April 18th, 2009

Mr. Patrick Leung
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby BC V5A 1S6

Re: ENSC440 Post-Mortem for a License Plate Recognition Auto-gate System

Dear Mr. Leung:

The attached document, *Post-Mortem for a License Plate Recognition (LPR) Auto-gate System*, outlines the final system behaviour of our project for ENSC 440 (Capstone Engineering Science Project). Our goal is to design and implement an auto-gate system for residential parking lots, using the LPR technology, which captures a license plate image of a vehicle and verifies its registration status by post digital image processing for the parking lot access control.

The purpose of the document is to describe the current status of our demonstrational system, deviations from the original design plans, and modifications for the future development. The actual time and budget will be discussed, and the individual member's experience will be presented for what we have gained after completing the project.

SECO Innovations Corporation consists of three talented 5th year Engineering students: Danny Choi, Wook Sun Shim, and Jaehoon Shin. Gathering various knowledge and strength from our disciplines in Electronics and Systems options and from industrial co-op work experiences, we are here to challenge on the project that can replace the current solution by providing better security and convenience to the public. If you have any questions regarding our proposal, please feel free to contact me by phone at 604-996-6012 or by e-mail at dchoi@sfu.ca.

Sincerely,

Danny Choi
President and CEO
SECO Innovations Corporation

Enclosure: *Post-mortem: License Plate Recognition (LPR) Auto-gate System*

Post Mortem:

License Plate Recognition (LPR) Auto-gate System

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Executive Summary

Today, vehicle theft is the common crime affecting parking lots. An underground parking lot at multi-residential buildings could be a great draw for thieves as they look for cars in an unattended area. The auto gate system with key entry device is installed to prevent a potential thief from entering the parking lot, but as the system provides no physical barrier while the gate is open, the trespassing can occur by a following-after vehicle or a walk-in, and cause a potential crime for auto theft.

Using the license plate recognition (LPR) system, which is a mass surveillance method for various usages today, SECO Innovations has developed a proof-of-concept for LPR auto-gate system that provides more secured and convenience solutions to the public. Using the fact that the system checks for verification on every vehicle passing the gate, it sounds an alarm for any entering of unregistered vehicle or walk-in, thus provide virtual barrier to the potential crime event even if the gate is open. The system will also eliminate the use of key entry device, provide convenience to residents for access to the parking lot by simply “come and enter”.

The following sections of this document will include the current state of the proof-of-concept system, and any deviations from the originally planned design. The future development of the system will be discussed, as well as time and budget for the project. At the end, the individual member’s experience and what we have gained through the project work term will be presented.

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1. Introduction

For the past three months since mid-January, SECO Innovations has been developing a proof-of-concept system for the license plate recognition (LPR) auto gate system. The system is expected to provide more secure and more convenient solution to multi-residential building with the underground parking area by automatically recognising the license plate of an approaching vehicle, and verifying its registration status. It provides better security because it provides a virtual barrier to the trespassers, and it provides better convenience because it removes the need of key entry devices, such as remote transmitters which could be lost or stolen. This document will describe the current state of the prototype system, the deviation from the original plan, the analysis on the budget and time planning, and the inter-personal and technical experiences gained during the work.

2. Current State of the System

In this section of the document, the current state of the overall system, the input and output hardware unit, and the LPR processing unit of the proof-of-concept system will be explained in detail.

2.1. Overall System

The system block diagram of LPR Auto-gate System is shown in Figure 1**: System Block Diagram**. The system is composed of two main sub-systems: Input and output hardware system and LPR processing system. The input and output hardware system includes the metal detector and microcontroller module, and the LPR processing system includes the LPR system. As a vehicle is approaching the metal detector, a digital signal is sent to the microcontroller which redirects the signal to the LPR processing unit via communication module. Upon receiving the signal from the microcontroller, the camera module in LPR system takes a snapshot of the approached vehicle and passes the image to the license plate locator. After the license plate locator localises the license plate from the image, the letter recognition module generates the corresponding letter string from the recognised letters. The verification module checks whether the letter string is in the database and passes a ‘pass’ or ‘fail’ signal back to the microcontroller module. Finally, microcontroller module outputs the corresponding result to the user, based on the verification status.

