements for the above sub-systems. It will be used as a guideline for designing and functionality testing. Each module must fulfill its requirements before it goes to the integration phase.

In the integration phases we will integrate each module and do more deliberated calibration and testing on the system. Hence, this phase will mainly establish the cooperation between each module. The final production phase will include additional features that will increase its reliability and functionality under difficult conditions.

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Glossary

A	Ampere. the SI unit of electric current
ADC	Analog-to-Digital Converter
AWG	American wire gauge
CSA	Canadian Standard Association
CM	Centimeter
DB	Decibels. A logarithmic unit of measurement
DHCP	Dynamic Host Configuration Protocol
FCC	Federal Communications Commission
FIR	Freedom Innovation Research
FPS	Frame per Second
G	Gravity = $9.8m/s^2$
GB	Gigabyte
GPIO	General Purpose Input/Output
GUI	Graphical User Interface
I2C	Inter-Integrated Circuit, a multi-master serial computer BUS that is used to attach low-speed peripherals to a motherboard, embedded system, or cellphone
IEEE	Institute of Electrical and Electronics Engineers
IEEE802.11	A set of standards carrying out wireless local area network (WLAN) computer communication in the 2.4, 3.6 and 5 GHz frequency bands.
LED	Light-emitting diode
Lux	the SI unit of illuminance and luminous emittance
MB	Megabyte
MTBF	Mean time between failures
OS	Operating System
PWM	Pulse-width modulation
QVGA	Quarter Video Graphics Array
RF	Radio Frequency
RFID	Radio-frequency identification
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
V	Voltage. The SI unit of electromotive force
WIFI	A trademark of the WiFi Alliance that may be used with certified products that belong to a class of wireless local area network (WLAN) devices based on the IEEE802.11 standards
WLAN	Wireless Local Area Network

1 Introduction

The Robotic Item Retrieval System is a household robot that could self-navigate in a room and retrieve items for the user. The robot is running on a wheeled base and it is equipped with an elevator platform and robotic arms for item retrieval. The robot is equipped with a surveillance camera and ultrasonic sensors for navigation and item identification. A computer graphical interface is used to control the robot. The robot will be operating wirelessly through 802.11g/n wireless network to perform bi-directional communication with the host computer GUI. Aside from manual remote control, the robot will support two automated navigation methods: line following and map generation. The line following method requires pre-placed markers on the floor to guide the robot through the room[1]. The map generation method is more sophisticated, as it enables the robot to generate its own room map and use it for navigation later[2]. Due to the time constraint of this project, our functional prototype may only support line following navigation. However, the map generation navigation will be implemented for the final product.

1.1 Scope

This document describes the complete functional requirements of our project, including both ideal and minimum requirements. The ideal functional requirements for our prototype device cannot be guaranteed. However, our prototype device must meet the minimum functional requirement to be an acceptable product. The listed requirements will guide the development of the Robotic Item Retrieval system and will lead it to its completion.

1.2 Intended Audience

The functional specification is intended for use by all members of Freedom Innovation Research. During the development phase the team will implement the product based on the functional specifications. During testing cycles before the product goes to the market, testers should follow these specifications to help assessing the product and evaluating its features. Lastly, manufacture industry should refer to the specifications for each component in order to meet the overall system requirement.

1.3 Classification

The following convention describes the functional requirements throughout the remainder of this document:

[Rn-p]: Here is the functional requirement
Where **n** is the number of functional requirement, and **p** is the priority of the functional requirement as denoted by one of three values:

[I] The requirement is nonessential, it is for the proof-of-concept system only.
[II] The requirement is essential for both the proof-of-concept and the final production system.
[III]The requirement is optional. It's the additional feature in final production system.

2 System Overview

The Robotic Item Retrieval System consists of several functional modules: the robot control circuit, the drive train, the robotic arm platform, the sensor module, the wireless module and the computer graphic interface. Figure 1 detailed the system architecture of our robot.

