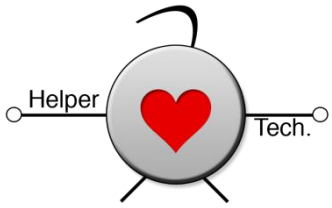


HelperTech.
School of Engineering Science, Burnaby, BC, V5A 1S6

February 14, 2010

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, BC
V5A 1S6

Re: ENSC 305/440 Functional Specification for Remote Control Snow Blower Robot

Dear Dr. Rawicz:

The enclosed document clearly describes the functional specification of our developing snow blower robot, RoboBlow, which is a wireless remote control robot for snow removal. Our proposed robot will provide the utility of snow removal without the necessity of going outdoors in person. The main functionality of the robot will include salt spraying, snow throwing, and real time video transmission from the robot to the remote controller.

The attached functional specification document outlines various requirements and consideration for the robot system and functionality. It also briefly describes our safety consideration and the test plan of the robot.

HelperTech is a research team found by four talented and innovative senior engineering students: Leo Cheng, Peter Hsiao, Joseph Shen, and YuYuan Liu. If there are any questions or concerns regarding our proposal, please feel free to contact me by phone or by email.

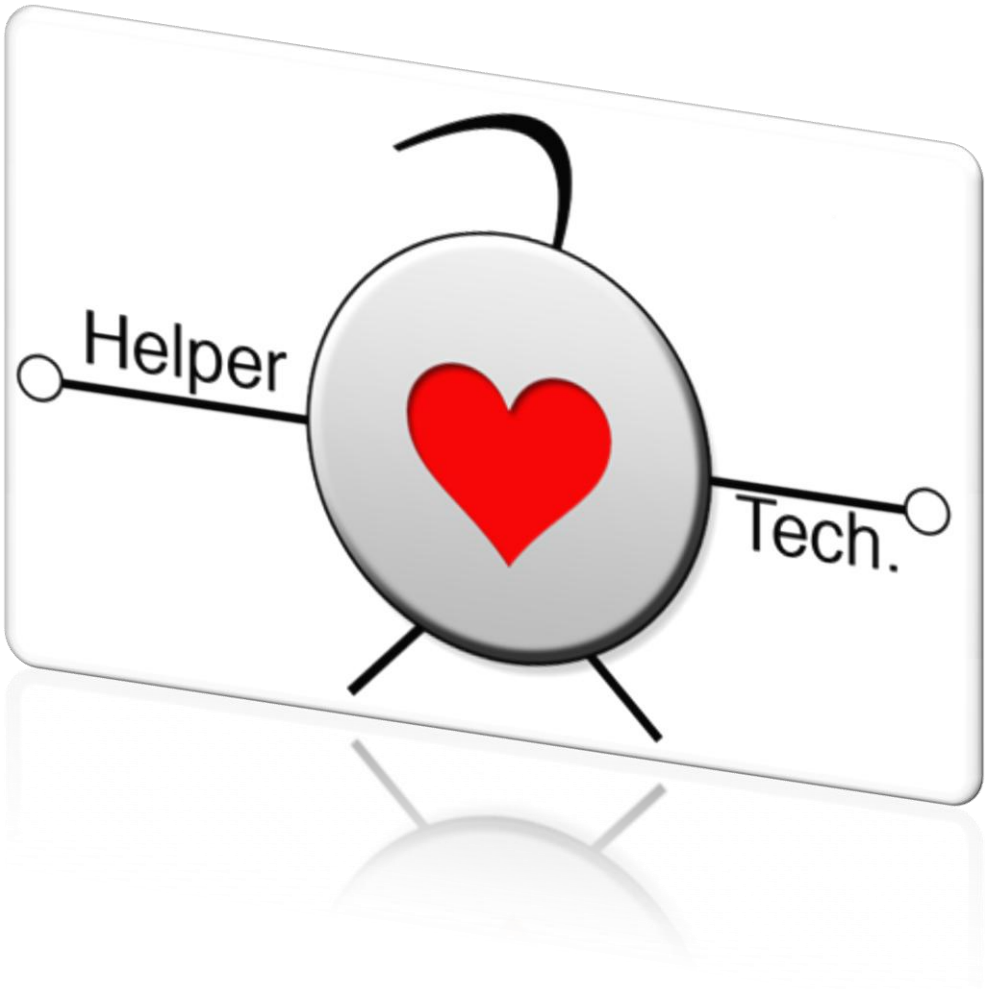
Sincerely,

Leo Cheng
President and CEO, HelperTech
Phone: (604) 760-1283
Email: hpc5@sfu.ca

Enclosure: *Functional Specification for Remote Control Snow Blower Robot*

Functional Specification
Remote Control Snow Blower Robot

Spring 2011



Submitted to: Andrew Rawicz (ENSC 440)
Michael Sjoerdsma (ENSC 305)

Project Team: Leo Cheng (301084573)
Peter Hsiao (301025638)
YuYuan Liu (301046236)
Joseph Shen (301032167)

Executive Summary

Despite the well developed snow removal tools in the market, each year a considerable amount of injuries and heart failures are resulted in snow removal for the hard exercise in the slippery and hazardous environment.

In order to protect people and provide the most comfort to people for snow removal, HelpTech is developing a robot for snow removal such that our robot users can stay in the house while the robot is cleaning snow outdoors.

