Department of Computer Science & Engineering
The University of Texas at Arlington

Project Charter
CSE 4317: Senior Design II
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Dream Team
Autonomous Mower

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Revision History

Revision	Date	Author(s)	Description
0.1	9.23.2019	UA, JO, AH, PN, OA	Document creation
0.9	9.30.2019	UA, JO, AH, PN, OA	Official release 1
1.0	5.15.2020	UA, JO, AH, PN, OA	Official release 2

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1 Vision

Mowing grass on a sizable farm can be a long, tedious chore. An average residential zero-turn mower moves at 5-8 miles per hour [4]. Assuming a cut length of 42 inches, this means it takes approximately 20 minutes to mow a single acre. On a small farm with only 25 acres of grass to cut, this works out to 8 hours of sitting in the sun driving a mower. This is akin to an 8 hour road trip with no A/C anytime the lawn needs to be mowed. We aim to remove this large inconvenience, allowing a large plot of land to be mowed without having to leave the comfort of one's own home.

2 Mission

Our mission is to create a safe, fully autonomous lawn mower that can handle the task of mowing large plots of grass. We want to also implement a manual piloting system utilizing a VR headset and controller, allowing the user to have finer control over mowing, or simply letting one mow without sitting out in the hot sun. The mower will utilize many sensors and safety systems to ensure it is safe to use and doesn't accidentally mow anything that isn't grass, whether its running autonomously or being piloted manually.

3 Success Criteria

Upon completion of the project our lawn mower will have the following features implemented:

- Level of comfort while mowing will increase.
- Mower will reduce human mowing time by 95% since there will be some setup required.
- Level of safety will be 99%

Within 6 months after the completing the lawn mower, we expect the following success indicators to be observed:

- The cost of hardware will decrease by 20%
- The time the mower take to mow the grass will decrease by 10%
- The power used by the mower decreases by 5%

Within 12 months after the lawn mower delivery date, we expect the following success indicators to be observed:

- Our lawn mower control system will be implemented on 2 other mowers
- Implementation of our software will be expanded to a small robotic edger.
- An additional 10% reduction in cost of system

4 Background

Currently, the sponsor owns a large field of 40 acres with 25 acres of grass area that needs to be cut. There are several problems that need to be addressed and solved.

Firstly, mowing-time for a large field is very time-consuming task. Mowing is usually done by landscaping companies. Individuals can also mow their residential lawn as they wish, but not for a large field of 25 acres. Below is an estimated calculation of how much time one will spend to mow 25 acres of land using the commercial CXR-52 lawnmower.

CXR-52 speed = 10 mph (maximum speed) [1]
25 acres = 156,800,000 square inches (area of the field in inches)
156,800,000 square inches / 52 inches = 3,015,385 inches = 47.59 miles (distance travel of the lawnmower)
47.59 miles / 10mph = 4.759 hours of mowing each time

According to the one-third rule of cutting grass, one should mow every two weeks during the summer and every week during the spring and the fall season
[3]. Assuming each season has 13 weeks:

1/2 x 13 summer-weeks + 13 fall-weeks + 13 spring-weeks = 33 times / year
33 times x 4.759 hours = 157 hours per year for mowing using the CXR-52

Secondly, the operator of the commercial CXR-52 lawnmower is at risk of sickness or injury. Working outside can be joyful or awful; it's dependant on the weather and health of the working person. During the spring, the lawnmower can enjoy the flowers and the wind, but might be at risk of getting sick if their body is sensitive to pollen. The crazy temperature of Texas may also dehydrate water from oneâs body quickly, causing dehydration, headache, and even fainting. Another cause of potential injury is the inexperience of using a commercial lawnmower. Landscaping companies are required train their employee well on safety procedures to operate the machine, ensuring the job is done efficiently and safely. Ordinary people might not have the skills and experience needed to safely operate the equipment.

Lastly, the whole farm cannot be fully automated if the lawn is still under human-intense-mowing. If the farm was to be controlled by Artificial Intelligence (A.I.), then it cannot just notify the owner that the lawn is needed to be mow, the mower is going to mow the field immediately. This is sound like the A.I. is controlling human rather than human controlling A.I. The job of A.I. is to monitor the length of the grass, check the weather, and command the lawnmower to cut grass if the grass is too tall and the weather is favorable to operate. So, the whole lawn mowing business is up the A.I. to decided it should mow the lawn or not.