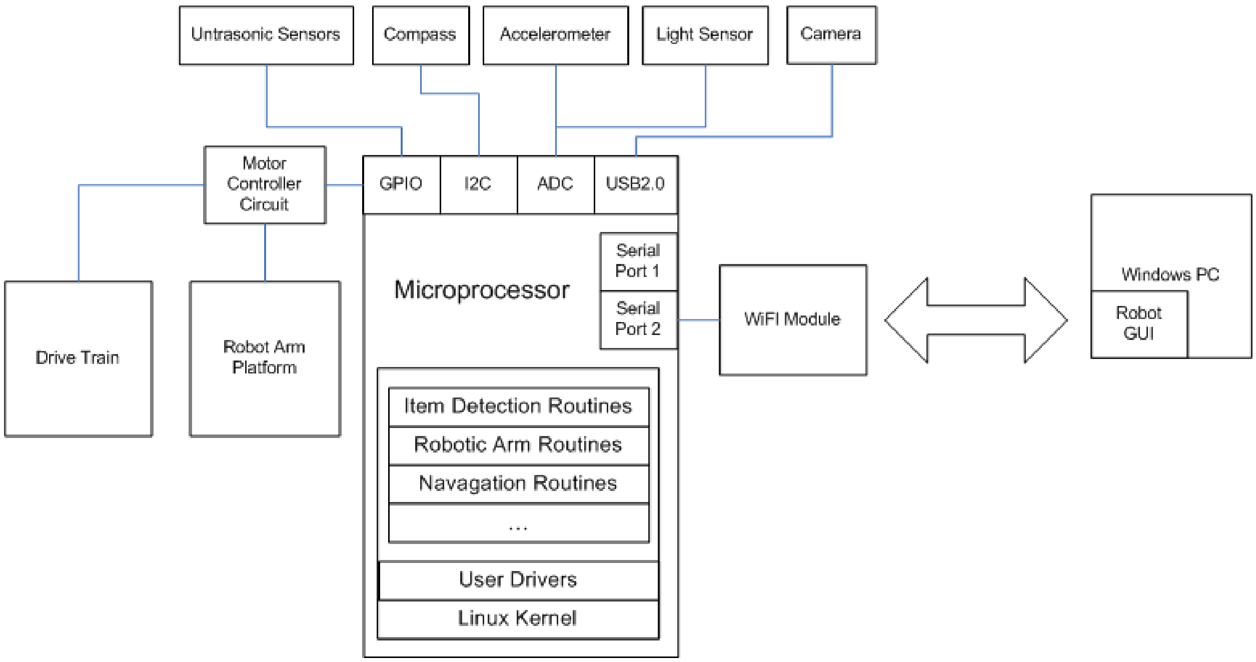

Figure 1. Architecture of the Robotic Item Retrieval System

As illustrated in Figure 1, the heart of our project is the robot control circuit built around a DMP Vortex x86DX microprocessor. The Vortex microprocessor provides all necessary interfaces for communicating with the rest of the system. It will be running Linux operating system to host the routines that control the operation of the entire system. The drive train and the robotic arm platform are controlled by the microprocessor through the motor control circuit. The drive train consists of 4 driving wheels, and both the front wheels and rear wheels can be used for steering. The robot arm platform can be raised from 40cm to 1m. For the proof-of-concept prototype, we will use a simplified design for the robotic arm which only has the capacity of retrieving items placed in a tray. A more sophisticated robotic arm design will be used for the final product. A combination of a video camera and a variety of sensors are used for robot navigation and item identification[2]. The ultrasonic sensors will be installed all around the robot to provide a 360 degree coverage. For the proof-of-concept prototype, the robot will be able to navigate in a room using the line following method. While a more sophisticated navigation method will be implemented for the final product to allow map generation and optimal path calculation. The robot is controlled wirelessly from a computer GUI that support real time video stream from the robot's camera[3].

2.1 Overall System Requirement

This section describes the functional requirements that apply to the complete Robotic Item Retrieval System.

2.1.1 General Requirement

[R1- II] The robot must be able to navigate inside a room wirelessly.

[R2- II] The robot must be using rechargeable batteries and be able to recharge itself when battery level is low.

[R3- II] The robot must be able to locate the item to be retrieved.

[R4- III] If wireless signal is lost, the robot must know how to return to its home location.

[R5- II] A wheel driving system is used to provide movement of the robot.

[R6- II] A lifting platform that can rise from 40cm to 1m (from ground).

[R7- III] A lifting platform that can rise from 10cm to 2m (from ground).

[R8- I] A simple robotic arm is used to simulate the idea.

[R9- III] For the final product, a sophisticated robotic arm system will be used to retrieve the item.