Our proposed robot is called RoboBlow which will have the following modules and functionality:

- Snow Thrower Module
- Salt Spraying Unit
- Snow-Out Direction Control
- Speed and Direction Control
- Camera Direction Control
- Wireless Remote Control
- Real-time Video Transmission From the robot to the controller

As with these modules and functionality, the robot users can control the robot to clean snow with a wireless robot controller. The robot will have the full utility for snow removal and also provide the utility of remote control without looking the actual robot as the robot working condition can be monitored through the robot controller.

More detailed and specific requirements to accomplish above functionality are listed in this document.

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Glossary

LCD	Liquid Crystal Display, a flat electronic visual display
Snow Intake	The amount of snow that the snow thrower can handle at a given moment
H-bridge	A well know electronic circuit used to control motor rotation direction
ARM9	The version 9 ARM CPU. ARM is a global leading company for designing embedded system processor. ARM9 is one of their product models.
MCU	Micro-controller. It is a small computer on a single IC containing a processor, memory and programmable I/O [2]. It is usually used in automatically controlled products and devices.
Seven segment display	Please refer to the figure below.

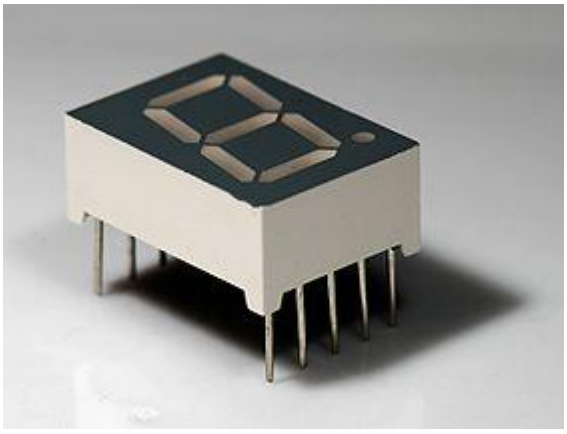


Figure 1: A seven segment display [1]

IEEE 802.11	It is a set of standards carrying out wireless local area network computer communication in the 2.4, 3.6 and 5 GHz [1].

1. Introduction

RoboBlow is a remote-controlled snow thrower robot. This task oriented robot enables its operator to remove the snow and prevent ice formation on walkways or driveways while staying inside his/her home. Through the remote controller, the operator is able to move RoboBlow in any direction with desirable speeds. The operator can also turn on the snow thrower when it reaches a job site and turn off the snow thrower while the robot is travelling. There is also a salt spraying unit on the robot that can be switched on/off by using the remote controller. The requirements of this robotic system are proposed by HelperTech Inc. and will be discussed in depth throughout this document.

1.1 Scope

The scope of this document mainly focuses on the functional requirements and specifications of our product. The document will first go through the system requirement where an overview of the entire system is briefly introduced. Secondly, the detailed requirements and the functional goals of every module will be discussed in each section. Next, the plans of composing different types of user documentation will be discussed. Finally, a conclusion will be provided to summarize our functional specification.

1.2 Audience

The purpose of this documentation is to ensure that the expected functional requirements by the company executives are met. It serves as a general guideline for the project managers to accomplish each module of the project. Also, this document provides the design engineers with the necessary information to carry out the actual implementation of each module and how each component should be integrated. Lastly, the test plan indicated by this documentation shall bring the test engineers with the necessary instructions to execute the test cases indicated.

1.3 Classification

The following convection is used throughout this documentation:

[Rn-s] - A function requirement

R: Stands for “Requirement”
n: The assigned number for each requirement
s: The priority of the requirement in the following order where I is the highest and III is the lowest

2. Overall System Requirement

The Snow Thrower Robot can be modeled by the following block diagram and system diagram:

