Department of Computer Science & Engineering
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System Requirements Specification
CSE 4317: Senior Design II
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Dream Team
Autonomous Lawn Mower

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Revision History

Revision	Date	Author(s)	Description
0.1	10.15.2019	UA, JO, AH, PN, OA	document creation
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1 Product Concept

This section describes the purpose, use and intended user audience for our Autonomous Lawn Mower. The Autonomous Lawn Mower will be able to mow the lawn autonomously, or by remote control with virtual reality 360 degree live video feed.

1.1 Purpose and Use

The mower's primary purpose is reduce the time users spend mowing the lawn, allowing the user to accomplish other tasks. The user will be able to select between autonomous mode and remote control mode.

1.2 Intended Audience

The intended audience for our system are people who already have an electric zero-turn mower, because our system is essentially an add-on. Our system is more suitable for people with large open fields of grass.

concept.png

Figure 1: X conceptual drawing

2 Product Description

This section provides the reader with an overview of our autonomous mower. The features of the system, user interface, and primary operations of the system will be listed below.

2.1 Features & Functions

The two main operations of the mower are the autonomous mode, and the remote control mode. The user will have ability to choose what mode to run the mower with a client side computer. The user will be able to stop or pause the system at any time. In autonomous mode the system will be guided by GPS, and will determine a path using GPS boundaries. Once on the path, it will use cameras and Lidar sensors to detect obstacles and act accordingly. Updates for the system will only happen with major upgrade to the functionality.

2.2 External Inputs & Outputs

Name	Description	Use
On Board Server	Inputs and Outputs	The main control system of the mower
Client Computer	External Input and Output	Sends command to mower, and receives data from mower.
Remote Control	External Output	Sends user command to client which then get sent to mower.
VR Headset	External Output	Receives live feed from client computer which receives feed from the on board server through WIFI.
GPS	External Input	Used by mower to keep track of location
LIDAR	External Input	Produces distance measurements from surrounded object.
Radio Transmitter Receiver	External Input and Output	Sends correction data from the base GPS to the GPS on the vehicle.
Magnetometer	External Input	Produces angular displacement between the goal and the current orientation.

Table 2: Inputs and Outputs

2.3 Product Interfaces

3 Customer Requirements

All requirements derived from the customer are listed below.

3.1 The system shall be able to mow the lawn remotely

3.1.1 Description

In manual mode, the user will be able to control the lawn mower with a remote controller and be provided a 360 view of the enviornment via VR headset.

3.1.2 Source

Customer

3.1.3 Constraints

Must be controlled through a 200-300 mbps wifi connection

3.1.4 Standards

N/A

3.1.5 Priority

Critical

3.2 The system shall be able to mow the lawn autonomously

3.2.1 Description

In autonomous mode, the system will mow the area with no human input once the user selects autonomous mode.

3.2.2 Source

Customer

3.2.3 Constraints

N/A

3.2.4 Standards

N/A

3.2.5 Priority

Critical

3.3 The user shall be able to stop the system remotely

3.3.1 Description

The user can choose to stop the system from the controller during manual mode or a button on the client.

3.3.2 Source

Brainstorming

3.3.3 Constraints

N/A

3.3.4 Standards

N/A

3.3.5 Priority

Critical

3.4 The system shall display a video feed to VR

3.4.1 Description

The 360 degree camera will record and live stream video to the client computer through wifi and the client will stream the video to the VR headset.

3.4.2 Source

Customer

3.4.3 Constraints

VR Headset must support a live video steam

3.4.4 Standards

Real Time Streaming Protocol (RTSP)

3.4.5 Priority

Critical

3.5 The system shall be able to be controlled by a controller

3.5.1 Description

The system will have a manual mode that allows the user to pilot the mower remotely via a controller.

3.5.2 Source

Customer

3.5.3 Constraints

Must be controlled through a 200-300 mbps wifi connection

3.5.4 Standards

Xinput Controller

3.5.5 Priority

Critical

3.6 The system's boundaries shall be defined by GPS

3.6.1 Description

The system will use a RTK GPS system to keep track of all boundaries of lawn and its relative position.

3.6.2 Source

Customer

3.6.3 Constraints

System is limited by accuracy of REACH RS+ RTK GNSS Receiver for GPS coordinates.