[R10- II] The cost of the robot hardware must be less than CAD$2000.

[R11- II] Robot must not produce more than 60dB noise while operating.

2.1.2 Physical Requirement

[R12- II] The robot must be smaller than the size of 60cm (length) x 50cm (width) and 50cm (height).

[R13- II] The robot must weights less than 20kg.

[R14- II] The robot must be able to go through a door easily.

[R15- II] The robot must be able to carry a maximum of 1kg load.

[R16- I] Aluminum is used to build the frames, no shell/casing is included.

[R17- III] Acrylic or plastic is used to build the shell/casing.

[R18- III] The shell/casing must protect all sensing components (ultrasonic sensors, IR sensors, all internal circuits, motors and wheels).

[R19- III] The robot must be able to withstand a shock of 2G from the surrounding.

[R20- III] The robot must be able to withstand a drop from 30cm height.

[R21- II] The wheels must not do any damage to the floor.

[R22- II] The robot must be able to get over a bump of height 2cm.

2.1.3 Electrical Requirement

[R23- II] The robot must be power by sealed lead-acid batteries.

[R24- II] Maximum instantaneous ampere must not exceed 20A.

[R25- II] Maximum continuous ampere must not exceed 10A.

[R26- II] Maximum circuit boards temperature is 60 °C.

[R27- II] A minimum wire gauge of 22AWG must be used for circuit boards to ensure safety.

[R28- II] A minimum wire gauge of 16AWG must be used for power motors to ensure safety.

[R29- II] Every sub-circuit must be protected by fuse.

[R30- II] Circuit boards must be protected by fast blown fuse.

[R31- II] All high power circuit and motors must be protected by slow blown fuse.

[R32- II] Components must be able to switch on and off independently.

[R33- II] Robot must shutdown itself if any electrical component malfunctions.

[R34- III] Diagnosis code must be given in case of malfunction.

2.1.4 Mechanical Requirement

[R351- II] The robot must be driven by wheels.

[R36- I] The robot must use front wheel drive topology.

[R37- III] The robot must use all wheel drive topology.

[R38- II] The maximum acceleration must be 2cm/s.

[R39- II] The minimum deceleration must be 3cm/s.

[R40- I] Robot chassis must be able to endure a 1G impact.

[R41- III] Robot chassis must be able to ensure a 2G impact.

[R42- II] The maximum weight of the robot base must be less than 15KG.

[R43- II] The maximum weight of the elevator platform and robotic arm must be less than 5KG.

[R44- II] Jackscrews design must be used for elevator platform.

[R45- II] The elevator platform must not swing more than 10 degree.

2.1.5 Performance Requirement

[R46- I] The designed average uptime must be greater than 1 hours.

[R47- III] The designed average uptime must be greater than 5 hours.

[R48- I] The battery must be charged from empty to full in less than 8 hours.

[R49- III] The battery must be charged from empty to full in less than 6 hours.

[R50- II] The robot must be able to climb a 10 degree tilt slope.

[R51- II] The maximum speed of the robot must be greater than 20cm/s.

[R52- II] Robot must be able to operate on carpet or hard floor.

2.1.6 Environmental Requirement

[R53- II] Robot must be able to operate in the temperature range of 0°C to 40°C.

[R54- II] Robot must be stored in the temperature range -20°C to 60°C.

[R55- II] Robot must be stored and operated in humidity from 10% to 90%.

[R56- II] Robot must not be stored or operated in dusty environment.

[R57- II] Robot must not be stored and operated in any type of fluid.

2.1.7 Standards

[R58- III] Robot must comply the Energy Star Standard[4].

[R59- II] Robot must not produce any RF interference that is forbidden by FCC[5].

2.1.8 Reliability and Durability

[R60- III] Robot must have a MTBF of 30000 hours.

[R61- III] Robot must be able to call for assist when malfunction.

2.1.9 Safety Requirements

[R62- III] The robot must be spill resistance.

[R67- II] The Robot must have an emergency stop button.

[R68- II] Robot must not interfere with critical medical equipments.

[R69- II] The chassis of the robot must not cause electric shock to users.

2.2 Drive train

This section describes the functional requirements that applies to the robotic base and the driving system.

2.2.1 General Requirement

[R70- II] The geared motor must supply a total torque of 10Kg-cm to the wheels.

[R71- II] Both front and rear wheels must be able to steer.