Block Diagram

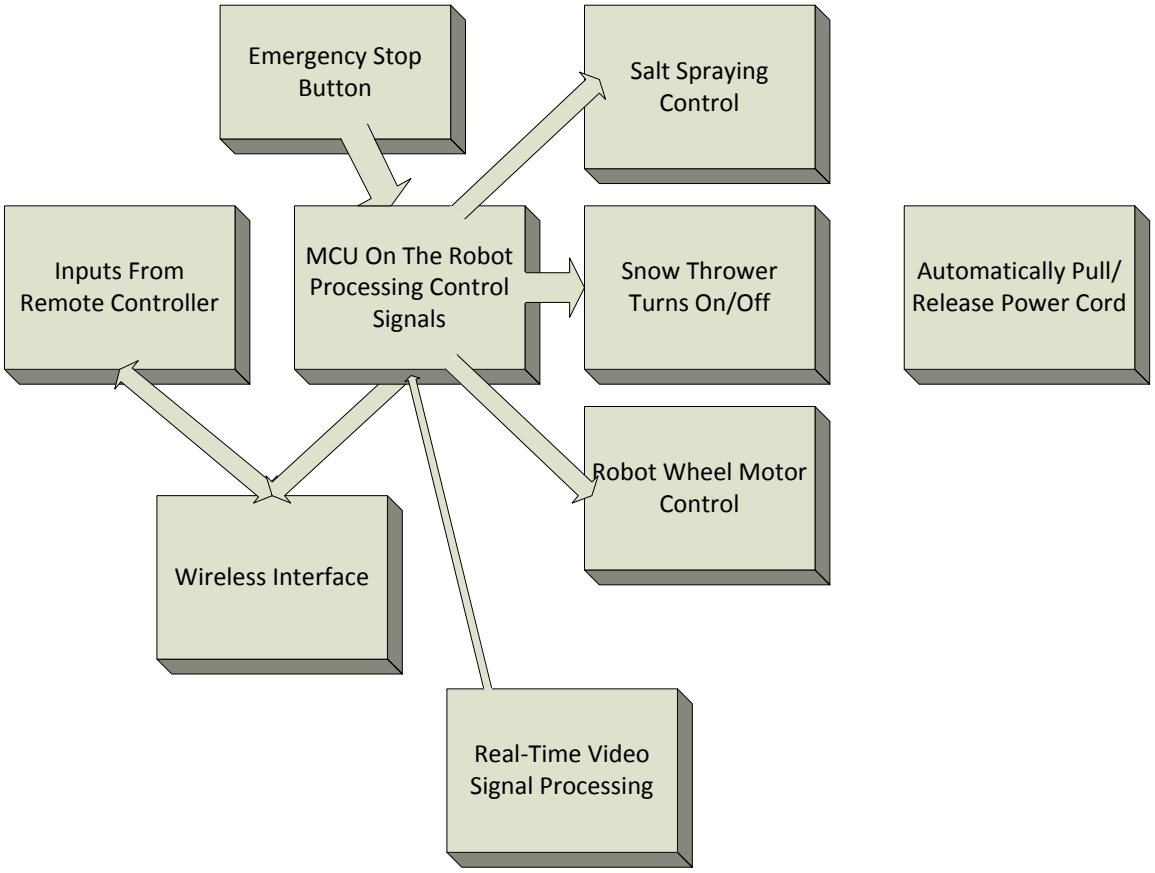


Figure 2: Block Diagram

System Diagram

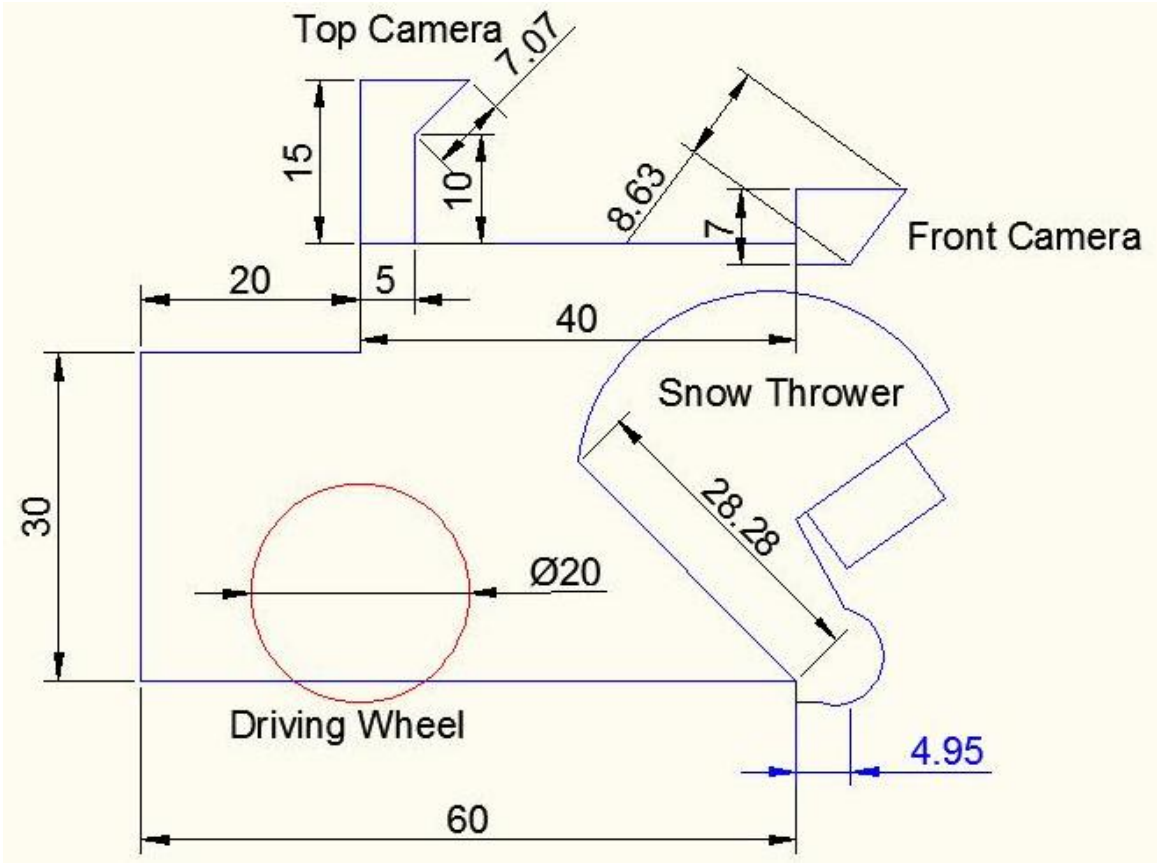


Figure 3: System Diagram

This robot system can be divided into 11 sections, including wheel motors, motor to control the snow spitting direction, the snow thrower, salt spraying mechanism, remote controller, video processing, wireless interface, power switch, automatically pull/release power cords, and body building.