In conclusion, there are several benefits for this project to change the status-quo of the farm:
Quantitatively, 157 hours will be saved annually.

Qualitatively, reducing the chance of getting sick for mowing outside for extended period, minimizing the dangerous of operating a commercial lawnmower, and initializing the automation process of the whole farm that is going to be controlled by A.I.

The sponsor of this project wanted the Dream Team to work on this project to inspire current students of the University of Texas at Arlington and future engineers. Students will be motivated toward the interesting project that they really want to be involve and contribute to the common living space, the earth. He also hopes team member be brave, take initiative, and be success as him in the future. The sponsor also has a very close relationship to the team member, he is also an alumnus of the University of Texas at Arlington.

5 Related Work

There currently exists commercial robotic lawn mowers. The most prominent of these robotic mowers is the Robomow. It works by first installing a perimeter wire around the lawn. The mower uses special sensors to stay within the perimeter built by the wire and autonomously mows the yard [2]. This product would not be feasible in our case due to the large amount of land that needs to be mowed. In order to use this product and mow all the grass that needs to be mowed on Jeff's land, it would take approximately 34 Robomow units with their own area to mow. The performance of the Robomow can also be unreliable, especially operating in the type of land that our product has to operate in. Even though this product won't be able to perform the task needed, there is still some things from the Robomow that can be utilized in our project. The pathing algorithm that the Robomow uses would be a good reference for creating our pathing algorithm. We won't have the physical wire that the Robomow's algorithm relies on, but we can create a geofence system that would make it possible to use a pathing algorithm similar to the Robomow's. Another thing we can use is the Robomow's safety features. Our system is going to have to have collision avoidance functionality which we can again look to the Robomow as a guide.

Figure 1: Robomow RS630

Our lawn mower will also have a manual control mode in which the lawn mower will be controlled by either an Xbox controller or an RC controller (the decision on what controller will be used will be made after testing). In this way, our lawn mower works similar to a BattleBot, more specifically BattleBots that utilize a spinning blade. The blade on the CXR-52 runs independent of the lawn mower itself and will be able to be started and stopped by the remote controller much like a BattleBot. BattleBots are also very mobile and most of them have 0 degree turn capabilities. The CXR-52 also has the ability to turn in place so controlling the lawn mower with a controller will be very similar to how a BattleBot is controlled.

Figure 2: Son of Whyachi

6 System Overview

The Autonomous Mower System will consist of a Control System, a VR Display System, a Safety System, and an Autonomous Mowing System, shown in Figure 3.

- Control System
  - Sends the user input over WiFi or Radio to the server on the mower, which will execute the input if it does not violate the Safety System's Hazard Avoidance check.
- VR Display System
  - Utilizes the 360 Camera on the mower to display a 360 degree live video feed to the user's VR headset. It will also include a HUD to show current information and notify the user of any hazard warnings.
- Safety System
  - Uses sensors to ensure the mower does not hit anything or go beyond the programmed boundary. If it approaches a living object, it will safely stop. If it approaches a stray inanimate object (such as a piece of scrap wood), it will go around the object.
- Autonomous Mowing System
  - Uses the GPS system to navigate the full acreage of the farm, mowing the majority of the area while utilizing the safety system to avoid any hazards.