[R72- II] Steering is done by servo motors[6].

[R73- II] Drive train must be powered by electricity.

[R74- III] Bearings must be used on movable joints.

[R75- II] The drive train must be controlled by the onboard microprocessor.

[R76- II] PWM signal is used to control motor speed.

[R77- II] PWM signal is used to control steering servo motors.

2.2.2 Physical Requirement

[R78- II] Drive train must fit inside the robot frame.

2.2.3 Electrical Requirement

[R79- II] Geared motor must be powered by the 12V rail.

[R80- II] H-bridges must be used to control forward/reverse motion of the motors.

[R81- II] The speed of motors must be controlled by PWM signal from the microprocessor.

[R82- II] The H-bridges must provide a maximum of 2 amps per motor.

[R83- II] The servo motors must be powered by the 5V rail.

[R84- II] The drive train must consume less than 20A instantaneous current.

[R85- II] The drive train must consume less than 5A continuous current.

[R86- II] Stall motor protection must be implemented.

[R87- II] Wire connections must be able to withstand frequent movement and vibration.

2.2.4 Mechanical Requirement

[R88- II] The wheels must be able to withstand a loading of 30kg.

[R89- II] The minimum wheel diameter must be 85mm.

[R90- II] The maximum wheel diameter must be 130mm.

[R91- II] The minimum wheel width must be 40mm.

[R92- II] The maximum wheel width must be 80mm.

[R93- II] The maximum total steering angle must be 45 degree.

[R94- II] The maximum turning radius must be 2m.

2.2.5 Reliability and Durability

[R95- II] The drive train must have a MTBF of 10km.

2.2.6 Safety Requirements

[R96- II] The maximum braking distance must be less than 2 meter.

2.3 Camera and Sensors

The robot is equipped with a video camera and a variety of sensors for navigation and item identification. This section describes the functional requirements of the onboard camera and sensors.

2.3.1 General Requirement

[R97- II] The camera must support QVGA resolution (320x240) at 10 fps.

[R98- II] The camera must be working correctly with typical ambient light level (30 lux to 10000 lux).

[R99- II] The ultrasonic sensors must operate correctly when the robot is moving at less than 20cm/s.

[R100- II] The ultrasonic sensors should not interfere with each other or with any other device on the robot.

[R101- II] The LED/Photo diode pairs must be able to distinguish black and white colors[7].

[R102- II] The RFID sensor must be able to detect a RFID tag within 5 cm.

[R103- III] The robot should be able to learn about its orientation from the onboard compass.

2.3.2 Physical Requirement

[R104- II] The camera must be mounted on the elevator platform.

[R105- II] The LED/Photo diode pairs must have at least 2cm clearance from the floor.

2.3.3 Electrical Requirement

[R106- II] The sensors must be powered by the 5V rail.

2.3.4 Performance Requirement

[R107- II] The maximum respond time for the ultrasonic sensors, measured from sending pulse to data ready, must be less than 200ms.

[R108- II] The ultrasonic sensors must be able to detect the first object in front of it in the range of 5cm to 1m

[R109- II] The LED/Photo resistor pairs must return accurate readings within 3cm.

[R110- II] The accelerometer must have an accuracy of $0.1 m/s^2$.

2.3.5 Safety Requirements

[R111- II] The ultrasonic sensors must not be harmful to human beings and the environment.

[R112- II] The LEDs must not be harmful to human eyes.

2.4 Navigation

The Robotic Item Retrieval System is navigated by pre-placed marks on the floor when not being remotely controlled by the user. This section describes the functionality of the robot's navigational system.

2.4.1 General Requirement

[R113- II] The robot must be able to move through open doors.

[R114- II] The robot must be able to follow a straight line[1].

[R115- II] The robot must be able to follow a curved line.

[R116- II] The robot must be able to detect the end of line and move back from it.

[R117- III] If the line is broken or if the robot accidentally moves away from the line, the robot must be able to trace back to its previous position.

[R118- II] The robot must recognize special markers along the line and perform the appropriate actions.

[R119- III] The robot must be able to handle intersections on the line.

[R120- II] The robot must be able to detect the item to be retrieved.

[R121- II] The robot must return to the user after retrieving the item.

[R122- II] The robot must detect non-moving obstacles and avoid collisions with them.