The robot is driven by two wheels at the back, with small decorative wheels in the front to decrease friction. The thrower itself will be mounted on the acrylic body alone with the wheels, along with two webcam cameras and the salt spraying unit. The user sends input signals from the remote controller to the MCU on the robot through wireless interface. The MCU in the robot processes the signals and sends processed signals to the control circuits to control the robot.

The cameras on the robot send data to the MCU on the robot which processes the real-time image and sends back to the user LCD by wireless interface.

For convenience purpose and to solve the messed up cord problem, the robot has a

feature which can pull/release the power cord depending on the distance from the wall plug. This allows the user to save time from dealing with knotted cords and prevent disconnection.

The emergency button on the robot allows people walk by the robot to stop the robot when emergency happens. When the robot is operating, the user can turn on/off the snow thrower as desired when the robot moves around. The user can get a clear view of real-time environment by looking at a LCD screen in the controller. The user can also choose the direction of the snow spitting direction through the remote controller and can also control the spaying unit to spray salt along the road.

2.1 General Requirement

[R1-I] The position and the direction of the robot are controlled by the user through the remote controller.

[R2-I] The snow thrower can be switched on/off by the user through the remote controller

[R3-I] There are cameras on the robot to capture the environment information

[R4-I] The remote controller should be able to receive the real-time images from the cameras on the robot and display these images on LCD monitors embedded in the remote controller.

[R5-I] The salt spraying unit on the robot can be switch on/off by the user through the remote controller.

[R6-II] The power cord automation unit should automatically release or pull back the power extension cord from the wall socket.

[R7-II] The robot and remote controller should not cost more than $2000 CDN.

2.2 Physical Requirement

[R8-II] The width of the robot shall not exceed 50 cm.

[R9-II] The length of the robot shall not exceed 60 cm.

[R10-II] The height of the robot shall not exceed 40 cm.

[R11-II] The weight of the robot shall not exceed 40 Kg.

[R12-II] The maximum height of the snow intake shall be less than 15 cm.

[R13-I] The robot shall have enough traction so it can move in the snow or on the ice.

2.3 Electrical Requirement

[R14-II] The power extension cord shall be connected to ordinary external wall socket (110V/120V at 60Hz) in order to provide power supply to the robot.

[R15-II] The total amount of power drawn by the robot from ordinary external wall socket (110V/120V at 60Hz) shall not exceed 1700 Watt.

[R16-II] The maximum power drawn by the snow thrower alone shall not exceed 1080 Watt. (120V, 60 Hz, 9A)

[R17-II] The power supply unit on the robot is used to distribute and regulate power to each module of the robot except for the snow thrower which connects to the power cord directly.

[R18-I] The power supply unit shall draw maximum of 600 Watt of power from the power cord.

[R19-I] The two DC geared motors driving the wheels of the robot shall not draw more than 480 Watt of power from the power supply unit on the robot. (12V, 20A maximum each)

[R20-I] The power drawn by the rest of the components on the robot, such as stepper motors, microcontrollers, control circuits, and cameras shall not exceed 120 Watt

2.4 Mechanical Requirement

[R21-I] The speed and direction of motors for the wheels can be controlled by the remote controller

[R22-I] The direction and location of motors for camera, snow output direction, and power cord should also be controlled by the remote controller

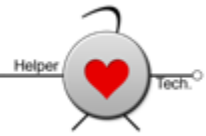
[R23-I] The camera should be able to rotate freely by the remote control

[R24-I] The robot is 2 wheel drive by 2 DC geared motors, and with small wheels on the front to decrease friction

[R25-I] The body which supports the snow thrower is built by customized acrylic boards

[R26-I] The remote controller should be user friendly (PS2 buttons and joystick)

[R27-I] The mechanical components should be visually well hidden inside the robot.



2.5 Environmental Requirement

[R28-I] The robot shall be operated under snow condition (slippery road), cold weather (-30℃~20℃)

[R29-I] The robot shall be waterproof

[R30-I] The robot shall have safety mechanism to prevent from hurting people passing by

[R31-III] The robot should have mechanism to reduce the operating noise

2.6. Reliability and Durability

[R32-I] The bottom part of the robot is water-proof.

[R33-I] The remote controller is resistant to breakage under normal operating conditions.

[R34-III] The robot can be continuously working for at least 3 days.

[R35-III] The robot will be closed automatically if no command received for 1 hour.

[R36-II] The MTBF (mean time between failures) of the robot is no less than 8000 hours.

[R37-II] The MTTR (mean time to repair) of the robot is no less than 15000 hours.

2.7. Safety Requirement

[R38-I] If for some reason, the connection between remote controller and robot is broken, the power of the robot will be cut off immediately.

[R39-I] The electronic and mechanical components should be enclosed.

[R40-II] The robot can detect the objects other than snow that are approaching to it and warn the user.

[R41-II] When objects other than snow are very close to the snow thrower, the robot will shut down the snow thrower engine automatically.

2.8. Performance Requirement

[R42-II] The boot up time for the whole system is less than 10 seconds.

[R43-II] The robot response time for the command issued from remote controller is less than 1ms.

[R43-I] The real-time image displayed on the LCD screen should be clear and fluent.

