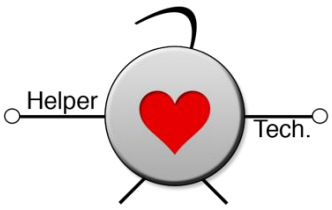


HelperTech.
School of Engineering Science, Burnaby, BC, V5A 1S6

April 20, 2011

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

Re: ENSC 305/440 Post-Mortem for Remote Controlled Snow Blower Robot

Dear Dr. Rawicz:

The enclosed document discusses the post-mortem in detail of our developed 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 document provides the post-mortem of our project. In this post mortem, we examine our development status according to our project proposal and functional specifications. It provides further guidelines for us to improve our robot towards commercialization. Finally, we share our experience from both technical and interpersonal point of views upon the completion of our project.

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,

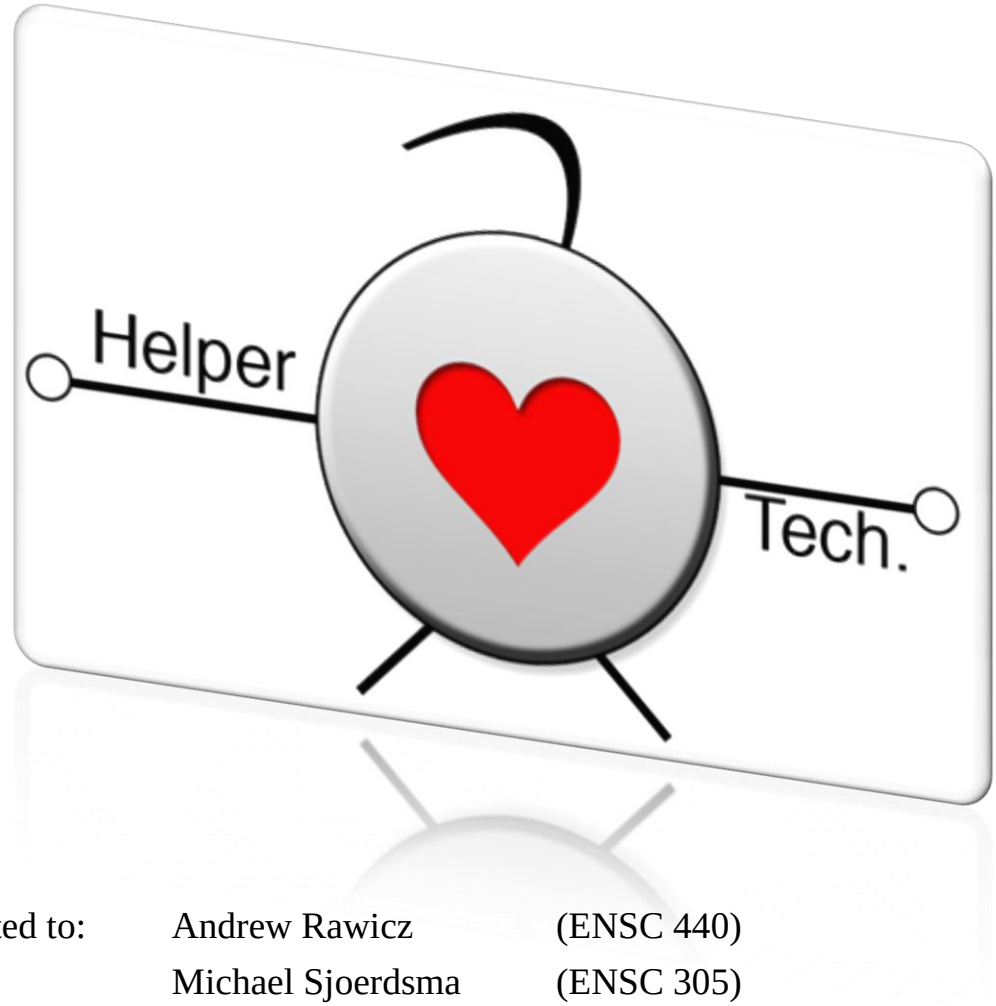
Leo Cheng

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

Enclosure: *Post Mortem for Remote Control Snow Blower Robot*

Post Mortem
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)

Table of Contents

1. Introduction

RoboBlow, the remote controlled snow thrower robot, has been brought to real world from drawings on scratch papers in twelve weeks. These twelve weeks have definitely been an exciting experience and life-long memories for each of the members in HelperTech. Each of us have developed technical skills in depth, improved our problem solving skills, and the most importantly, practiced teamwork mindsets which are essential in the field of engineering.