[R123- III] The robot should have a routine to map the room using its sensors.

[R124- II] The robot must respond immediately to the remote control from the user. The remote control commands include but not limited to forward, backward, turn left, turn right and stop[8].

[R125- II] Collision detection must still be in effect with manual control.

2.5 Robotic Arm Platform

The Robotic Item Retrieval System is equipped with two robotic arms attached to a elevator platform[8]. Once the robot arrive to the designated location the platform will lift up to match the height of the item to be retrieved. The, the robot arms will extend forward to reach and hold the item. Figure 2 shows the conceptual model of the robotic arm platform design.

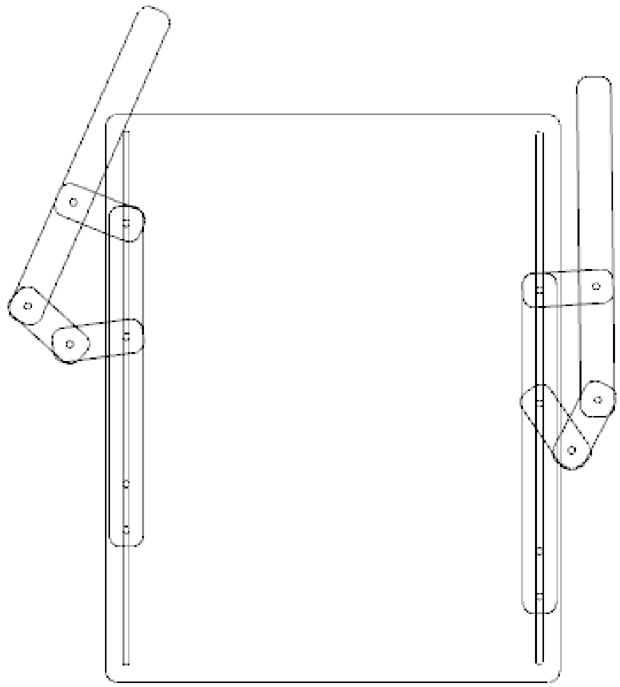

Figure 2. Conceptual Model of the Robotic Arm Platform Design

2.5.1 General Requirement

[R126- II] The robotic arms must be built on top of the elevator platform.

[R127- II] The elevator platform must be able to raise from 40cm to 1m (from ground).

[R128- II] The robot arms must have the ability to collect a 30cm x 40cm tray placed in front of it.

[R129- II] The robotic arms and the elevator platform must be controlled by the microprocessor.

2.5.2 Physical Requirement

[R130- II] The robotic arms must be separated by 50cm maximum when not in use.

[R131- II] The robotic arms must be constructed by aluminum and rubber.

[R132- II] The maximum dimension of the elevator platform must be less than 60cm x 50cm.

[R133- II] The elevator platform must be located on the central top of the robot base.

2.5.3 Electrical Requirement

[R134- II] The motors on the robotic arms must be powered by the 5V rail.

[R135- II] The robotic arms must be controlled by the micro switches which tell the motor when to stop.

2.5.4 Mechanical Requirement

[R136- II] The robotic arms must have two degrees of freedom in the XY-plane.

[R137- II] The platform must be able to rotate about the Z-axis.

[R138- II] The robotic arms must be able to extend forward by at least 30cm.

[R139- II] The robotic arms must be able shrink the robotic arms toward each other.

2.5.5 Performance Requirement

[R140- II] The platform must be able to hold items without causing the robot to tip over.

[R141- II] The platform must be able to match the height of the table where the item is located.

2.5.6 Normal Operating Requirement

[R142- II] The item to be retrieved must be put in a 30cm x 40cm tray.

[R143- I] The weight of the item must not exceed 1kg.

[R144- III] The weight of the item must not exceed 5kg.

2.5.7 Environmental Requirement

[R145- II] The electrical components of the robotic arms and the platform must be protected from water spills.

2.6 Wireless communication

The communication between the robot and host computer is transmitted wirelessly. This section describes the requirements for the wireless modules and communication protocols.

2.6.1 General Requirement

[R146- II] The robot must be able to communicate with the host computer wirelessly[9].

[R147- II] The robot must support DHCP.

[R148- II] Non-critical data are transmitted by UDP; mission-critical data are transmitted by TCP.

2.6.2 Physical Requirement

[R149- II] The length of the wireless antenna must not exceed 10cm.