[R44-I] The robot can climb up the road with minimum 10 degree of slope

2.9 Usability Requirement

[R45-II] The robot should execute the commands received from remote controller. However if there is safety problem, robot will take safety response instead of implementing the commands from remote controller.

[R46-I] The heat output from robot will not affect its normal operation.

[R47-I] The remote control panel interface should be easy to understand.

[R48-II] The robot operation should be easy to learn by the users without any computer background.

2.10. Standards

[R49-II] The robot shall conform to ISO/TC 184/SC2 standards.

[R50-II] The robot shall conform to ISO 10218 safety standards.

3. Snow Thrower

The snow thrower is part of the market product bought from Canadian Tire. It has a motor and a specially designed mechanical steel fan which is able to spin the snow in and spit the snow out at desired direction.

3.1 General Requirement

[R51-I] The thrower needs be mounted on the body of an acrylic robot with the wheels

[R52-II] The thrower must have angle of 30~45 degrees to the ground in order to spin the snow properly

[R53-II] The noise produced by the thrower should be minimized

[R54-II] The thrower should be directly plugged in extension cord to the wall plug.

3.2 Physical Requirement

The following criteria of the snow thrower is prescribed by Canadian Tire website

[R55-II] 16" (41 cm) clearing width and 6" (15 cm) intake height

[R56-II] 14" (36 cm) plastic impeller gathers and expels snow through 180° directional chute

[R57-II] Discharges snow up to 25' (7.6 m)

[R58-II] Draws power of 108 Watts and 9A of DC current

[R59-II] Weighs about 24 lbs

4. Robot Speed and Direction

The robot speed and direction module includes two DC geared motors, two rubber wheels and two motor direction control circuits. This module is responsible for:

- driving the robot to desired position and orientation
- pushing the thrower into the snow in order to remove the snow

While the direction of the motor rotation (robot orientation) is controlled by direction control circuit which takes input from the microcontroller embedded in the robot. The speed of the robot can be adjusted by using the pulse-width modulation signal from the microcontroller.

4.1 General Requirement

[R60-II] 34:1 gear ratio is needed in the DC geared motor in order to reduce the speed of rotation and to transform it with higher torque.

[R61-I] The alignment of the two motors and wheels must be precise so that the robot will be moving in a straight manner when desired.

[R62-I] Traction of the wheel must be accomplished by using slipping proof material on the surface of the two rubber wheels such that the robot can move in the snow or on the ice.

4.2 Physical Requirement

[R63-III] The direction control circuits are implemented by two H-bridges which can handle at least 360 Watt of power rating and 20 A of current.

[R64-II] Torque produced by the two motors should sum up to at least 13.54 Nm.

[R65-II] When the direction of motor rotation is switched by the operator, the motor should come to a stop or slow down for at least five seconds without drawing any current in order to reduce the inertia and possible heating up of motor and control circuit.

[R66-III] The two rubber wheels are 20.32 cm in diameters each

5. Vision detection

This section aims to define the functional specification of camera modules.
Camera modules will be used to capture the real-time images and to send the image data to the MCU in the robot.

5.1 General Requirement

[R67-II] Three Cameras are used to obtain the environment information around the robot.

[R68-I] Camera 1 is used to capture the real-time images around the robot. The video from this camera will be mainly used for user to control the movement of the robot.

[R69-II] Camera 2 is used to monitor the snow blower working situation. The video from this camera will be used for user to check if the snow blower works normally.

[R70-II] Camera 3 is used to see the snow out direction. The video from this camera will be used when user adjusts the snow out direction.

5.2 Physical Requirement

[R71-I] All the cameras need to be protected by transparent covers.

[R72-I] A motor needs to be installed under the camera 1 to provide the possibility of camera rotation.

5.3 Electrical Requirement

[R73-II] All the cameras will be powered by USB plug on the MCU development board.

5.4 Usability Requirement

[R74-II] In order to keep the good image quality in dark environment, the robot needs to have lighting equipments.

[R75-II] When the environment is getting dark, the lighting equipment can be switched on automatically.

[R76-I] Camera 1 can be rotated 360 degrees.

6. Power Cord Control

The robot has the feature of pulling/releasing the power cord automatically by the change of distance from the robot to the power supply. This feature is implemented for:

- Unnecessary mess of wires curling together
- Add convenience for the user to clean up after using

6.1 General Requirement

[R77-II] The power cord is attached to a stepper motor powered by low DC current

[R78-II] An IR sensor is used to detect the distance from the cord to the robot and the wall plug

[R79-II] When the robot gets far away from the wall plug, the motor will spin to release the power cord, and vice versa.

6.2 Physical Requirement

[R80-II] The power cord is 6 feet long

[R81-II] The cord is maximum 1.5 kilogram

[R82-II] The motor must have torque more than 15 N*ft in order to deal with the cord properly

7. Remote control system

With our system, user can control the RoboBlow without directly watching it. The real-time images captured by cameras on the robot and displayed on the LCD screen of the control panel will assist users to control the robot.

7.1 General Requirement

[R83-I] The robot can be fully controlled by remote controller wirelessly.

[R84-I] The control system of the robot will use two ARM9 development boards (MCUs), one in the remote controller, and one in the robot.

[R85-II] Both MCUs operates in Linux OS

7.2 Physical Requirement

[R86-II] The size of the remote controller will be 215.9 mm × 279.4 mm

[R87-I] The weight of the remote controller will be less than 1 kg.