In our post-mortem, we will first discuss the current developing status of our prototype and how it differs from our original design. Secondly, the future plans will be provided for any potential improvements for our prototype. We will also mention financial and time constraints we face during development. Lastly, each of us will share our own experience from both inter-personal and technical perspectives.

2. Current Development Status

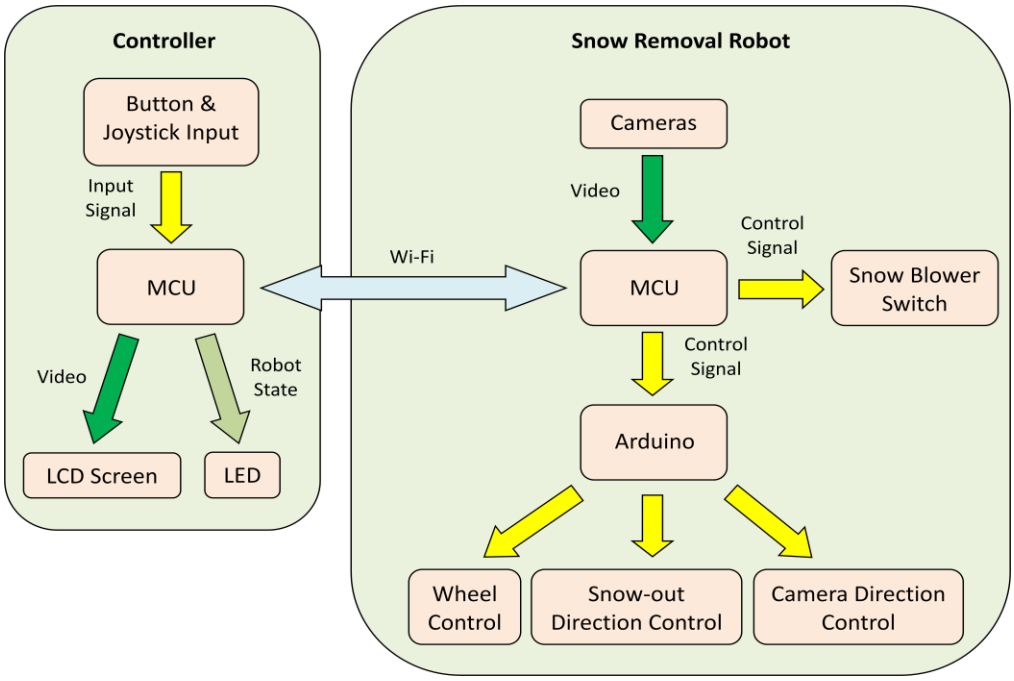


Figure2.1: System overview – current status

RoboBlow has been prototyped closely according to our original proposal. The basic functions have been mostly fulfilled. Figure 2.1 portrays the current status of RoboBlow in block diagram. Although we have already developed a working prototype, there are still a lot of deficiencies existed and potential improvements for us to carry out and fix. These issues will be mentioned in the next two sections.

From the software aspect, the wireless communication between the microcontroller on board and the one in the remote controller has been successfully implemented through complex embedded software development. At the remote controller side, we had to write our own drivers and firmware to interface hardware such as push buttons and joystick. For the microcontroller on board, we had to do extensive tastings. Within the two embedded system, the user commands can be transferred to the robot, and real time image can be sent to the remote controller as well.