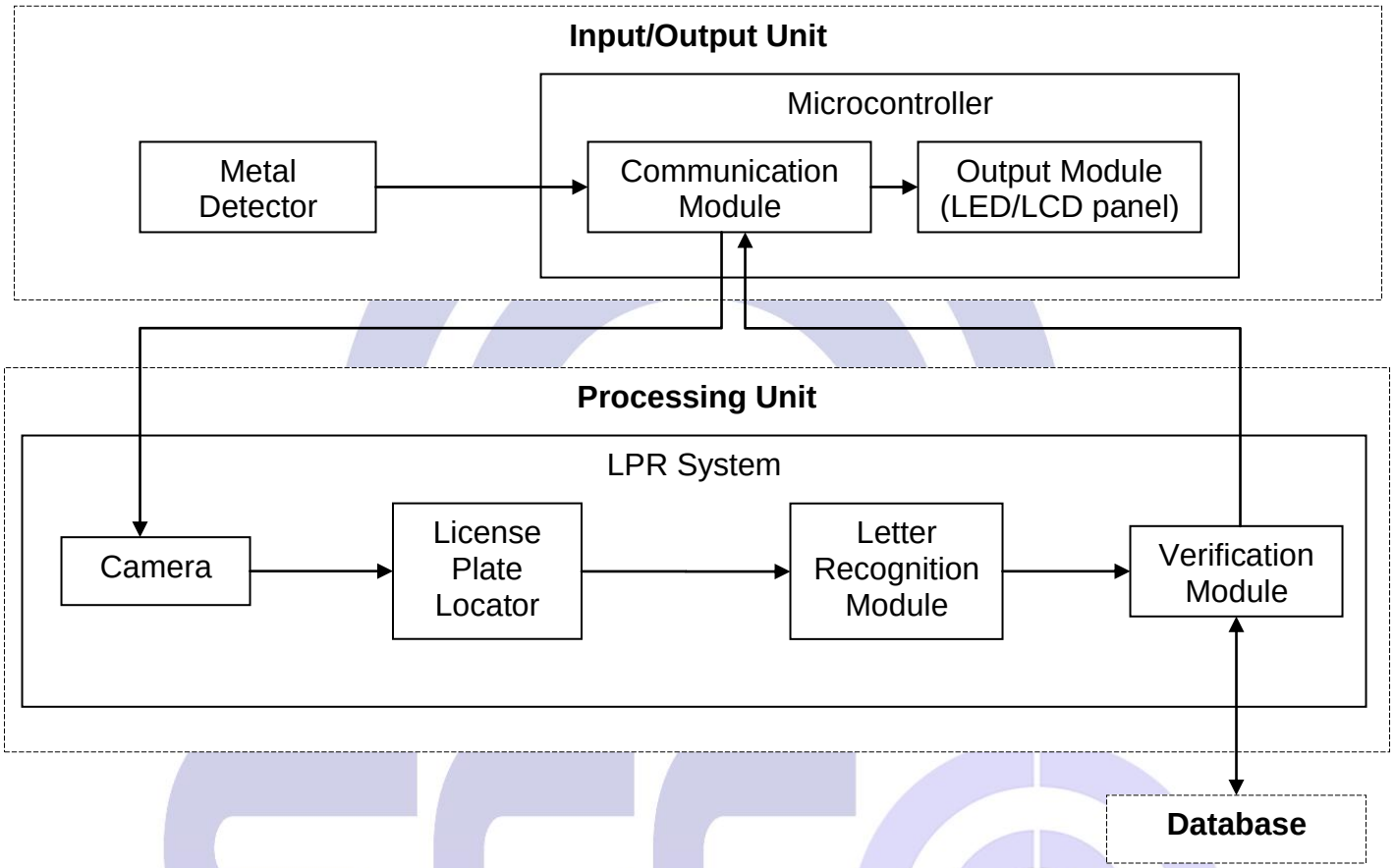

Figure 1: System Block Diagram

The output generated by the output module in the microcontroller unit defers by case. When an approaching vehicle is a verified resident of the building, a green LED will be lit for 30 seconds, indicating that the gate is opening and staying opened. If another vehicle approaches the gate and is verified while the green LED is on, the LED will remain turned on for another 30 seconds. If a vehicle is verified as an unregistered vehicle while the gate is open, an alarm will sound to indicate that the vehicle is trying to trespass the gate. If the vehicle is recognised to be unregistered while the gate is closed, or in other words, the green LED is off, a red LED will be turned on to notify the driver that the vehicle is not registered and is not authorised to enter the parking area. The flowchart of the overall system is presented in Figure 2**: Flow Chart of System** on the following page.

