Maple Robotics

April 6, 2021

Dr. Craig Scratchley
Dr. Shervin Jannesar
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 405W/440 Project Proposal for Lawnsweeper Mark I

Dear Dr. Scratchley and Dr. Jannesar,

The Lawnsweeper Mark I is a highly automated, robot-based collection system which combines obstacle detection, avoidance, and a rover-mounted collection system to collect fallen leaves on residential lawns. By combining efficient mechanical design, various sensor feedback, and an intuitive user experience, the Lawnsweeper Mark I strives to accomplish its high-level objective of easing the laborious task of collecting fallen leaves from residential yards.

The attached Proposal document highlights the project's scope, background, cost considerations, planning and milestones. The document will also discuss the risks and benefits associated with our product along with illustrating market competition and analysis. Additionally, it will provide information regarding our team, Maple Robotics.

The Maple Robotics team is composed of a diversified interdisciplinary team of computer engineers Daimon Gill, Haoming (Mark) Jing, Zi Zhou (John) Qu, Johnny Tsai, and Bin Xiong and systems engineer Ziniu Chen. Our team possesses an assortment of complementary skills required for the success of this project, including: process automation and controls, electromechanical and electronics engineering, 3D printing, web and mobile application development, and real-time systems programming.

If any questions regarding the Lawnsweeper Mark I arise please contact Chief Communications Officer, Daimon Gill, at daimong@sfu.ca. On behalf of the Maple Robotics team, we thank you for reviewing our Design Specification document.

Gratefully,

Daimon Gill
Chief Communication Officer
Maple Robotics

Maple Robotics

Project Proposal

Lawnsweeper Mark I

Project Members: Ziniu Chen
Daimon Gill
Haoming (Mark) Jing
Zi Zhou (John) Qu
Johnny Tsai
Bin Xiong

Contact Person: Daimon Gill
daimong@sfu.ca

Submitted To: Dr. Craig Scratchley (ENSC 405W)
Dr. Shervin Jannesar (ENSC 405W)
Dr. Andrew Rawicz (ENSC 440)
School of Engineering Science
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Issued Date: April 6, 2021

Executive Summary

In a world increasingly dependent on automation, industrial fields such as healthcare, manufacturing, and agriculture are already reaping the benefits of robotics such as decreased risk of bodily harm, increased productivity and efficiency, and reducing the number of repetitive tasks [1]. Likewise, the rapidly growing field of robotics has expanded into the common household by automating monotonous tasks such as vacuuming, pool cleaning, and lawn mowing [2]. It is estimated that nearly 15 million American households owned a robotic vacuum cleaner in 2018, with this number quickly growing [3].

Today, one area of home care has thus far escaped the attention of robotics companies: fallen leaf collection. Current solutions do not include a robotic option. Substandard solutions exist, including manual raking which is too tiring for aged homeowners, and hiring professionals, often at a substantial cost. Various non-ideal mechanical tools also exist ranging from leaf blowers to large, commercialized leaf collectors.

Our team at Maple Robotics strives to provide a solution to the monotonous task of collecting fallen leaves while also addressing limitations of current solutions. The Lawnsweeper Mark I combines an intelligently designed collection system and a sensor-equipped rover to traverse residential yards collecting fallen leaves while avoiding various obstacles, thus decreasing the physical work required by homeowners. The Lawnsweeper Mark I seeks to integrate itself into the leaf collection workflow by replacing the need for users to have to manually rake leaves themselves. Instead, users will only be required to empty a full collection bag into the respective organic disposable bins. By decreasing the amount of effort and time required to collect fallen leaves, the Lawnsweeper Mark I allow users to spend more time enjoying their yard, rather than maintaining it.

To successfully bring the Lawnsweeper Mark I to market, it is paramount that our team successfully identifies a target market, receives adequate funding to develop proof of concept and production prototypes, and follows a timeline allowing for adequate development and testing. A comprehensive market analysis, potential funding options, and detailed timeline for achieving various milestones are discussed in this proposal.

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Version History

Version #	Implemented By	Revision Date	Approved By	Approval Date	Reason
1.0	Company 19	04/05/21	Company 19	04/05/21	Final Submission

Glossary

CAD	Canadian Dollar
ESSEF	Engineering Science Student Endowment Fund
PoC	Proof of Concept
SFU	Simon Fraser University
USA	United States of America
USD	United States Dollar

1. Introduction

1.1. Background

In a span of mere decades, the digital revolution has transformed the world through the widespread adoption and application of powerful and inexpensive integrated circuits. Leveraging their massive computation power and communication capabilities, engineers have been able to automate a myriad of tasks that were previously performed manually or with human supervision. Starting from scientific applications, the technology trickled down to industrial and home uses soon after. Around the turn of the century, autonomous household robots began appearing on the market. The modern robotic lawnmower was introduced in 1995 [4], followed by the robotic vacuum cleaner in 1997 [5].