From the hardware perspective, the snow thrower on board is able to perform the task of cleaning the snow and can be switched on/off remotely upon the completion of our power switch circuit. The snow blowing direction can also be adjusted with a 3 Amp stepper motor and our own stepper driver circuit. The robot can also be positioned to desired job sites to perform its task given enough power from the two DC geared motors. We have spent about two weeks investing the best methods to build the H-bridge for our DC motors; however, due to safety reasons and time constraints, we decided to purchase an existing motor driver which turned out to work very

well with our high power DC motors. Moreover, with the assistance from the monitoring cameras on board, the users can operate the robot without actually watching the robot itself.

3. Prototype Deviation

As pointed out from the last section, there are still a few deficiencies that we need to improve and design specifications that we haven't completed. Figure 3.1 displays the original proposed design specifications. Compare figure 2.1 to the block diagram below, we can notice there are modules that are missing. This section will talk about the deficiencies and the deviations of RoboBlow from both software and hardware perspectives.

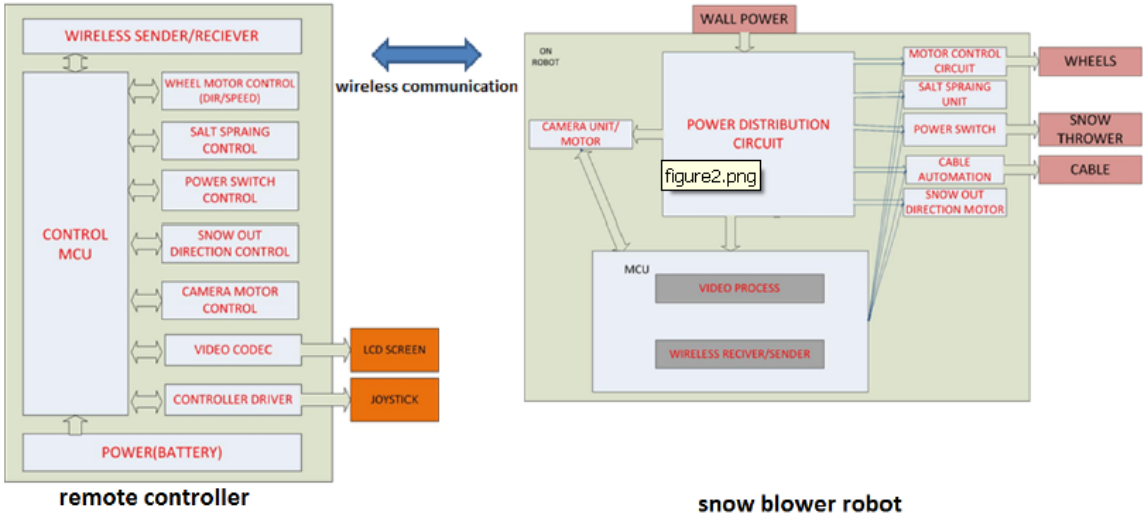


Figure 3.1: System overview – originally planned

3.1 Software

Video streaming

Originally, we planned to use three webcams. However, we only used two for our prototype. Since the webcams working principle are the same, it is very easy to add another one to our system.

Sensors and feedback from robot

We planned to have some sensors so that our robot will operate safely. Due to the budget problem, we have not implemented that. We will implement that during the summer. However, we do reserve the extension place for the sensors feature. On software side, we reserve an I/O extension port to receive the sensor data. The driver has been well developed by us. On the hardware side, there is plenty of space on the robot to add sensors.

3.2 Hardware

Traction

Traction is definitely a deficiency on RoboBlow. The wheel surfaces are made of rubber, they are flat and smooth. There are other options of wheels on the market that have grids and threads on their surfaces. However, they are really expensive. Therefore, we chose this pair of wheels and were planning to modify the surfaces such as adding snow chain, or gluing threads by ourselves. However, we decided to carry out this modification for our future plan because we ran out of time as the due date of our project approached.

Power cable management

We planned to implement a mechanism that can manage the extension power cord providing electrical power to our robot. Originally we were going to install a roll to store the power cord and to use a motor and sensors to control whether it should extend or pull. However, we discovered that there are actually plenty of retractable power cords available on the market. Most of them are expensive and from other countries which requires shipping. Therefore, we decided to leave this module until we are closed to the full completion of our prototype.