3.6.4 Standards

GPS, RTK

3.6.5 Priority

Critical

3.7 The system shall have a client side application

3.7.1 Description

The system shall have a client side application that the user can use to start autonomous/manual mode. In autonomous mode it will display a map with the location of the mower and its route, in manual mode it will show what the viewer sees in VR. Both modes will have a button to stop the mower and/or return it to base.

3.7.2 Source

Brainstorming

3.7.3 Constraints

N/A

3.7.4 Standards

N/A

3.7.5 Priority

Critical

3.8 The system shall communicate to the client via WiFi

3.8.1 Description

WiFi standards 802.11a/b/g/n. The speed range 200-300mbps.

3.8.2 Source

Customer

3.8.3 Constraints

Must be controlled through a 200-300 mbps wifi connection

3.8.4 Standards

WiFi 802.11 a/b/g/n

3.8.5 Priority

Critical

3.9 The system shall maintain all original functionality

3.9.1 Description

The user will be able to mow with the mower as if the system did not exist.

3.9.2 Source

Customer

3.9.3 Constraints

N/A

3.9.4 Standards

CXR-52 must be able to mow as a normal zero-turn mower.

3.9.5 Priority

High

3.10 The system shall pre-calculate and store its autonomous route

3.10.1 Description

The system will use its GPS system to calculate a route before it starts mowing autonomously

3.10.2 Source

Brainstorming

3.10.3 Constraints

N/A

3.10.4 Standards

N/A

3.10.5 Priority

High

3.11 The user shall be able to pause the mowing operation in autonomous mode

3.11.1 Description

In the GUI and the VR headset, the user will see the "Pause" button. When this button is pressed, the client computer will send the stop command to the lawnmower.

3.11.2 Source

Brainstorming

3.11.3 Constraints

N/A

3.11.4 Standards

N/A

3.11.5 PRIORITY

High

4 Packaging Requirements

The packaging requirements listed below.

4.1 The system shall have a mower with an onboard server

4.1.1 Description

The electric mower has potentiometer that can be control by microcontroller. The server is the intermediate computer that connect 360 degree camera, microcontroller and the client.

4.1.2 Source

Customer

4.1.3 Constraints

The mower must be a battery powered lawn mower

4.1.4 Standards

N/A

4.1.5 Priority

Critical

4.2 The system shall be installed personally by the developers

4.2.1 Description

The developers will be required to install the system on the mower, server, and client computer.

4.2.2 Source

Brainstorming

4.2.3 Constraints

N/A

4.2.4 Standards

N/A

4.2.5 Priority

High

4.3 The system shall have a server that runs 18.04 Ubuntu on the mower

4.3.1 Description

The server will be running Ubuntu 18.04 because it's linux version that is compatible with ROS Melodic.

4.3.2 Source

Brainstorming

4.3.3 Constraints

System must run on LInux OS

4.3.4 STANDARDS

N/A

4.3.5 PRIORITY

High

5 Performance Requirements

Performance requirements listed below.

5.1 The system controls shall update at a minimum of 120 updates per second

5.1.1 Description

The client will be the main way the user interfaces with the system

5.1.2 Source

Brainstorming

5.1.3 Constraints

Must be controlled through a 200-300 mbps wifi connection

5.1.4 Standards

UDP Protocol

5.1.5 Priority

High

5.2 The system shall stream a 360 video feed at a resolution of 2560x1440

5.2.1 Description

This is the scale down solution. But the Ricoh Theta V can support up to 4k which is 3840 x 1920 pixels.

5.2.2 Source

Brainstorming

5.2.3 Constraints

Detailed description of applicable constraints...

5.2.4 Standards

RSTP

5.2.5 Priority

Low

5.3 The system shall stream a 360 video feed at 30 FPS (frames per second)

5.3.1 Description

The Ricoh Theta V camera can only stream in 30 FPS.

5.3.2 Source

Brainstorming

5.3.3 Constraints

Must be controlled through a 200-300 mbps wifi connection

5.3.4 Standards

N/A

5.3.5 Priority

Moderate

5.4 The system shall not exceed a max speed of 8 MPH

5.4.1 Description

8 MPH seems like a decently safe speed for the system.

5.4.2 Source

Brainstorming

5.4.3 Constraints

N/A

5.4.4 Standards

N/A

5.4.5 Priority

Moderate

6 Safety Requirements

Safety requirements listed below.