However, one common household task that has not been addressed by a robotic solution is the laborious task of collecting fallen leaves. The task of collecting fallen leaves often leads to various lower-back related injuries in aged homeowners, mainly pertaining to the twisting and compressive motions of your vertebrae when conducting the back-and-forth motion of raking leaves [6]. Though this tedious task can be outsourced to professionals, this becomes a substantial, recurring expense. Additionally, leaf blowers present a non-ideal result, since many municipalities consider leaf blowing a finable offense [7].

This project is inspired by a combination of existing manual leaf sweepers and robotic lawnmowers, which are both highly-mature designs and produced as a part of the competitive lawn care industry today. The leaf collection system found on manual leaf sweepers serve as a direct inspiration for our sweeper design. Most robotic lawnmower designs traverse lawns using forward movement combined with object detection and random bouncing, which is also utilized by the Lawnsweeper Mark I. However, unlike robotic lawnmowers, the leaf collection goal of our product necessitates a larger frame design that is capable of carrying collected leaves.

1.2. Scope

1.2.1. Goal

This goal of this design is to be able to perform leaf collection on lawns with minimal human supervision. A robot would perform leaf collection in an automated manner, and the user can control and monitor it using a mobile application. Lawnsweeper Mark I is intended to provide a product that fills the niche between small-scale manual methods and large-scale commercial alternatives. This is achieved by offering a solution that outcompetes commercial solutions on amortized cost, while being capable enough as an easy-to-use labour-saving lawn care appliance for a large portion of homeowners.

1.2.2. Operating Assumptions

The Lawnsweeper Mark I is intended for home and personal use, for typical North American suburban single-detached households. Through relevant research during the design phase, our team at Maple Robotics made design choices with respect to various assumptions while defining the optimal conditions of the environment for the product's operation. In particular, assumptions are made about the existing conditions of the lawns such as the operating area, slope, soil composition, shape, and level of maintenance. in addition to other environmental factors such as ambient temperature and weather. While the Lawnsweeper Mark I is designed to save labor and costs, it requires suitable operating conditions and cannot automate the entire lawn care process.

1.2.3. Deliverables

The development of the project will be split into 2 phases: PoC and beta phase. Deliverables will be demonstrated for both phases, and will comprise a robot and mobile application.

The PoC phase prototype will consist of the first iteration of the frame design, along with powered wheels. The collection system is to be able to gather leaves from the ground when turned on. For the Bluetooth module, the goal is to establish pairing to a phone via the first iteration of our mobile application, and transmit simple movement signals between them. This phase demonstrates the core functionality of a leaf collector robot and confirms the viability of Bluetooth controls.

In the beta phase, the physical robot design will incorporate feedback from the PoC phase, and implement quality of life features such as weather-proofing and easily removable bags. A pathfinding and boundary detection system will be developed to control the robot movement autonomously. The application will add more communication features to provide users with robot's various status updates. This phase includes refinements to the design to be more customer friendly and implements autonomous features to ensure the product indeed reduces manual labor and cost.

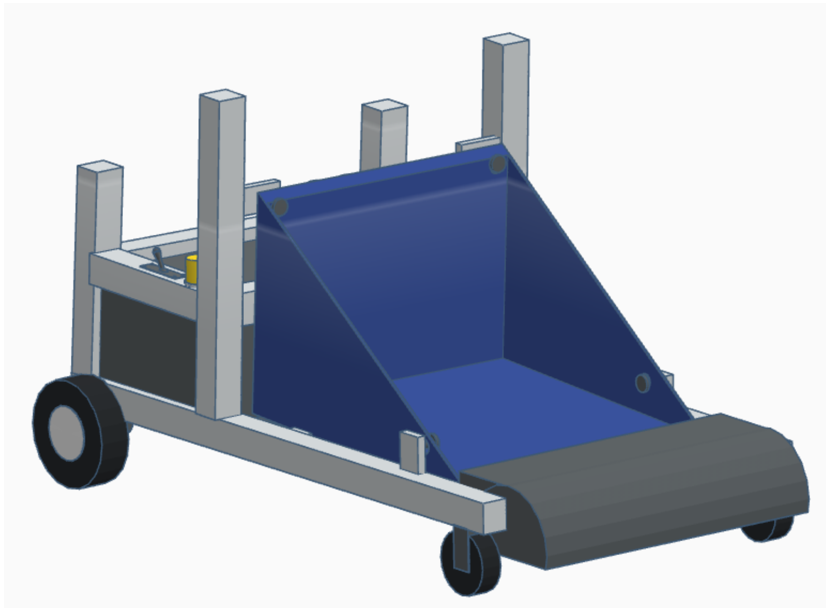


Figure 1: Concept Design of Lawnsweeper Mark I
A three-dimensional model of the Lawnsweeper Mark I used throughout Proof of Concept development.