[R88-II] The remote controller will be powered by 5 volts DC battery.

[R89-I] The robot is a real-time system. Any command issued from the remote controller must be implemented by the robot as soon as possible.

[R90-II] The user interface of the remote controller will consists of one joystick, 8 buttons, 5 LEDs and one 5.6 inches LCD screen.

[R91-I] All the buttons on the control panel should be easy to access. The button and joystick distributions should by intuitive and easy-to-use.

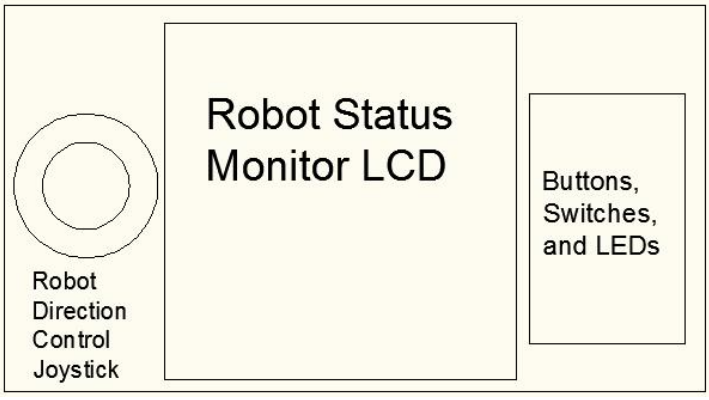


Figure 4: Remote controller layout

7.3 Direction Control Requirement

[R92-I] Joystick is designed to control the moving direction of the robot.

[R93-I] Robot should move toward the direction where the joystick is pushed

[R94-I] When joystick is pushed forward, the moving direction of the robot is along the positive direction of y-axis.

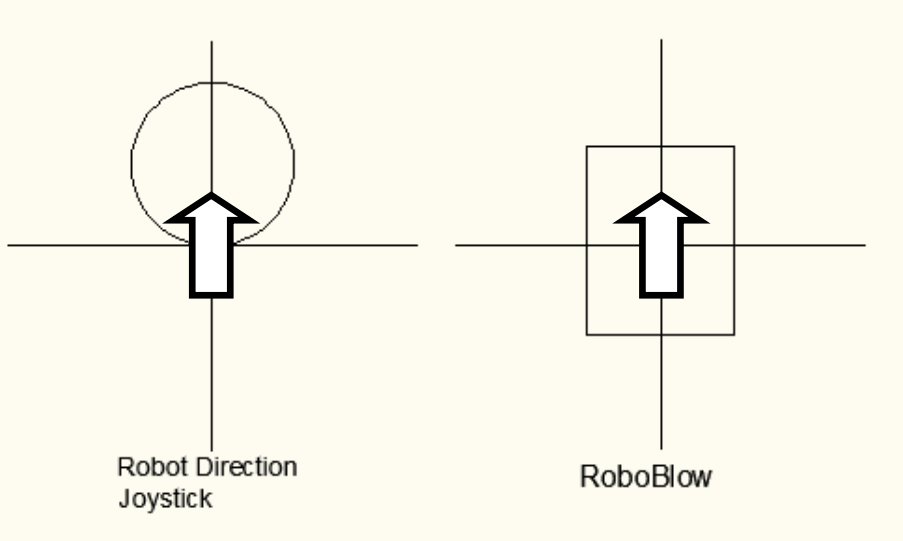


Figure 5: Robot movement when joystick is pushed forward

[R95-I] When joystick is pushed forward-right, the moving direction of the robot is along the 45 degree of x-axis.

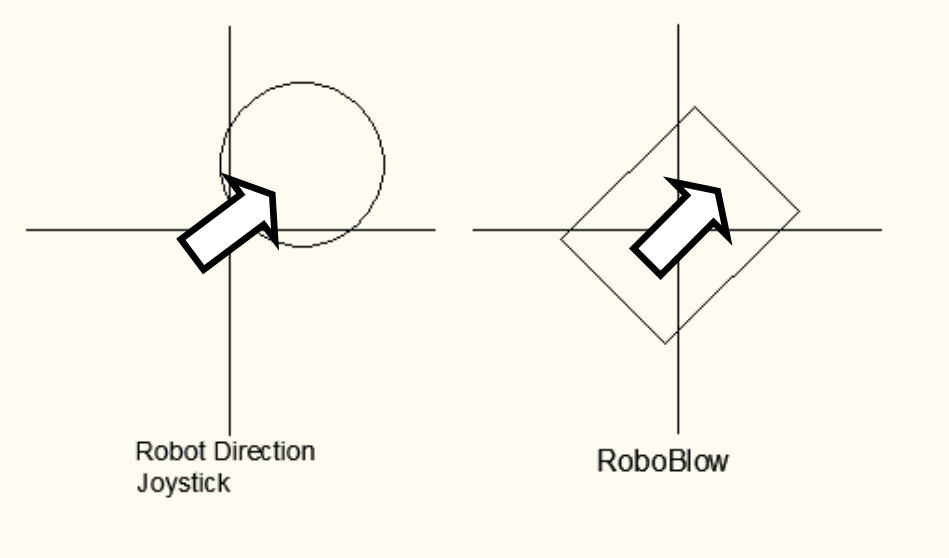


Figure 6: Robot movement when joystick is pushed forward-right

[R96-I] When joystick is pushed backward, the moving direction of the robot is along the negative direction of y-axis.