6.1 Laboratory equipment lockout/tagout (LOTO) procedures

6.1.1 Description

Any fabrication equipment provided used in the development of the project shall be used in accordance with OSHA standard LOTO procedures. Locks and tags are installed on all equipment items that present use hazards, and ONLY the course instructor or designated teaching assistants may remove a lock. All locks will be immediately replaced once the equipment is no longer in use.

6.1.2 Source

CSE Senior Design laboratory policy

6.1.3 Constraints

Equipment usage, due to lock removal policies, will be limited to availability of the course instructor and designed teaching assistants.

6.1.4 Standards

Occupational Safety and Health Standards 1910.147 - The control of hazardous energy (lockout/tagout).

6.1.5 Priority

Critical

6.2 National Electric Code (NEC) wiring compliance

6.2.1 Description

Any electrical wiring must be completed in compliance with all requirements specified in the National Electric Code. This includes wire runs, insulation, grounding, enclosures, over-current protection, and all other specifications.

6.2.2 Source

CSE Senior Design laboratory policy

6.2.3 Constraints

High voltage power sources, as defined in NFPA 70, will be avoided as much as possible in order to minimize potential hazards.

6.2.4 Standards

NFPA 70

6.2.5 Priority

Critical

6.3 RIA robotic manipulator safety standards

6.3.1 Description

Robotic manipulators, if used, will either housed in a compliant lockout cell with all required safety interlocks, or certified as a "collaborative" unit from the manufacturer.

6.3.2 Source

CSE Senior Design laboratory policy

6.3.3 Constraints

Collaborative robotic manipulators will be preferred over non-collaborative units in order to minimize potential hazards. Sourcing and use of any required safety interlock mechanisms will be the responsibility of the engineering team.

6.3.4 Standards

ANSI/RIA R15.06-2012 American National Standard for Industrial Robots and Robot Systems, RIA TR15.606-2016 Collaborative Robots

6.3.5 Priority

Critical

6.4 The system shall fail-safe if any essential connection is lost

6.4.1 Description

If the system loses connection to GPS, the server, or the the client computer, it will shut down operation and await reconnection to resume.

6.4.2 Source

Customer

6.4.3 Constraints

N/A

6.4.4 Standards

N/A

6.4.5 Priority

Critical

6.5 The system shall stop if it detects a moving object within the minimum range

6.5.1 Description

The system will maintain a minimum range using the LIDAR sensors, stopping if anything enters this range.

6.5.2 Source

Brainstorming

6.5.3 Constraints

The system will be relying on AWS Recognition and LiDAR sensors for detection

6.5.4 Standards

N/A

6.5.5 Priority

Critical

6.6 The system shall not leave its boundaries

6.6.1 Description

The boundary is a GPS-based invisible fence created by the user. The mower will automatically turn or stop when it reaches a boundary.

6.6.2 Source

Customer

6.6.3 Constraints

N/A

6.6.4 Standards

N/A

6.6.5 Priority

Critical

6.7 The system shall fail-safe if any essential connection is lost

6.7.1 Description

The system shall fail-safe if any essential connection is lost

6.7.2 Source

Customer

6.7.3 Constraints

N/A

6.7.4 Standards

LIDAR

6.7.5 Priority

Critical

6.8 The system shall resume operation after an obstacle moves out of the minimum distance required

6.8.1 Description

The system will resume operation when a obstacle moves, as opposed to waiting for a user to resume.

6.8.2 Source

Brainstorming

6.8.3 Constraints

N/A

6.8.4 Standards

N/A

6.8.5 Priority

High

6.9 The user shall be able to lock manual operation

6.9.1 Description

The user can lock out controls on the controller, disabling it until it is unlocked.

6.9.2 Source

Brainstorming

6.9.3 Constraints

N/A

6.9.4 Standards

N/A

6.9.5 Priority

High

6.10 The system shall not exceed 3 MPH if obstacles are within a certain distance

6.10.1 Description

3 MPH is the safest traveling speed when the obstacles are close by.The safety distance will be determine later when actual measurement of the lawnmower is obtained.

6.10.2 Source

Brainstorming

6.10.3 Constraints

System must be able to stop in time if minimum distance is reached

6.10.4 Standards

N/A

6.10.5 Priority

High

7 Maintenance & Support Requirements

Requirements relating to Maintenance Support for the Autonomous Lawn Mower are listed below.

7.1 The system's controlls shall be documented in a manual

7.1.1 Description

A layout of the controller and the functions that each button preforms will be provided with the system.