Salt Spraying Unit

Salt Spraying is proposed in order to prevent the snow-free road to freeze and become icy again. Since this is not a critical module that would delay the completion of a basic working snow-blowing robot, we decided to leave this component till the end of our project. However, the planned schedule cannot be followed most the time, and as the matter of fact, we met our time constraint and couldn't implement this unit before our presentation. This is definitely a promising potential feature to add on our robot in the future.

4. Future Plans

We believe that our product will be more competitive on the market after adding multiple modifications. Peter and Yuyuan will implement these modifications in the summer. The potential features are mentioned below:

Video streaming

Video streaming are not very smooth. We need to make it smoother. We will first take a look at the webcam specifications and try to explore the Linux video API more. Since from the camera specification, we found that the camera can do the image compression which would be the key to solve video streaming problem. Compression processing from hardware is much faster than the compression processing from software. It can also have higher data transfer speed because of the smaller image size after compression.

Robot command delay

When doing the testing, we found that sometimes command sent from joystick and buttons can reach the robot quickly while sometimes not. The real-time property is very important for controlling the robot. Thus we need to minimize this delay. The problem needs to be further investigated. One of the possible reasons could be because video streaming takes up a lot of WI-FI network traffic.

Sensors and feedback from the robot

A good controller can not only control the motion of the robot but also monitor the state of the robot. The latter function is done by sensors and feedback from the robot. We can implement these functions to make our robot more reliable and robust.

Artificial intelligence

Adding AI to RoboBlow is definitely a plus for commercialization. Most of the potential buyers of our robot might not have time to control RoboBlow to clear the snow on their walkways and driveways. Therefore, if RoboBlow can automatically carry out the task of cleaning the snow without user commands, we can draw attentions to more buyers by providing further convenience.

Fixing the deficiencies

We have to be able to fix the deviations discussed in section three in order to complete our prototype. The traction issue and feedback systems are a must in order for Roboblow to operate properly and safely. Improving video streaming is also necessary in order for the user to better understand the operating conditions. Adding the salt spraying unit and cable management are a plus too.

5. Financial and Time Constraints

Just like any other engineering projects, financial and time constraints are the two main issues we face in developing our robot. We have to improve our budget and time management skills in order to be successful on our careers as engineers and even entrepreneurs. The table below provides a comparison of the proposed cost and the actual cost of our project.

Table 5.1 Budget Constraints

Materials	Proposed Cost	Actual Cost
Arm Development Board X2	$200	$215
Webcam Camera X2	$200	$30
NPC DC Geared Motor Set X2	$300	$575
Yardworks 9A Snow Thrower	$170	$172
Arduino Microcontroller X2	$0	$70
Aluminum Welding	$0	$700
White Acrylic Board X3	$100	$70
ATX 600W Power Supply	$120	$50
Extension Chord + Multi-Power Plugs	$0	$90
0.33A Bipolar Stepper Motor	$0	$27
4A Bipolar Stepper Motor	$0	$37
Glue Gun, PCB Board, Screws and Other Tools	$0	$30
H-Bridge DC Motor Driver	$0	$160
WIFI Adaptor	$0	$30
Joystick + Control Buttons	$5	$5
Electronics	$120	$246
Total:	**$1315**	**$2507**

As we can see, although most of the materials are within our budget, we didn't consider for many items at the proposal such as aluminum welding, which costs 700 dollars. We encountered many problems during the project, and we came out with solutions that required extra components which are not planned in the proposal, such as the H-Bridge DC Motor Driver.

The software team controls their budget really well. Since we don't have any previous experience in developing such a complicating project, this project is very hardware-consuming for us and the hardware team spent most of the money. However, we believe we would be better in estimating our cost in the future from the lessons in this project.

The two figures below compare the proposed and actual timeline of our project development.