[R150- II] The size of the wireless module must not exceed 20cm x 20cm x 10cm.

2.6.3 Electrical Requirement

[R151- I] The wireless module must be powered by the 5V rail.

[R152- II] The wireless module must be able to operate in the presence of interference signals.

2.6.4 Performance Requirement

[R153- II] The minimum wireless communication range between the robot and wireless access point must be greater than 30m (indoor).

2.6.5 Standards

[R154- II] The wireless transmission must be comply with IEEE 802.11g/n protocol.

[R155- II] The wireless signal strength must compile the regulatory FCC standards[5].

[R156- II] The wireless module must be certificated by FCC, ICES-003.

2.6.6 Reliability and Durability

[R157- II] The wireless receiver must allow a maximum of 10% packet loss.

2.6.7 Safety Requirements

[R158- II] The wireless signals must not be harmful to human beings and the environment.

2.7 User Interface

2.7.1 Computer Graphical User Interface

The main control interface of the robot is a computer GUI program running on Windows PC[10]. It will be used to control the operation of the robot through 802.11g/n wireless network. It must provide the functionalities detailed below.

2.7.1.1 General Requirement

[R159- I] The computer graphical user interface (GUI) must be compatible with Microsoft Windows 7.

[R160- III] The computer GUI must be compatible with Microsoft Windows XP, Windows Vista, Windows 7 and Mac OS 10.0 and above.

[R161- II] The computer GUI must be able to communicate with the robot wirelessly.

[R162- II] The computer GUI must support video streaming from the robot at QVGA(320x240) resolution.

[R163- II]T he computer GUI must allow the user to assume direct control of the robot

[R164- II] The computer GUI should provide the following information:

- WIFI signal strength
- Battery level
- Sensor readings (distance from each sides, accelerometer reading, etc)
- Position of the robotic arms
- Operating mode
- Current command

[R165- II] The computer GUI must provide the following manual commands:

- Move forward/backward
- Turn left/turn right
- Stop
- Raise/lower platform
- Reach/retrace robotic arm
- Open/close robotic arm
- Collect item using robotic arm

[R166- II] The computer GUI must provide the following commands:

- Invoke line following item retrieval routine

- Invoke room mapping routine (optional feature)

[R167- II] The computer GUI must give sound or visual feedback when there is a user input.

[R168- II] The computer GUI should return error message for illegal command.

[R169- III] The computer GUI should have indications for robot malfunctions.

[R170- III] The computer GUI should support voice commands from Windows 7/Vista speech recognition.

[R171- III] The computer GUI should support joystick inputs.

2.7.1.2 Performance Requirement

[R172- II] The computer GUI must have an input lag of less than 100 ms.

2.7.1.3 Normal Operating Requirement

[R173- II] The host computer must fulfill the following requirements:

- CPU: Intel Core 2 duo E6300 or AMD Athlon 64 x2 4200+ or above
- Memory: 1GB
- Hard drive: 200MB free space
- Minimum screen resolution of 1024x768.

2.7.2 Robot User Interface

The Robot will be equipped with a onboard control panel that allow the user to quickly configure and diagnose the system. The onboard interface must meet the following requirements.

2.7.2.1 General Requirement

[R174- II] The robot must have a master on/off switch.

[R175- II] The robot must have an emergency stop button.

[R176- III] The robot must have a keypad interface for system setup.

[R177- III] The robot must give sound or visual feedback when there is a user input.

[R178- II] The robot must have LED indicators to display its working mode.

2.7.2.2 Physical Requirement

[R179- II] The location of the interface panel should be easy to reach by the users.

[R180- III] The interface panel should have a flip-door cover so the buttons won't be pushed accidentally.

2.7.2.3 Reliability and Durability

[R181- III] All buttons must withstand more than 5000 operations.

3 Conclusion

The detailed functional specification of the Robotic Item Retrieval System has been outlined in this document. The implementation of our project is mainly based on these requirements. We are currently focusing on implementing the functionality of each system module. For example, we have developed the basis GUI program for sending data between a computer and the robot. The construction of the mechanical structure of the robot base has also begun, and we have managed to obtain data from sensors such as a ultrasonic sensor and photo resistor. Finishing the implementation of all sub-systems within the time constraint is challenging, but we are steadily making progress and meeting millstones. We are thus optimistic that by April, 2010 we will be ready to deliver a functional prototype that meet the requirements outlined in this document.