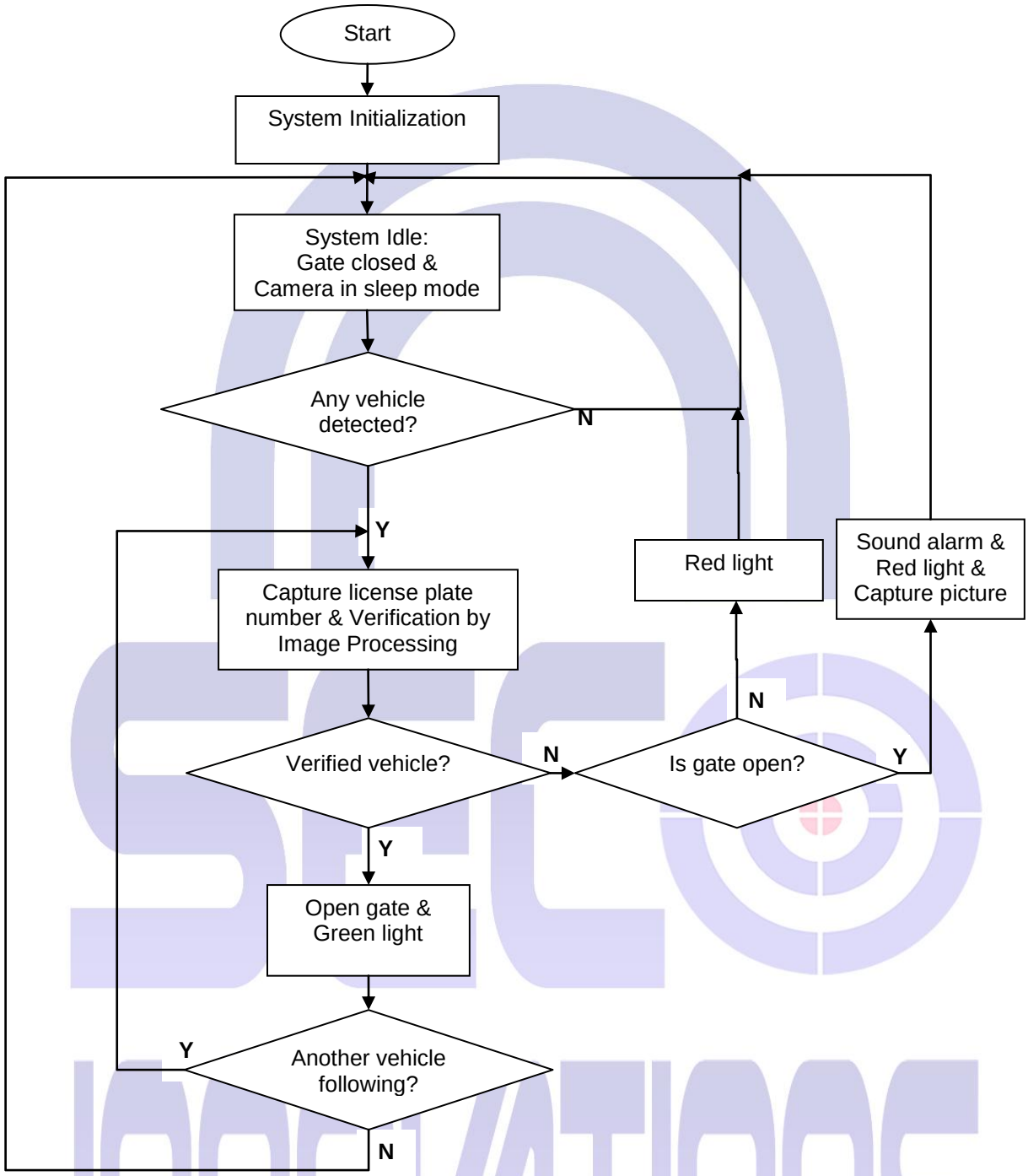

Figure 2: Flow Chart of System

2.2. Hardware

Hardware part in the LPR system is largely divided into two sub-systems, the metal detector and the microcontroller module. The each module is connected and communicated each other by the standard RS232 I/O serial cable. Also there is camera module on the PC site. Seco Innovations is currently employing the built-in webcam on the PC.

Seco Innovations built its own metal detector circuit instead of using a commercially available product from market. Doing so, the company could reduce its expenditure from the estimated cost. However, in turn, there is a limitation on its detecting range. It can detect about 20cm from the ground where the module is installed at. It is reasonable detecting range and works without raising any limitation as far as the proto-type is concerned. However, since the proto-type product is scaled down much less than the actual environment, it needs to be improved for the commercialized product. This will be explained more in the later section.

The microcontroller module consists of ATmega168 as its main processor. The chip is run at 14.74 MHz with an external clock device. It performs in the system as a middle person between the PC and the metal detector. It processes 3V output signal from the metal detector and send a flag to the PC to take picture. In the opposite direction, when the PC sends verification information to it, it reads the string, open one of the output ports which are LEDs and alarm and display the verification information on the LCD module. The LCD module display 2x24 characters, so the verification status is printed out in the first line and the license plate number in the second line. Also, the microcontroller uses interrupt function to hold the green LED for 30 sec. This function is used instead of the implementation of a motor that can actually open the gate. The reason for the absent of the motor implementation will be explained in the next section.

2.3. LPR System