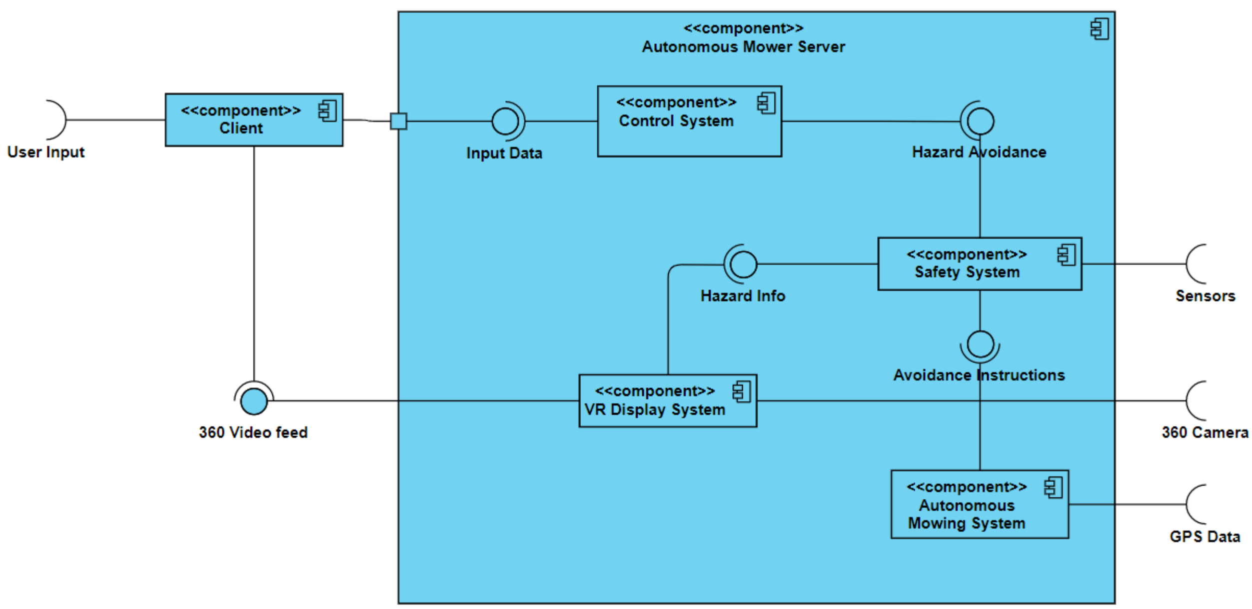

Figure 3: Component Diagram

7 Roles & Responsibilities

For our project, Jeff Smith is the stakeholder. We are implementing our autonomous lawnmower on his farm to help cut the grass. Our project team consists of Jerry Olds, Alex Ho, Phu Nguyen, Ulysses Aguilar and Aderinsola Oladaiye.

Jerry Olds will be the team's point of contact with Jeff Smith. His job is to maintain a cordial and professional relationship during project development, and to relay any information about the project to the team.

Throughout the duration of our project Ulysses Aguilar will be our product owner. As the product owner, Ulysses will determine the features of the product, decide on the release date and content of the product, and guide the team on every sprint. They will adjust features on the project as needed and accept or reject results.

Alex Ho will be our scrum master. As scrum master, Alex Ho will be the one to facilitate the management of the project development and apply agile scrum methodology.

Since we are all students with different schedules, the responsibilities of the product owner and scrum master may change periodically. For now, Ulysses Aguilar and Alex Ho will maintain these positions. Due to their experiences, Ulysses Aguilar, Aderinsola Oladaiye and Phu Nguyen will work on the hardware aspect of the project. Alex Ho and Jerry Olds will focus their skills on the software aspect.

8 Cost Proposal

For our lawn mower we need a VR headset, appropriate 360 degree camera, and a remote control for the system with a board that interfaces with the motor controller. For the autonomous aspect of the project, we need a computer on the mower with significant processing power, cameras for computer vision, and LiDAR for obstacle detection.

8.1 Preliminary Budget

Product	Cost
EMLID RS+ GPS	$799
EMLID M+ GPS	$265
Ricoh Theta V 4K 360 camera	$376
Arduino uno wifi REV2	$45
Xbox One controller	$44
Spektrum RC RX6e	$199
LPC-862 Server	$2,625
Oculus Rift S	$400
Magnetometer	$15
RPLIDAR S1	$650
Wireless Data Transmission Radio	$40

Table 1: Products Needed and Cost

8.2 Current & Pending Support

- CSE Department budget = $800
- Project sponsor Jeff Smith = $4,554.55 ++

9 FACILITIES & EQUIPMENT

Facilities

- ERB 203
- Open Fields around campus for testing
- Jeff's farm

Equipment

- Sparkfun GPS-RTK2 board
- Reach RS+ GPS reciever
- Reach M+ RTK GNSS module
- Ricoh Theta V 4K 360 camera
- Oculus Go
- Xbox one controller
- Spektrum RC RX6e
- Arduino Uno WiFi REV2
- LPC-862
- Robot Operating System (ROS)

Most of the work that will be done on this project will be done in the lab in room ERB 203 on an motorized wheelchair to simulate the CXR-52. We will also have to utilize open areas around campus to test our work. Once the work we have done can be up-scaled to the CXR-52, we will have to drive over to Jeff's farm and implement what we have done to the wheelchair.