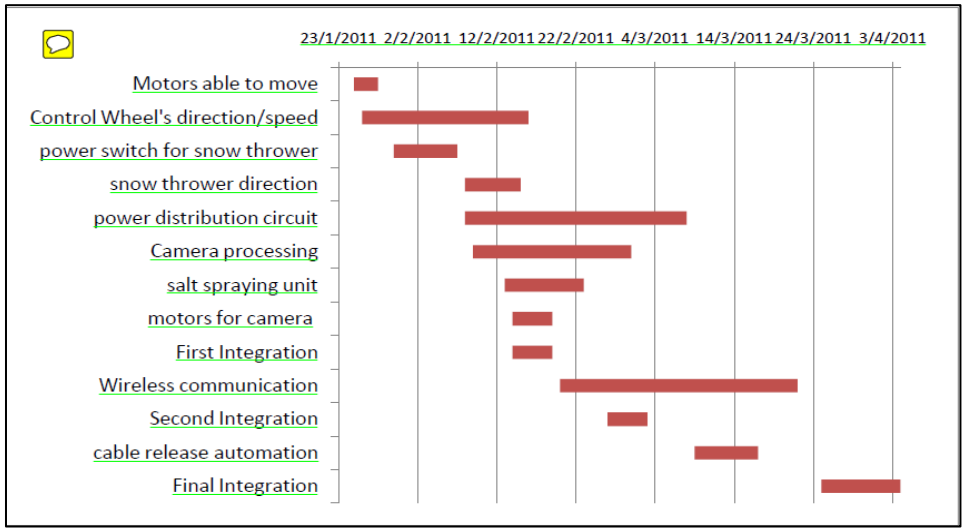


Figure 5.1: Proposed timeline

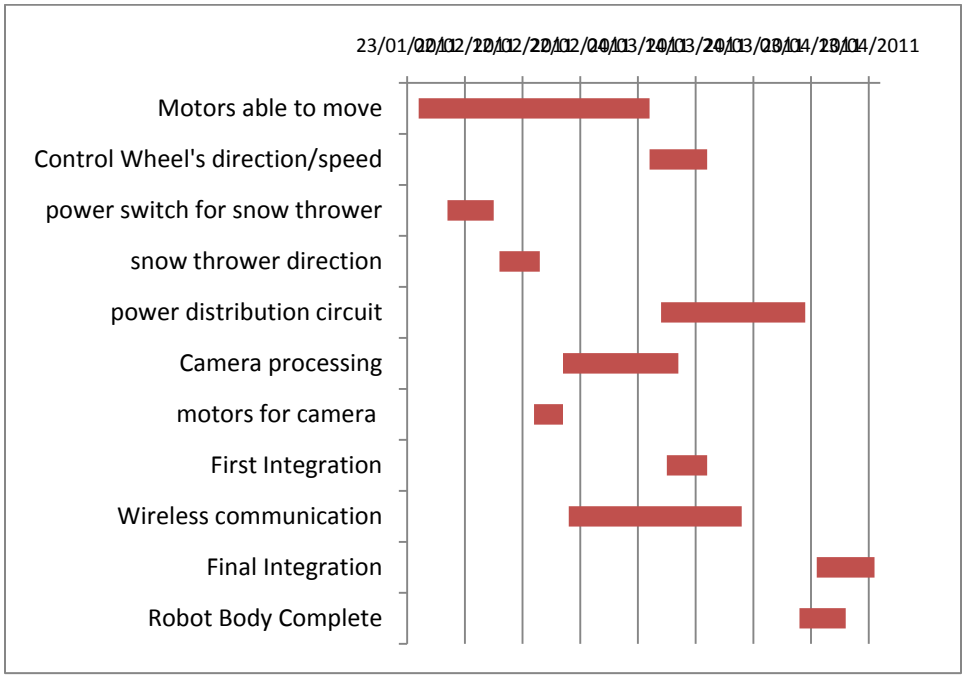


Figure 5.2: Actual timeline

As we can see from the comparison, driving the two DC motors and power distribution are two of the main delays in our project since we have never had experience on these two modules. However, we are able to meet our timeline by working diligently as our project completion date approaches. We are able to accomplish the basic working prototype on time because we have done our testing on each module extensively and carefully. However, we should leave sometime for errors and non-expecting events in the future in order to prevent potential huge delays. We should also do integrations often in order to verify everything works together at the early stage.