The LPR system is the brain of the overall system. Hence, it is the most critical unit of the proof-of-concept system. Currently, the processing unit can detect the license plate from the image of a vehicle with the acceptable accuracy, and recognise the license plate number with the minimum error. The unit consists of two main subsections that are localization and recognition. The morphological methods, dilation and erosion, are used to remove the characters on the license plate of the input image and then subtracted from the input image to distinguish the plate region. Then the horizontal and vertical projections are used to localize the plate by detecting the corresponding gaps from the projections contours. For the recognition, the localized plate is segmented by each character using also, the projections, and then the characters are matched with letter and digit templates. Finally, the characters are identified by calculating the minimum absolute difference.

The communication between the module and the microcontroller is also stable. The processing time takes approximately 2 seconds if the intermediate results are not displayed on the screen. The localization would go longer process time than the recognition, due to its relatively more complexity in process.

3. Deviation of the System

The current system differs from the original plan in some aspect. The deviations of overall system, the hardware unit and the LPR system are discussed in this section of the document.

3.1. Overall System

The overall system does not differ a lot from the proposed schedule. One of the deviations is the alarm. Currently, the system turns on the alarm if an unverified vehicle is detected while the green LED is on, which indicates the gate is open. However, the original plan was that the alarm shall sound if and only if the unregistered vehicle is tried to pass the open gate. This is the result of a downsizing the overall project, which has led to removal of the line-of-gate sensor that can detect an object under the gate.