Equipment we'll need will include the Sparkfun GPS-RTK2 board, Reach RS+ GPS reciever, Reach M+ RTK GNSS module for GPS functionality. We will be using the Ricoh Theta V 45 360 camera and an Oculus Go for vision while controlling the vehicle remotely. For control we will be using either an Xbox one controller or a Spektrum RC RX6e and an Arduino Uno WiFi REV2. Lastly, we will be using a LPC-862 and Robot Operating System (ROS) to implement all the functionality of the system

10 ASSUMPTIONS

- The prototype has components, features, software, hardware, and functionalities that are very similar to the CXR-52 lawnmower.
- Implementing hardware and software to the CXR-52 will work perfectly as it works for the prototype
- Lidar (SICK or any other brand) will be provided by the 2nd sprint cycle
- No strange objects will be on the way of the lawnmower when it is operating on the farm. These objects can be rocks, metal sticks, alien spaceship, small pond of mud, pot holes, etc.

- The CXR-52 is charged and maintenance regularly by the customer
- A suitable outdoor testing location will be available by the 2nd sprint cycle
- The customer will provide ample power and network connectivity at the installation site
- An account will be created on AWS for the team to work with cloud application by the 2nd sprint cycle

11 Constraints

- Final prototype demonstration must be completed by May 1st, 2020
- Field testing can only be done on stakeholder's farm
- Customer installation site will only be accessible by development team during normal business hours
- Total development costs must not exceed $800
- Programming languages that we are allowed to use are C++ and/or Python.

12 Risks

Risk description	**Probability**	**Loss (days)**	**Exposure (days)**
Testing of lawn mower causes damage	0.10	20	60
Shorting a specific piece of hardware during setup	0.20	10	20
Chosen components will not work with our system	0.20	10	30
Delays in shipping	0.30	7	30
conflicts in schedules between team members and project sponsor	0.30	7	270

Table 2: Overview of Highest Exposure Project Risks

13 Documentation & Reporting

13.1 Major Documentation Deliverables

13.1.1 Project Charter

Project Charter will be maintained and updated at the end of each sprint with any significant change.
Initial delivery will be on October 1st, 2019.
Final version will be May 2020.

13.1.2 System Requirements Specification

System Requirements will be created at the beginning of sprint 2, October 4th, 2019. It will be created as concrete as possible, and updated if new requirements are discovered.
Initial version will be delivered on October 21st, 2019.
Final version will be May 2020.

13.1.3 Architectural Design Specification

Architectural Design Specification will be created at the beginning of sprint 3, October 25th, 2019. It will only be updated if there is a major flaw in the design and requires new hardware.
Initial version will be delivered on November 11th, 2019.
Final version will be May 2020.

13.1.4 Detailed Design Specification

Detailed Design Specification will be created at the beginning of sprint 4, November 12th, 2019. It will only be updated if there is a major flaw in the design.
Initial version will be delivered on December 2nd, 2019.
Final version will be May 2020.

13.2 Recurring Sprint Items

13.2.1 Product Backlog

When adding items to the Product Backlog from the SRS, we will rank priority with one being the most important. Decisions will be made via group voting. We will be using Asana to organize our backlog.

13.2.2 Sprint Planning

Each sprint will have a task assigned by Dr.McMurrough in addition to our own tasks that we feel we must complete within the time frame.
There will be 8 sprints total (4 per semester).

13.2.3 Sprint Goal

Our Sprint goals will be determined during group meetings at the beginning of each sprint. We will be in constant contact with Jeff Smith via Slack, Zoom, and Email.

13.2.4 Sprint Backlog

The group will discuss what backlog items will be required to be on the sprint at the beginning of each one. Our backlog will be maintained via Asana planning software.

13.2.5 Task Breakdown

Individual tasks will be assigned based off primarily volunteering, and anything not taken will be assigned based on individual's area of experience. Time spent on tasks will be documented in our engineering notebook and Asana's task management system.

13.2.6 Sprint Burn Down Charts

Alex, the Scrum Master, will be responsible for generating the burn down charts for each sprint. The Scrum Master will be able to assess the total amount of effort by obtaining it off the Asana management software. The format of the burn down chart will consist of a base line and a line of our remaining expended effort.