6. Inter-Personal and Technical Experience

Leo Cheng, CEO

First of all, I have to appreciate all the members' time and effort spent on this project.

It is really thankful to work with people who have the ability and enthusiasm to work and contribute to the project, especially YuYuan Liu, our VP operations, who I have spent majority of time working with him on the software development.

YuYuan has spent most of his time learning for new concepts such as Linux development, data compression, WiFi communication, and etc. He also researched on the devices and components which can be possibly used in our robot and has programmed the drivers and finally succeeded to setup the environment, communicate with the devices, perform video streaming with our cameras, and communicate with the WiFi module for data transfer.

In the software development, YuYuan managed to setup the programming environment and communicate and use the devices while I researched on the WiFi connection and designed the majority portion of software in the system level such as the overall system, the required methods, and the data structure. After all these are done, we programmed for the controller, the robot, and the Arduino together. Without YuYuan's help, the software development can hardly be done and completed on schedule.

Peter Hsiao and Joseph Shen have also done amazing job in the hardware development. They have built the whole robot from scratch and have managed to purchase all the required components such as the snow thrower, the H-bridge circuits, and the motors. It is amazing to see how the wires and circuits are made and connected with all the actuators and the old computer power supply. It is also a great pleasure to see how they brought my Solidworks design of the robot body to the aluminum welding and carried back the physical robot. The Arduino program they have made for testing their circuits and motors is really helpful too. It served as the example code for our Arduino software development and saved us a lot of time learning and programming for the Arduino.

Overall I have learnt a lot in this project in this project. In the technical side, I learnt about programming for Arduino, ARM, Embedded Linux, drivers, WiFi communication, video processing from cameras, the importance of choosing the suitable device, and etc. Then in the nontechnical side, I learnt about group dynamics, the importance of writing notes for ideas and design, how we can buy electronic components and device in the market and through the Internet, and the difficulty of making a real project/robot. The amount of time, money, and effort required to build a robot is actually out of my expectation. Doing this project is one of the greatest experiences I have ever had.

Finally once again, thanks you guys. Everyone has done great in this semester.

YuYuan Liu, VP Operations

It is my great pleasure to work with these three guys, Peter, Joseph and Leo. This project can not be done without any of them. Everybody is very responsible to their area and did a very good communication to other team members.

The hardware team and software team were working in parallel and hold a regular meeting once a week to keep tracking with each other. This way boosted up our working efficiency a lot. Peter and Joseph are responsible for hardware side. They worked really hard. They made the whole robot from scratch, from choosing the right motor, constructing the aluminum robot body to dealing with the high power issues. On the software side, Leo and I worked as hard as Peter and Joseph. We learned ARM board and Ardunio board from scratch. We tried to get the video and WIFI working for a very long time. Since our development was test oriented, we were not such painful when doing the integration.

For me, I learned a lot of embedded system knowledge from this project which is critical for my future career. I also developed my hands-on skills on ARM development board. In details, I learned how to do the cross-compilation, understood deeper about Linux kernel, understood some ARM CPU architecture and knew how to program with the webcam and LCD screen. Since I plan to be an embedded system developer in the future, this project provided me a valuable chance to learn embedded system.

From non-technical perspective, I also learned something that is important for the project development. Making notes for the project is also a good idea. By taking notes, we can keep tracking our project progress and every detail in our project. Thus, it is easier for us to decide the further action. I also wrote any valuable knowledge I newly learned in the notes. In this way, next time when I need them, I can find them from my notes quickly.

The other important point is timeline. We had our timelines, however, due to various reasons; we did not obey that timelines strictly, which results in the rush at the end. In order to develop a high quality product, meeting the timeline is critical. In the future, I will notice more about the timeline.

I always believe that our product has high business potentials. We just have to make it better and better. Since Peter and I will do the coop next semester, it is a good time to modify our product.

In the end, I want to thanks to my three brothers. Thanks you for helping me to finish this project. It is really a wonderful experience.