3.2. Hardware

The major deviation in the hardware part was to build its own metal detector circuit and use the built-in webcam on the PC. By doing so, SECO Innovations saved it budget for about $150 and achieved the requirements as proposed successfully at the same time. Another deviation was on the microcontroller module that SECO Innovations switched from the motor implementation for gate to displaying a green LED. Instead of opening a real gate for verified vehicle, a green LED is on for 30sec meaning that gate is open. Also the LED keeps on the functions that the gate would have. For example, while the green LED is on, if there is unregistered vehicle trying to get in, an alarm will sound. On the other way, if a verified vehicle comes again while the green is on, the LED will add another 30 seconds from there.

3.3. LPR System

The main deviation in the LPR system from its original plan, as described in the functional specification and design specification, is the removal of skew correction module from the proof-of-concept system. The module has been finally decided not to be integrated with the overall system for the following reasons. First, not every image had detectable edges, which the module highly depends on, to complete its job. Second, the system assumes that the camera is in the fixed position, which is almost perfectly

parallel to the ground. Last, the system is able to recognise the letter strings of the license plate from an image that is tilted approximately at most 10 degrees.

After careful examination of the cost and benefit of the removal of the module, SECO Innovations chose not to integrate the module with the other sub systems. In the future, should we have more time and budget the module will definitely be implemented in the system to give more accurate result for recognising the license plate numbers.

4. Future Development

In this section of the document, the possible future developments and improvements are discussed. In specific, future work on the overall system, the hardware unit and LPR system unit will be presented.

4.1. Overall System

The proof-of-concept: LPR auto-gate system shall provide a virtual barrier when there are any trespassing events followed by an opened-gate for a registered vehicle. Generally, a motion detector is equipped at the entrance line of the gate for the purpose of safety reason (the gate should not close in case of walk-in or vehicle passing). The motion detector should trigger an alarm if it detects any motion, while the gate is open, whenever an access has not been verified prior to the detection. If a registered vehicle has entered the gate, the motion detector would trigger the system to check for verification again before it detects any passing motion, otherwise the alarm will sound if any unregistered ones come in. Finally, at the event of trespassing, the image can be saved for further crime investigation and enforcement.

4.2. Hardware

There are two major components that SECO Innovations needs to improve for its future product. First of all, the webcam that is used in the current system will be replaced with one of the commercially available industrial camera. As mentioned earlier, the webcam is certainly not enough for being used for actual implementation with the limits on its resolution and features. One example product which will overcome these limits would be an outdoor surveillance camera which has high resolution, night vision and weather proof feature on it. This will provide much better quality of picture of license plate and improve the accuracy of the LPR system as a result.

Another component that needs to be improved is the vehicle detecting module. As similar to the camera module, the metal detector in the current system has a few limitations such as its detecting range. To improve these limitations, there are several different technologies which can be chosen from; a road tube, a piezoelectric sensor, a magnetometer, and finally an inductive loop as used in the current system. Among

these technologies, the choice will differ depending on the different sites which each module is installed on. However, the inductive loop would be the best choice due to its cost efficiency and easier understanding logic over others for the auto-gate system application.

Also, the LED module on the microcontroller module for auto-gate is only for the proto-type of the project. It must be replaced by actual gate system.

4.3. LPR System

The major improvement that can be achieved in the LPR system is the integration of the skew correction module with the overall system to improve the recognition accuracy. As discussed in the previous section, it was excluded as the system assumes the image is almost perfectly aligned with the ground. If the skew correction module can be integrated with the system, the overall accuracy of the system is expected to rise significantly. Also, based on our research during the development phase, it can be implemented using different techniques, such as the Hough transform or the Radon transform. Although the basic idea is very similar to what we had implemented on the skew correction module, the Hough transform and the Radon transform offers more complex algorithm to detect the edges and to calculate the tile angle, and hence, they are expected to provide enhance result.