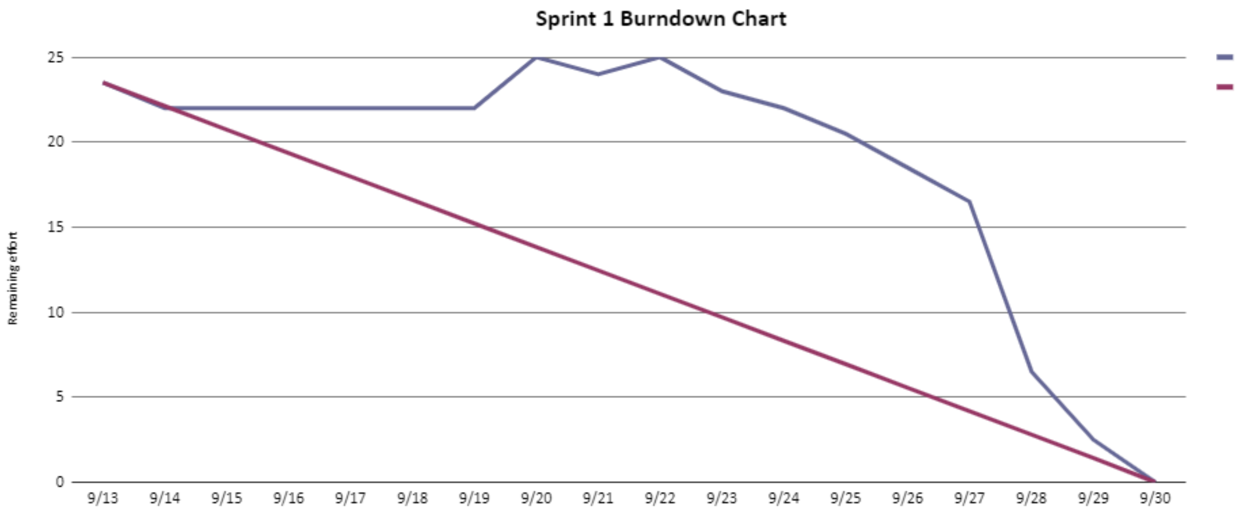

Figure 4: Burn Down Chart Example

13.2.7 Sprint Retrospective

Towards the end of the sprint, the group will discuss the outcome and accomplishments. It will be documented and presented before the next sprint starts.

13.2.8 Individual Status Reports

Each team member will document their task, and time spent on each task on Asana, and Engineering Notebook.

13.2.9 Engineering Notebooks

Engineering notebooks will be updated to log our tasks every time we have an individual or group work session. The minimum amount of pages per sprint will be at least 1. Each time we meet, we'll review each other's notebooks to ensure work has been done and sign off as a "witness" for each page.

13.3 Closeout Materials

13.3.1 System Prototype

What will be included in the final system prototype? How and when will this be demonstrated? Will there be a Prototype Acceptance Test (PAT) with your customer? Will anything be demonstrated off-site? If so, will there be a Field Acceptance Test (FAT)? An Electric Lawn mower that can be controlled via VR headset with a controller, and that is autonomous. We will also have a Wheel chair base that is capable of the same thing. The PAT will be completed in front of Jeff. There will be FAT at Jeff's farm to ensure proper functionality.

13.3.2 Project Poster

We'll display the Mower on the poster. The final dimensions would be 18â x 24â, and it will be delivered when our project is demonstrated.

13.3.3 Demo Video

The demo video will show the automated mower in action, including B-reel footage. It will be approximately 10 minute long and will cover the development process and the functionality of the automated mower.

13.3.4 Source Code

Our source code will be maintained on a regular basis via BitBucket. We will utilize Git for version control. Source code will be provided to the customer so that he may change it as needed even after the project is completed. The project will be closed source unless the customer requests otherwise. The license terms will be listed in a single readme file.

13.3.5 Source Code Documentation

Our team members will comment their code in a Doxygen format as it is being typed. Then the documentation will be generated at the completion of the project.

13.3.6 Hardware Schematics

As of now there are no hardware schematics, but this will be updated in a future sprint.

13.3.7 CAD files

As of now there are no plans to 3D print or laser-cut parts but that may change in the future.

13.3.8 User Manual

The system will come with a digital user manual to explain the functionalities of the system and how to use it. The system will be set up by us, as it would be too complicated otherwise.

References

[1] CXR 52/60 Zero-Turn Mower - Eco-Equipment Supply, LLC.

[2] How does Robomow Work?

[3] How often should one mow a lawn in Texas so the grass does not burn out? How high should the mower's blade be if mowing is done weekly? | Green Home Guide.

[4] Mowing Time Calculator - Estimate How Long It Takes to Mow a Lawn.