Peter Hsiao, CFO

It has been a great pleasure and honor to work with my partners, Yuyuan, Leo, and Joseph this semester to build our dreams into a real prototype. I have always wanted to work on a project that not only benefits our society, prevents injuries but also being environmentally friendly at the same time. RoboBlow is something that has a great potential of achieving both. It is able to reduce the risks incurred during snow plowing, and it also consumes electricity only instead of gasoline like most of the manual snowblowers on the market. With four of us sharing the same goal, RoboBlow is born.

From a technical point of view, there are several important knowledge that I have developed while working on our project. First of all, I have strengthened my fundamentals in electronics circuit and component operating characteristics. I have also learned how to use new circuit components such as relays, power transistors and ICs that I have never seen before. Moreover, I have developed techniques in designing electronic circuits such as H-bridge, power switch and power distribution using ATX computer power supply through solid hands on experiences. I have also strengthened my skills in implementing our designs onto PCBs and soldering. One other technique I have acquired is embedded system programming. Although most of my task is to develop hardware for our project, I still got chances to program the Arduino microcontroller in order to test the components we completed.

On the other hand, I would like to say that soft skills are the most valuable techniques that I have gained through the development of our project. The first thing comes into my mind is the problem solving skill that I have constantly improved while working on our project. Building a robot is something that we have never had experience before not to mention building a robot of the size like RoboBlow. However, with a strong problem solving mindset, I was able to overcome lots of problems we encountered and make things work with my partners. Becoming a better team player is the second most valuable thing that I have gained while working on our project. I have improved my communication skills, learned how to respect my partners, appreciated everyone's work, and knowing that without any of my partners, I wouldn't be able accomplished anything to achieve our goal.

Upon the completion of our capstone project, I have begun to recognize that I am ready to become an engineer. This couldn't have happen without all the help, motivation and courage supported by my other three teammates. Thank you guys!! I would definitely love to work with you again on any future projects.

Joseph Shen, VP Marketing

It's an amazing experience working with HelperTech for this semester. In the past 13 weeks, we demonstrated the definition of group dynamic. The leaders of the teams, Yuyuan and Peter are great leaders which always keep us going in our darkest time. There is absolutely no way the project could be done without any of the teammate. Beside group dynamic, the greatest skill I learned in ENSC440 is research skill. I learned how to create possibility, build and find the correct component we need out of pure darkness and blindness. I managed to learn everything I could about DC motors and stepper motors, learned to use the tools from the machine shop precisely, demonstrated more of the knowledge of power system I learned from books into the real world. One of the greatest difficulties was when dealing with the 25A NPC DC geared motor, everything melted instantly. Although we added a considerably large heat sink and power wires, the circuit still didn't function properly. We also had to be extremely careful since we might get killed under that amount of current. We managed to get the work done under pure frustration. By non-stopping research, we finally got the part we need in order to make the circuit work. I also learned how to use Arduino microcontroller to test hardware circuit and how to use the implemented PWM pins on the board and how to give correct sequence signals to DC motors and stepper motors.

One of the skills that I am strongly interested during developing the project is the PCB soldering technique. I have never used the soldering station before this project. After learning how to do it from the internet, I tried to solder my first circuit- the power switch control via my immature skill. However, my skill seems to develop very quickly in this area. I completed other harder PCB with almost no error. This hardest PCB I built this term is the one that control the 4A bipolar stepper motor, where I need to use special power wires for the power and ground line, add heat sinks for all of the tip122 transistors, add fuse to the power line, and connect all the diodes to the ground. It gave me a great pleasure of achievement and I am happy that I can distribute this kind of unique work to my group.

Thanks Yuyuan – He is an excellent work distributor and organizer. He keeps us going while some teammates lost motivation.

Thanks Peter – He's working very hard. Driving the robot, move the robot around, drive through Great Vancouver to get all the components we need. His contribution is absolutely critical for HelperTech.

Thanks Leo – Our CEO, we don't have a team without you. The ideas and software program is excellent. Thanks for always taking final care for our every documentation.