In addition, as the LPR system highly depends on the quality of the input image, the quality of the camera module, and the environmental condition, a higher resolution camera can be implemented on the current system for enhanced accuracy of the recognition. Other possible future development on the LPR system includes implementation of the database and faster database searching algorithm, development of user-friendly user interface, etc.

5. Budget and Timeline

The budget and the timeline of the project had a critical impact on the development of the proof-of-system. They will be discussed in this section in detail.

5.1. Budget

With the deviations on the hardware part mentioned earlier in this document, Seco Innovations could have reduced the cost on its proto-type product from the estimated cost as reported in the project proposal. The main reduction is from the microcontroller module since Seco Innovations ordered each electronic component separately and assembled them itself rather than acquired the development kit which cost a lot more. Another huge save on the budget is from the camera module. Instead of using a external camera as planned, the company decided to use the built-in webcam in the PC. The summary table of the budget is shown as follows.

Table 1: Budget Summary

Equipment	Estimated Cost	Actual Cost
Camera	$100	$0
Microcontroller & development kit	$300	$20
Metal detector	$50	$0
Miscellaneous (LCD, cable, case, alarm, etc)	$50	$80
Total	$500	$100

5.2. Timeline

The members of SECO Innovations successfully completed the project within the deadline, and are satisfied with the fact. While some component required about twice longer time to be completed, the effort to keep the original projected timeline made it possible to develop, integrate and test each module and overall system. The major deviation from the original plan is the hardware development and software development phase. The reason that their development time took longer than anticipated is that development phase started earlier with research period as they are closely related. Another reason is that we encountered some technical issues while working on localisation module. The Gantt chart and the project milestone presented below illustrate the actual timeline.