1.2.4. Development Constraints

In order to balance the features of this product versus design complexity and cost, Maple Robotics has made design decisions based on initial capital and the team's capabilities. These constraints limit the scope of our product and impact the decision process of the design as we source different materials and components to build our prototype.

2. Risks

As the Lawnsweeper Mark I is a robotic device consisting of electrical and mechanical components that may pose risks to the user. Maple Robotics has made substantial efforts through design decisions, and safety icons and warnings to reduce and inform users of risks during operation.

A primary risk associated with the operation of the robot comes with the fact that the collection system and rover are driven by three high powered motors rotating various components at high speeds resulting in potential risks that may arise due to the incorrect operation of the robot. For instance, a user may attempt to reach into the collection system during rotation. To deter this, the collection system is shielded by a plastic covering with various safety icons and warnings signifying the risk imposed by doing such actions. Moreover, a similar risk arises if users attempt to grasp the rear wheels while in motion. Similarly, appropriate warnings and labels are placed on the robot. Moreover, future iterations of the robot may include a gyroscope feature to detect if the robot is being lifted or tilted during operation. Upon detection of such movements, the robot will immediately stop all moving parts, drastically decreasing the risks of bodily harm to the user.

Another risk associated with the product comes with the electrical system powering the robot. Whenever possible, electrical wires, battery, and circuit boards will be enclosed in a weatherproofed enclosure to alleviate potential fires due to electrical shorts. Furthermore, enclosing cables and exposed contacts shall be sealed in an effort to minimize and eliminate the risk of an electric shock. Additionally, warning icons are displayed on the weatherproofed enclosure highlighting the risks associated with electrical components.

3. Benefits

The Lawnsweeper Mark I is a highly automated leaf collection robot that is designed to bring benefits for people who have a yard and dislike yard clean-up tasks. Our design teams are not only considering the functionality of the product but also the benefits it may offer to the customers.

One major benefit of the product is the highly automated functionality. By using our product, customers will spend less time on the laborious task of manual leaf collecting. Unlike push sweeper designs, the Lawnsweeper Mark I does not need users to operate it manually. The robot has an automated collection system and a rover equipped with various sensors to autonomously move around the lawn, avoid obstacles, and collect leaves, thus saving lawn owners hours of work and physical exhaustion.

One advantage of the rotating sweeper in the collection system utilizing a column brush is that it is grass-friendly ensuring that user's lawns are not damaged. The height of the brush will be user adjustable to sit on top of the grass to ensure the brush can collect leaves without harming the grass.

Another advantage is the ability to manually control the robot. Our company has developed a user-friendly application that can pair with the robot via Bluetooth, enabling the user to manually control the robots movements and turning the collection system on and off. Additionally, the product utilizes long-range Bluetooth for communication, ensuring that user operation is available up to 100 meters away.

Lastly, our product utilizes a durable, reusable, and removable polyethylene bag to hold the leaves swept by the collection system. This not only eliminates the need to spend extra money on purchasing disposable collection bags which are also more fragile and prone to tearing, but also reduces the environmental footprint. The frame design contains four mounting pegs to easily and securely attach and detach the collection bag to the rover with ease for users' convenience.

4. Market Analysis

A growing gardening industry suggests a maturing market with stable growth. According to a report published by Grand View Research in 2016, the gardening equipment market was valued at $74.1 billion USD in 2015 and projected to reach $102.3 billion USD by 2025 in the USA alone [8]. Additionally, the robotic lawn mower market was expected to reach $1.3 billion in 2020 [9].

Cleaning up leaves not only helps maintain a neat and visually pleasing yard, but it's also essential for the health of the grass. Depending on the amount of leaves accumulated on the lawn, they may block sunlight while also forming a barrier preventing water and nutrients from reaching the soil. The task of raking and disposing of leaves is not only frequent, but is either costly if done by professionals, or time-consuming and laborious if done by homeowners themselves.

Our product targets homeowners and elderly people with lawns by providing a solution to the burdensome task of sweeping leaves while saving time, energy, and money. Currently, forms of leaf removal equipment ranges from manual raking to commercial products such as tractor-towed sweepers. The Lawnsweeper Mark I fills the void in between by providing an alternative for the residential market. Maple Robotics' priority is to fulfill the current residential market by providing an intuitive and easy to use design.

5. Competition

Manual Rake

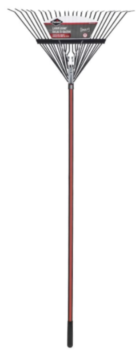


Figure 2: Lawn Rake [10]

Traditionally, the manual method of leaf collection is by using rakes as shown in **Figure 2**. While it can be found cheaply for around $50 [10] and simple to use, it’s repetitive, time-consuming and physically straining, and requires users to bend over and awkwardly pick up and move the gathered leaves for disposal.