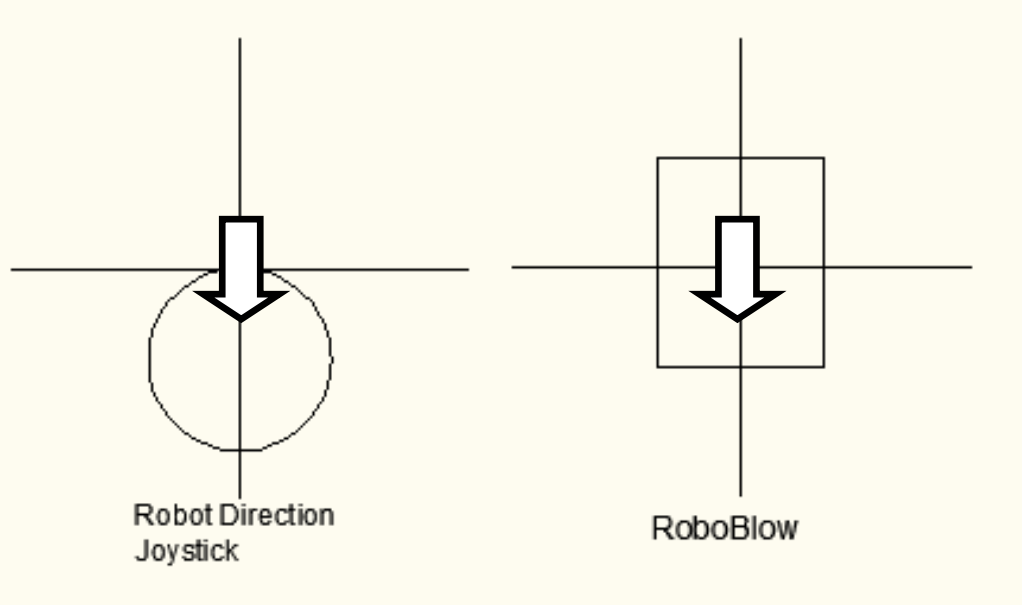


Figure 7: Robot movement when joystick is pushed backward

[R97-I] When joystick is pushed to forward-left, the moving direction of the robot is along the 135 degree of x-axis.

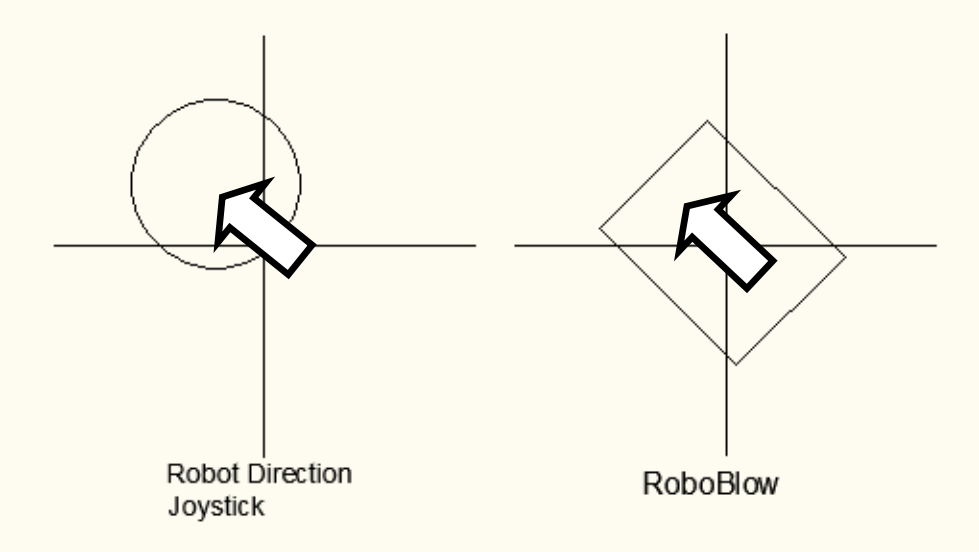


Figure 8: Robot movement when joystick is pushed forward-left

7.4 Power Control Requirement

[R98-I] Button 0 is the power switch of the remote controller.

[R99-I] LED 0 is the status indicator LED for button 0.

[R100-I] If button 0 is pressed while the remote controller is switched off, the remote controller will be switched on and LED 0 is lighted.

[R101-I] If button 0 is pressed while the remote controller is switched off, the remote controller will be switched off and LED 0 is off.

7.5 Speed Control Requirement

[R102-II] Button 1, button2 and button 3 are the speed control buttons of the robot, and a seven segment display is associated with these buttons.

[R103-II] If 0 is displayed on the seven segment display, it means the average speed of the robot is zero.

[R104-II] If 1 is displayed on the seven segment display, it means the average speed of the robot is 0.1m/s.

[R105-II] If 2 is displayed on the seven segment display, it means the average speed of the robot is 0.15m/s.

[R106-II] If 3 is displayed on the seven segment display, it means the average speed of the robot is 0.20m/s.

[R107-II] If button 1 is pressed, the speed will be increased by one level.

[R108-II] If the speed has already been in the highest level, pressing button 1 should not change the speed level.