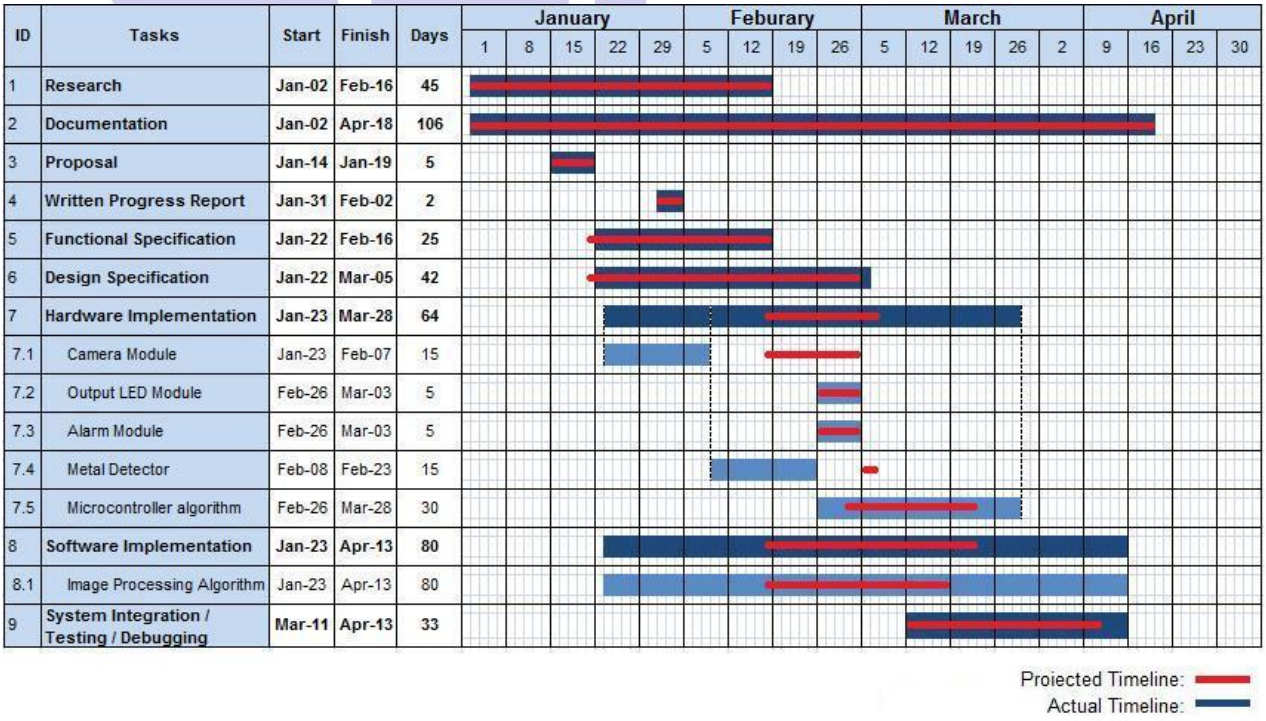

Figure 3: Gantt Chart

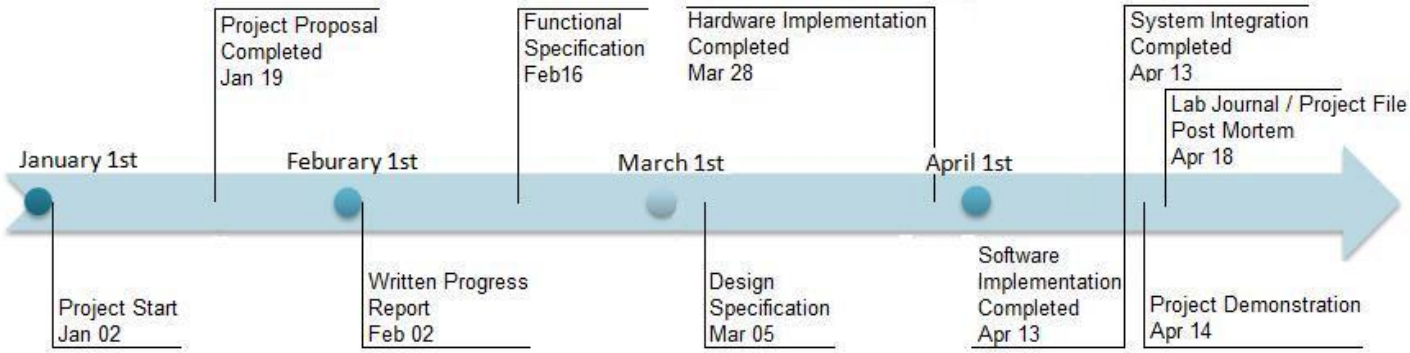

Figure 4: Project Milestone Chart

6. Inter-personal and Technical Experiences

Each member of SECO Innovations had great experience and enjoyment during the project development stage. In this section of the document, each member shares their feelings and thoughts they had during the project work.

Danny Choi – President and CEO

As a leader of the group, SECO Innovations, I have gained a strong leadership skill as well as technical skills, which have led me and my members to the accomplishment of a long time span project. Staring as a group of three members was fearful as we heard many troubling issues for a small group size, but we have managed time very well, and by distributing our responsibilities efficiently, accomplished our goals and integrated successfully at the end. The project proposal, which we have received a high mark, was the first and biggest achievement that have led us to believe that we can accomplish this project.

The LPR system is what I have really focused into, and its numerous ideas and challenges were indeed very enjoyable. There were some of frustrating moments for implementing the algorithm as many dependencies were not countable, but the achievement that came after working algorithm has had all of them to disappear. The localization part of the LPR system was the most challenging part and changing its method at the end was luckily successful. Also, finding the appropriate threshold value to clearly invert and binary the license plate was time consuming, but the data that were collected during the experiment have lead us to successfully enhance the accuracy of the system.