Leaf Blower

Figure 3: Leaf Blower [11]

Electrical or gas powered leaf blowers offer an alternative to removing the leaves from a lawn quickly and efficiently. However they’re often noisy and potentially destructive to greeneries in the garden. Additionally, it poses the difficulty of collecting leaves in an area for collection. Lastly, blowing leaves onto streets may be illegal in different municipalities [12].

Tow-Behind Lawn Sweeper for Riding Mowers & Tractors

Figure 4: Tow-Behind Lawn Sweeper [13]

The Tow-Behind Lawn Sweeper shown in **Figure 4** is a manual sweeper that collects leaves as it's pulled along while attached to the back of a riding mower or tractor [13]. Pricing can be found starting upwards of $300 CAD. Additionally, users must also already own or purchase a lawn tractor to utilize this tool.

Kobi Robot

Figure 5: Kobi Robot [15]

The Kobi robot as shown in **Figure 5** is very versatile and offers 3 lawn care module options that can clear snow, mow grass and remove leaves [14]. However it's method of leaf removal is by blowing leaves to the side, and as previously mentioned with the leaf blower it may be illegal. As with its versatility, it comes with a hefty price of $3,999 USD, with extra modules potentially incurring additional cost.

6. Finances

6.1. Cost Analysis

During research and development, the Maple Robotics team allocated $1000.00 CAD to developing a functional proof of concept and production level prototype. To date, 76% of the allocated budget has been used to develop a proof of concept prototype. From the beginning of development, it was anticipated that much of the budget would be spent on the proof of concept, as the physical aspects that would be implemented in this phase would account for much of this spending.

It is anticipated that a substantially smaller amount of spending will be required for the beta phase of development. During the beta phase, $240.00 remains to purchase hardware required for object detection and avoidance, and pathfinding algorithms.

Table 1: Cost Breakdown of the Proof of Concept Development

Item	Cost per Unit (CAD)	Quantity	Total Cost (CAD)	Percentage of Budget
Mechanical Components System				
Caster Wheel	$17.50	2	$35.00	3.5%
Back Wheel	$8.50	2	$17.00	1.7%
Physical Power Switch	$4.60	5	$23.00	2.3%
Aluminum Mounting Plate (Square)	$1.60	6	$9.60	0.96%
Aluminum Tie Plate (Rectangle)	$2.00	2	$4.00	0.4%
Aluminum Flat Bar (8 feet)	$11.50	1	$11.50	1.15%
White Plastic Panel	$47.00	1	$47.00	4.7%
Aluminum Angle Bracket	$1.60	2	$3.20	0.3522%
HEX Nuts	$3.00	5	$15.00	1.5%

Aluminum U-Channel (8 feet)	$17.82	3	$53.46	5.3%
Aluminum L-Bracket	$0.62	25	$15.50	1.6%
Bolt stolve	$3.00	1	$3.00	0.3%
Lock Washers	$0.12	92	$11.04	1.1%
Wing Nuts	$3.00	3	$9.00	0.9%
Nuts and Bolts	$5.20	1	$5.20	0.52%
Electrical System Components				
L298 H-Bridge Motor Driver	$25.00	2	$50.00	5.0%
100 RPM Motor	$26.00	2	$52.00	5.2%
200 RPM Motor	$15.00	1	$15.00	1.5%
Battery Charger	$50.00	1	$50.00	5.0%
KMG (12V) Battery	$49.00	1	$49.00	4.9%
Optical Encoder	$3.00	5	$15.00	1.5%
Sparkfun Bluetooth Module	$50.00	1	$50.00	5.0%
Arduino Mega R3	$50.00	1	$50.00	5.0%
Material Cost			$623.50	
Tax (12%)			$74.82	
Estimated Shipping Costs (10%)			$62.35	
Total Cost			$760.67	
Percentage of Budget			76%	

6.2. Funding

Various funding sources are available to assist new companies in researching and developing potentially marketable ideas and offer financial support during the implementation of the project. A variety of organizations associated with Simon Fraser University provide funding opportunities to support students' projects. The funding will greatly help in reducing the cost of projects.

6.2.1. Engineering Science Student Endowment Fund (ESSEF)

The engineering science undergraduate student project awards will be given annually for projects proposed by SFU Engineering Science undergraduate students. This fund will be granted by the Senate Undergraduate Awards Adjudication Committee on the nominations of the Funding Council and the Director of the school of Engineering Science [16]. ESSEF has four different categories: A, B, C, and D. As the capstone project originates from an engineering class, our project falls under category C, while category B qualifies projects that can produce workable prototypes along with brief business plans. Upon submission and successful review of a proposal, a fixed budget may be provided.

6.2.2. Wighton Engineering Development Fund

The Wighton Development Fund that is administered by Dr. Andrew H.Rawicz will fund the student projects that satisfy Wighton's requirements. A proposal will have to be submitted and it will be evaluated by the fund's committee. Projects that benefit society will be treated preferentially. Successful proposals will be funded according to a fixed budget, which will be negotiated [17].