4 Reference

[1] Dale A. Heatherington, “Line Follower Robot,” Oct. 1999. [Online]. Available:http://www.wa4dsy.net/robot/linefollower. [Accessed: Jan. 19, 2010]

[2] Sebastian Thrun, Christian Martin, and Yufeng Liu, “A Real-Time Expectation-Maximization Algorithm for Acquiring Multiplanar Maps of Indoor Environments with Mobile Robots,” Jun. 2004. [Online]. Available: http://ieeexplore.ieee.org/search/freesearchresult.jsp?history=yes&queryText=(real-time+expectation-maximization+algorithm+for+acquiring+multiplanar+). [Accessed: Jan. 22, 2010]

[3] Wei-Meng Lee, “Monitor Your Web Cam from a Remote Computer,” Jan. 31, 2007. [Online]. Available: http://www.devx.com/dotnet/Article/33637. [Accessed: Feb. 2, 2010]

[4] Energy Star, “Product Specifications: Program Requirements,” [Online]. Available: http://www.energystar.gov/index.cfm?c=product_specs.pt_product_specs. [Accessed: Feb. 5, 2010]

[5] Federal Communications Commission, “Radio Frequency Safety,” Jul. 1, 2009. [Online]. Available: http://www.fcc.gov/oet/rfsafety/. [Accessed: Jan. 30, 2010]

[6] Seattle Robotics Society, “Standard Technologies of the Seattle Robotics Society,” Nov. 10, 2004. [Online]. Available: http://www.seattlerobotics.org/guide/. [Accessed: Jan. 14, 2010]

[7] Ibrahim Kamal, “Line Tracking Sensors and Algorithms,” Apr. 15, 2008. [Online]. Available: http://www.ikalogic.com/tut_line_sens_algo.php. [Accessed: Jan. 19, 2010]

[8] K. Hagan, M. Hillman, and S. Hagan, “The Design of a Wheelchair Mounted Robot,” Mar. 7, 1997. [Online]. Available: http://ieeexplore.ieee.org/search/freesrchabstract.jsp?arnumber=641219&isnumber=13917&punumber=5100&k2dockey=641219@ieecnfs&query=(robot)<in>metadata&pos=2. [Accessed: Jan. 26, 2010]

[9] Jonathan Bennett, “Wifi Robot,” Aug. 2008. [Online]. Available: http://www.jbprojects.net/projects/wifirobot/#hardware. [Accessed: Jan. 19, 2010]

[10] Chen Yimin, Zhang Tao, and Wang Di, “A Robot Simulation, Monitoring and Control System Based on Network and Java3D,” Jun. 2002. [Online]. Available:

http://ieeexplore.ieee.org/search/freesrchabstract.jsp?arnumber=1022085&isnumber=21984&punumber=7949&k2dockey=1022085@ieeecnfs&query=(robot)<in>metadata&pos=0. [Accessed: Jan. 26, 2010]

[11] Libo Yang and Steven M. LaValle, “The Sampling-Based Neighborhood Graph: An Approach to Computing and Executing Feedback Motion Strategies,” Jun. 2004. [Online] Available: http://ieeexplore.ieee.org/search/freesearchresult.jsp?history=yes&queryText=(sampling-based+neighborhood+graph). [Accessed: Jan. 23, 2010]

[12] Joo-Hyung Kim, Jeong-Eom Lee, and Hyun-Gu Lee, “Identification and Control for an Unkown Robot in Intelligent Space,” Jun. 2004. [Online]. Available: http://ieeexplore.ieee.org/search/freesrchabstract.jsp?arnumber=5326287&isnumber=5326035&punumber=5306517&k2dockey=5326287@ieeecnfs&query=(robot)<in>metadata&pos=19. [Accessed: Jan. 24, 2010]

[13] U. Rembold, T. Lueth, and T. Ogasawara, “From Autonomous Assembly Robots to Service Robots fro Factories,” Sept. 16, 1994. [Online]. Available: http://ieeexplore.ieee.org/search/freesrchabstract.jsp?arnumber=407567&isnumber=9158&punumber=3221&k2dockey=407567@ieeecnfs&query=(robot)<in>metadata&pos=1. [Accessed: Jan. 26, 2010]