After completing this project, I have gained a strong writing skill through the project documents, team organization skills, management skills, and communication skills.

I have also learned the importance of team dynamics, and I really thank my members for being responsible with their duties, and works they have contributed. The presentation we had for the final project demo was also a great experience that I will never forget from my SFU academic career.

Jaehoon Shin – CFO and CMO

Throughout the tough journey to the completion, I have improved both of my technical and non-technical skills as I took an active part in this project. As being in a group, our members have been working hard and taking their own responsibilities under the well organized team dynamics. From the repetition of facing challenges and difficulties during the project cycle, our members have put ourselves more deeply into the problems, fully used our knowledge and energy, and finally overcome over the hardness. It was always the best part of the project. I greatly appreciate for all of the energy and effort that our members put together into this project.

I have been mainly working the hardware part in the LPR system consisting of building the metal detector circuit and the microcontroller module. It was the biggest challenge and the most favourite part that I worked with the microcontroller. As a beginner of the C programming language, I had to put myself harder to learn and use my knowledge at the same time to achieve the requirement. From this, I was able to expand my programming and debugging skills in computing language. Also from building the metal detector to integrating it with the microcontroller module, I have gained and improved my circuitry skills as well.

As I have been doing my co-op term in parallel to the project, it was definitely challenge for me to manage my time. Since I couldn't work in day time on weekdays, I had to work till late and spent most of my time into this project on the every weekend. For this I am really thankful to our members who understood my schedule and tried to make it work together. From the efforts I put and the cooperation with my members, I can confidently say that I have been doing my best on my duties and the time management to achieve the great success in this project. One more thing I want to mention is that the work experience from the coop also took a huge part to achieve the project. I thought it would be only hard if I do coop and the project at the same time. However, with the technical and non-technical skill that I have gained from the coop, I could think more widely and dig deeply into every problem to come up with better solution. Lastly, I thank to my members again for our great achievement in our academic history in SFU.

Wook Sun Shim – CTO and COO

I found the project work was challenging, complex, frustrating, yet enjoyable. I also expanded my technical, as well as non-technical, horizon since the beginning of the project. As a group, I believe we all learned the importance of smooth and well-organised team dynamics. Throughout the semester, the team members shared their

ideas and thoughts with each other during regular or irregular team meetings, and had discussed them in professional manners. Each of us contributed his knowledge and skills to make the development possible. Our team dynamics were great, and I am greatly thankful to our members for their efforts and dedications to the project.

As a CTO of the group, I was responsible for developing and debugging the LPR system with Danny, as well as debugging the microcontroller algorithm and integrating the hardware with the software with Jaehoon. As I had my hands on both the hardware units and the software algorithms, I was able to gain tremendous amount of knowledge in both hardware and software aspect of the system. In specific, I had chance to learn the digital image processing algorithms, programming and debugging skills in C and C++ computing language, as well as circuitry and embedded software programming.

In addition to the above mentioned skills, this project also exposed me to learn the time management skills, team organization skills and document writing skills during the semester. Also, most importantly, I am glad that we remain friends at the end of the project. I strongly believe this project work was the most precious and enjoyable experience I had during my academic career. In closing, I am proud of my team and myself that this project experience was a positive one and that the LPR system is a success.

7. Conclusion

The members of SECO Innovations believe that the development of the proof-of-concept system was a success. By implementing the digital image processing algorithms, the system was able to detect the license plate from an image of a vehicle, detect each letter on the plate, and recognise them to produce the letter string. The system was also able to verify whether the plate was registered in the database and send pass or fail flag to microcontroller to indicate the verification status back to the user. By incorporating excellent teamwork and team dynamics within the team, SECO Innovations managed to develop the working prototype system within the proposed timeline and budget. In the future, we certainly can improve our current state of the system, and we strongly believe LPR auto-gate system can help improving the quality of life for everyone.