7. Project Planning

7.1. Timeline (Gantt Chart)

The Maple Robotics team has divided development into two phases: the PoC phase and the beta phase. The two phases will span over 8 months, from January 2021 to August 2021.

The PoC phase makes up the first 4 months of development, from January 2021 to April 2021, where a functional proof of concept will be delivered. Similarly, the beta phase composes the following 4 months, from May 2021 to August 2021, ultimately culminating in the delivery of a production level prototype.

Gantt charts in **Figures 6 - 9** illustrate the timeline and completion of a milestone from the brainstorming ideas to requirements specifications, design specifications with UI Appendix, proposal and proof of concept, and the beta phase respectively.

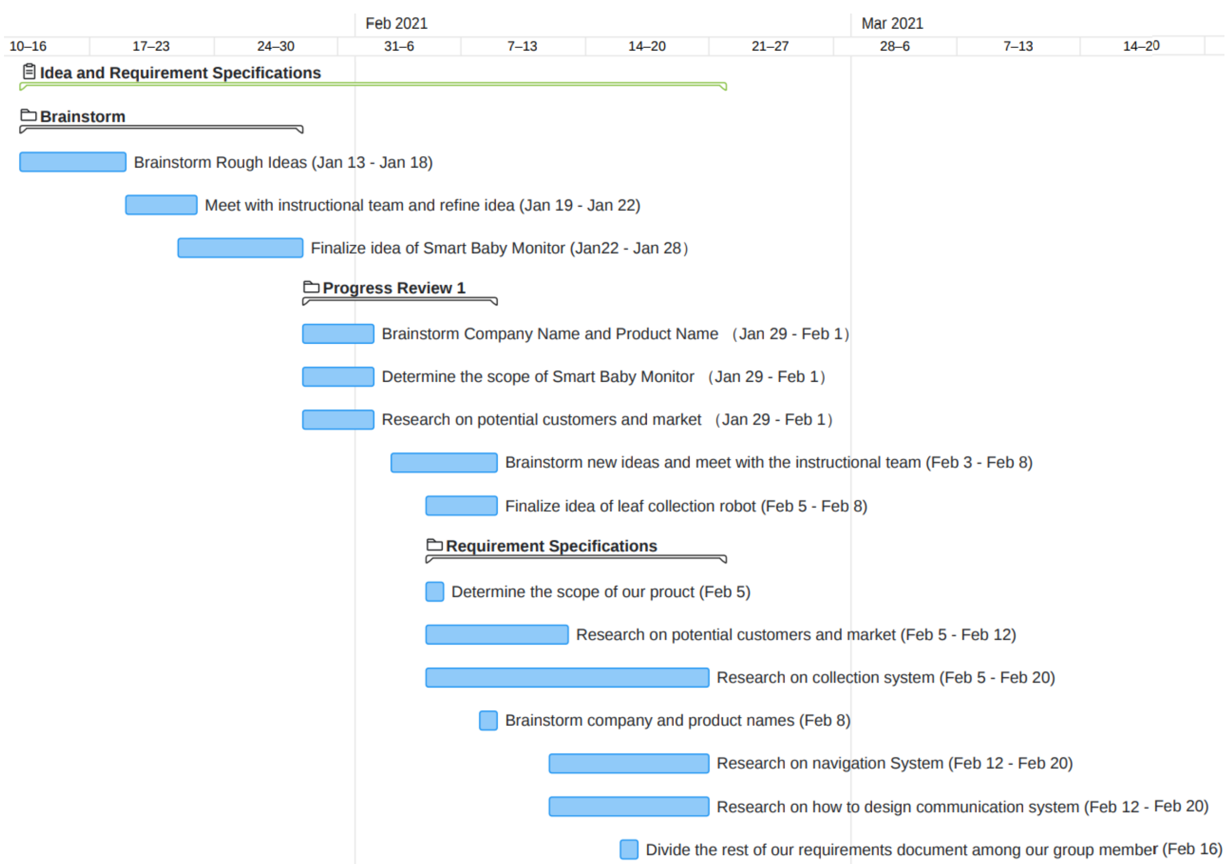


Figure 6: The Timeline of Idea and Requirement Specifications

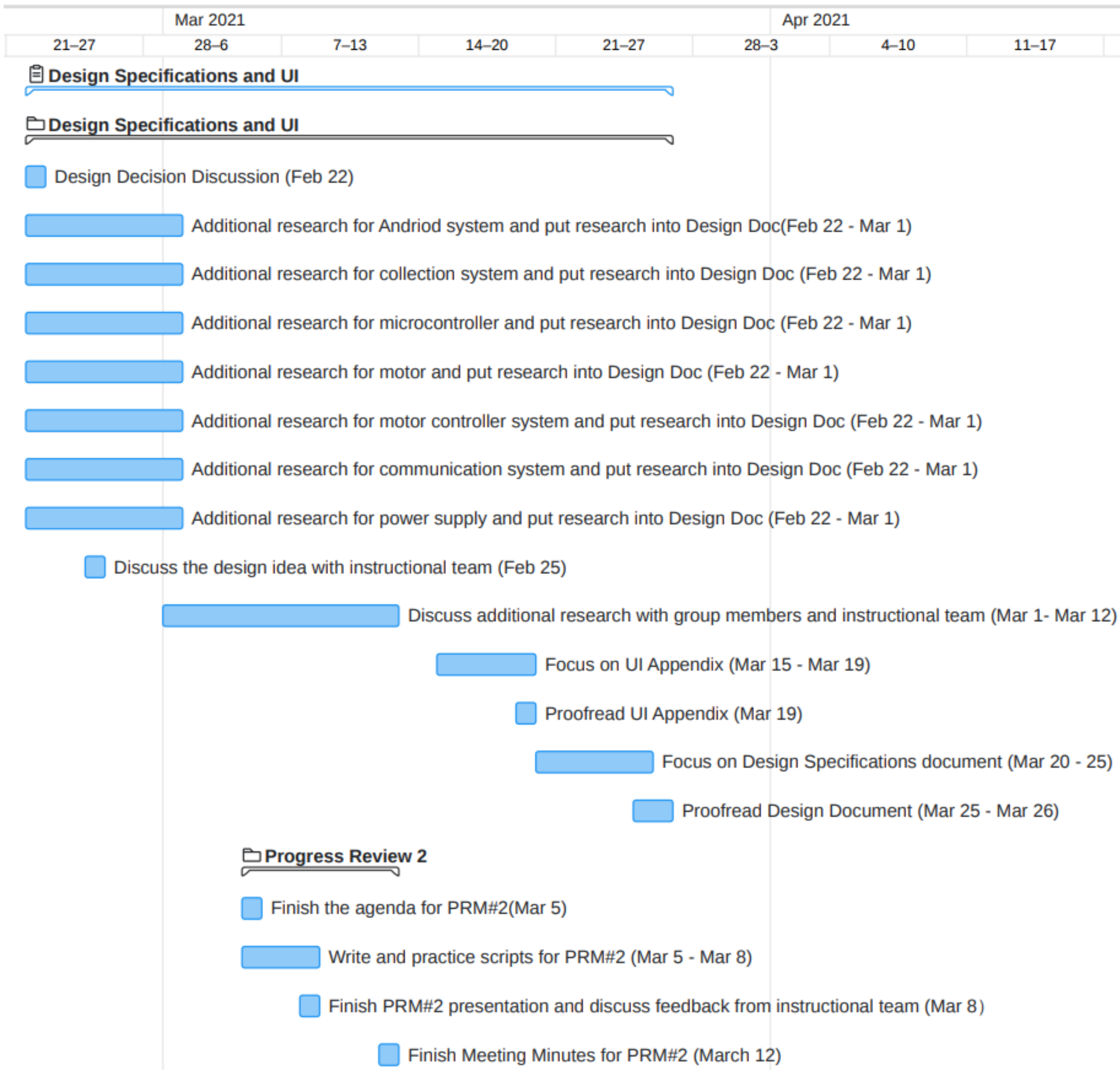


Figure 7: The Timeline of Design Specifications and UI Appendix

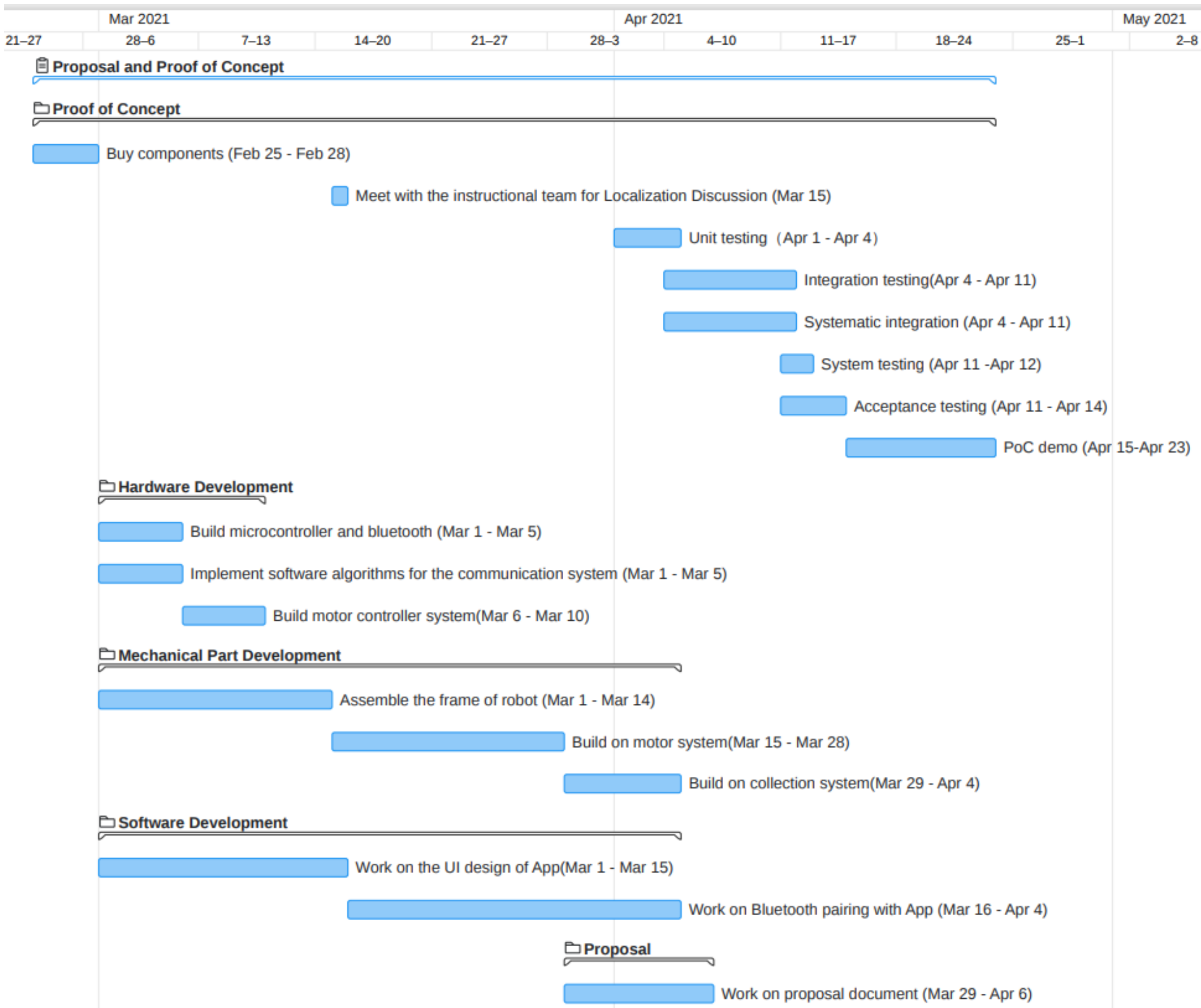


Figure 8: The Timeline of Proposal and Proof of Concept

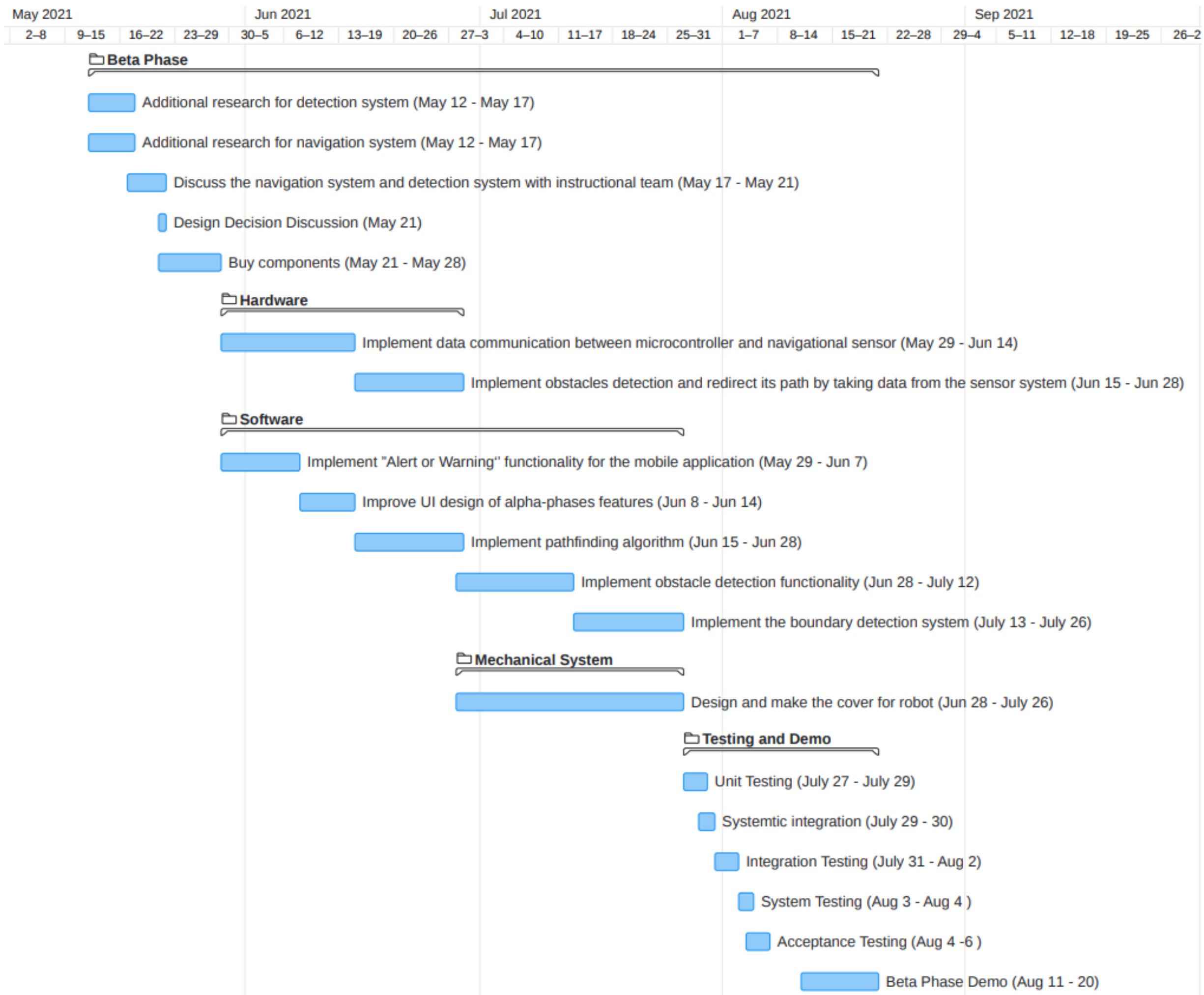
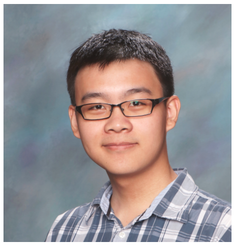