[R109-II] If button 2 is pressed, the speed will be decreased by one level.

[R110-II] If the speed is zero already, pressing button 2 will still keep the zero speed.

[R111-II] If button 3 is pressed, the robot will stop immediately no matter how fast the robot is moving before.

7.6 Salt Spraying Control Requirement

[R112-I] Button 4 is the switch of salt spraying.

[R113-I] LED 4 is the status indicator of the salt spraying.

[R114-I] if button 4 is pressed while salt spraying is off and the LED 1 is off, the salt spraying function will be switched on and LED 1 will emit light.

[R115-I] if button 4 is pressed while the salt spraying function and LED 1 are both on, the salt spraying function will be turned off and LED 1 will be turned off also.

7.7 Camera Control Requirement

[R116-I] There are two states for camera control: “on state” and “off state”

[R117-I] Button 5 is the switch of the camera control

[R118-I] LED 5 is the status indicator of the camera control

7.7.1 Camera “on state” Requirement

[R119-I] LED 5 emits light.

[R120-I] LCD screen displays the real-time image captured from the cameras on the robot.

[R121-I] By pressing button 6 and 7, cameras can be rotated to capture images from different angles.

7.7.2 Camera “off state” Requirement

[R122-I] LED 5 is off.

[R123-I] LCD screen does not display images captured from cameras on the robot.

[R124-I] Camera does not rotate even if button 6 or 7 is pressed.

7.8 Snow Blower Control Requirement

[R125-I] Button 6 is the switch of snow blower.

[R126-I] LED 6 is the status indicator of the snow blower.

[R127-I] **S**now blower motor can be switched on and off by pressing button 6.

[R128-I] When snow blower is on, the LED 6 emits lights.

[R129-I] When snow blower is off, the LED 6 is off.

7.9 Snow-Out Control Requirement

[R130-II] Button 7 and 8 can control the snow out direction.

[R131-II] When either button is pressed, the LCD screen will be automatically switched to the view of the camera that monitors the snow out direction.

[R132-II] Pressing button 7 rotates snow out direction CW

[R133-II] Pressing button 8 rotates snow out direction CCW

7.10 Wireless Communication Requirements

[R134-I] Wireless communication protocol is IEEE 802.11.

[R135-I] The communication is bidirectional. In other words, both remote controller and robot can send/receive the data to/from each other.

[R136-I] The effective control distance is 100-200 meters depending on the environment condition.

7.11 Control System in the Robot

[R137-I] Control system in the robot can only receive the signals emitted from the remote controller.

[R138-I] Control system in the robot can process the different commands issued by the remote controller and send the right control signals to the robot.

[R139-I] Control system in the robot can receive the data from cameras and send the image data to the remote controller.

[R140-II] The main part of the control system (MCU with development board) in the robot will be powered by 5 volts voltage source inside the robot.

7.12 Emergency Mode & Safety Requirement

[R141-I] The emergency LED on by satisfying either condition in the following:

1. The robot detects some safety issues and automatically applies the corresponding strategies.
2. The robot cannot send/receive signals to/from the remote controller.

[R142-I] There should be an emergency stop button on the controller

[R143-I] There should be an emergency stop button on the robot

8. User Documentation Requirement

[R144-III] A user manual with all the operating instructions, safety warnings, general specifications, and proper installation instructions will be provided to the end users in order to correctly operate RoboBlow

[R145-III] The user manual should be written in English, French, German, Traditional Chinese, Simplified Chinese, Korean, Japenese

[R146-I] A website providing the descriptions of RoboBlow and brief technical specification might be developed for potential customers and vendors.

[R147-III] A shipping instruction will be provided to carriers that will transport the Roboblow in order to prevent any damage during shipping

9. Test Plan

The robot will be tested in separate modules individually by the software team and the hardware team during development stage, where the software team is responsible for the control system, and the hardware team is responsible for the electric circuits and the robot mechanism. During development stage, the teams should test the requirements related to their responsible field with the best of their ability whenever a specific task or module is completed and the testing of the requirement is possible.

After all modules are tested, the overall system will be integrated and tested in walkway in normal condition, and then the robot will be bring to real snow environment for final

testing and adjustment.

The robot is designed to meet all functionality requirements listed in this document, and thus, all requirements listed in this document should be tested. However, as requirements may vary during development stage and the test procedure can vary by different design and modules, detailed test procedure is to be determined by each team and some requirement can be omitted according to the final product. Still below requirements must be included and tested:

- The robot moving speed and direction can be controlled by the remote controller
- Snow thrower can be turned on/off by the remote controller
- Camera direction can be controlled by the remote controller
- The robot can climb up snow road with 10 degree slope.
- Remote Controller can display video captured by the robot camera in real-time
- Robot is water-proof
- Robot can operate properly in snow condition or on snow ground with rain
- The effective control distance is at least 100 meters
- Emergency stop button can terminate the robot operation immediately
- All safety requirements listed in this document

After all, the robot needs to be tested by naïve user. Failure testing is also required in order to investigate the consequence of any improper usage of the device. If any serious consequence is observed, modification on the robot system to prevent or mitigate the consequence is required.

10. Conclusion

The functional specification of our robot is clearly described in detail in this document. All or most of the requirements listed in this document with I and II priority are expected to be completed in the proof-of-concept model. Also the model is expected to be fully tested and completed by the end of March.

11. References

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