Figure 9: The Timeline of Beta Phase

8. Our Team



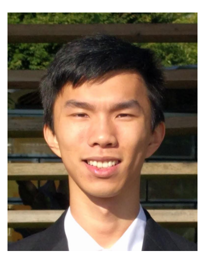
Johnny Tsai - CEO
Johnny is a fifth-year Computer Engineering student at SFU. With co-op experience in IT and systems administration, project management and integration, Johnny will be responsible for planning the company's strategy. He will also be primarily working on the software development of the product's mobile application.

Daimon Gill - CCO
Daimon is a fifth-year Computer Engineering student at SFU with co-op experience in system administration, and automation and controls. In his most recent role as a junior electronics engineer, Daimon assisted senior engineers in integrating and thoroughly testing three specially designed packaging robots into existing food-packaging lines at a food processing plant. Daimon is a member of Maple Robotics' mechanical design team and is assisting Ziniu in the mechanical design and assembly of the Lawnsweeper Mark I.

Haoming (Mark) Jing - COO
Haoming(Mark) is a fifth-year Computing Engineering student at SFU with 4 semesters of Co-op experience. He has experience with image analysis algorithms, and software development. Haoming is a member of Maple Robotics' communication design team and is assisting Bin with developing communication system and electronic circuit design for Lawnsweeper Mark I.

Ziniu Chen - CTO
Ziniu is a fifth-year System Engineering student at SFU. With Co-op experience in Robotic, FPGA and software areas. Ziniu is responsible for the mechanical design of the Lawnsweeper Mark I.

Bin Xiong - CSO
Bin Xiong is a fifth-year student in the Computing Engineering program at SFU, he developed a strong understanding of programming principles. He has experience in software designing and programming using C++, C, Python, Matlab, SQL and Swift. He is also familiar with operating systems and basic structures of OS. Bin Xiong will be responsible for developing communication system for the Lawnsweeper Mark I



Zi Zhou (John) Qu - CIO
John is a fifth-year Computer Engineering student at SFU with 4 semesters of co-op experience, as an ASIC design verifier and as an IT technician, in addition to a semester of USRA research. He has experience with MVC design patterns, digital logic verification, and mobile application development. John will be assisting Johnny with software development both for the Android application and the Arduino microcontroller onboard the robot.

9. Conclusion

The demand for lawn tools in the landscaping and lawn care industry is booming with revenue forecast to reach $102.3 billion USD in 2025. Research and analysis of the market and competition shows a lack of robotic leaf collection tools which our product can fill. Furthermore, decisions regarding the product have been carefully assessed and noted while considering the risks and benefits the product offers. Lawnsweeper Mark I by Maple Robotics is an unique product that provides an accessible alternative that solves the problem of time consuming, labour intensive leaf collection process while offering intuitive design and user interfaces and being affordable. The product is designed in such a way that users require no prior knowledge to operate the system, as design decisions were made to simplify the setup process aiming to minimize the frustration that comes with the frequent chore of raking and collecting leaves for disposal. Maple Robotics also proposes the project finances and budgeting in addition to project timelines and milestones the team plans to achieve by the end of August 2021.

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