7.1.2 Source

Brainstorming

7.1.3 Constraints

N/A

7.1.4 Standards

N/A

7.1.5 Priority

High

7.2 The system shall be documented via Doxygen

7.2.1 Description

Doxygen commenting format will be implemented so that documentation can be generated quickly if needed.

7.2.2 Source

Brainstorming

7.2.3 Constraints

N/A

7.2.4 Standards

Doxygen

7.2.5 Priority

Moderate

8 Other Requirements

Miscellaneous requirements listed below

8.1 The system shall utilize Node.JS for connection between the client and the server

8.1.1 Description

Node.JS will handle all networking between the client and server, being responsible the transfer of UDP and/or TCP packets

8.1.2 Source

Brainstorming

8.1.3 Constraints

N/A

8.1.4 Standards

N/A

8.1.5 Priority

Moderate

8.2 The system shall be coded in Python

8.2.1 Description

The server will install Python version 3.0+

8.2.2 Source

Brainstorming

8.2.3 Constraints

N/A

8.2.4 Standards

N/A

8.2.5 Priority

Moderate

8.3 The system shall utilize ROS Melodic Morenia

8.3.1 Description

The server will install ROS Melodic Morenia through ROS.org. This version will only support with linux Ubuntu 18.04

8.3.2 Source

Brainstorming

8.3.3 Constraints

N/A

8.3.4 Standards

N/A

8.3.5 Priority

Moderate

8.4 The system's client computer shall run 18.04 Ubuntu

8.4.1 Description

The client application will require 18.04 Ubuntu.

8.4.2 Source

Brainstorming

8.4.3 Constraints

System must run on Linux OS

8.4.4 Standards

N/A

8.4.5 Priority

Moderate

8.5 The system shall utilize the magnetometer for turn phase and move phase

8.5.1 Description

During the turn phase and the move phase, the magnetometer is used to measure the angular displacement between the goal and the current orientation.

8.5.2 Source

Brainstorming

8.5.3 Constraints

Must position the magnetometer at the center of the rear axle. Must stay away from strong magnetic/electric force.

8.5.4 Standards

N/A

8.5.5 Priority

High

8.6 The system shall transmit GPS correction data through radio

8.6.1 Description

The base GPS will provide the correction data to the moving vehicle when the public base station is out of 20km range.

8.6.2 Source

Brainstorming

8.6.3 Constraints

Must provide 10cm resolution.

8.6.4 Standards

N/A

8.6.5 Priority

High

9 Future Items

9.1 The system shall go around any stationary obstacles

9.1.1 Description

The system will attempt to go around a stationary object as opposed to stopping completely.

9.1.2 Source

Brainstorming

9.1.3 Constraints

N/A

9.1.4 Standards

N/A

9.1.5 Priority

High

9.2 The system shall display any detected obstacles in the HUD of the VR headset

9.2.1 Description

The LIDAR and software detection will detect any obstacle that is on the way or in the dangerous radius. Then VR headset will display a warning message in the HUD.

9.2.2 Source

Brainstorming

9.2.3 Constraints

N/A

9.2.4 Standards

LIDAR

9.2.5 Priority

Moderate

9.3 The system shall display a HUD with info in VR

9.3.1 Description

In VR, the system will display a heads-up-display with all necessary info such as battery life, obstacles, speed, and whether the blades are on or off.

9.3.2 Source

Source

9.3.3 Constraints

N/A

9.3.4 Standards

N/A

9.3.5 Priority

Moderate

9.4 The system shall return to base if finished

9.4.1 Description

The system will use its GPS system to calculate a route before it starts mowing autonomously

9.4.2 Source

Brainstorming

9.4.3 Constraints

N/A

9.4.4 Standards

N/A

9.4.5 Priority

High

9.5 The user shall be able to stop the mowing operation and return to base

9.5.1 Description

The client will have a button that allows the user to stop the mower and return it to base.

9.5.2 Source

Brainstorming

9.5.3 Constraints

N/A

9.5.4 Standards

N/A

9.5.5 Priority

High

9.6 The user shall be able to select manual or autonomous mowing modes via the client application

9.6.1 Description

User can select between the two modes in the client computer. The GUI shall display "Manual" button and "Autonomous" button.

9.6.2 Source

Brainstorming

9.6.3 Constraints

N/A

9.6.4 Standards

N/A

9.6.5 Priority

Critical

9.7 The system shall tell the user if the blades are on or off in VR during manual operation

9.7.1 Description

Status of the mower's blade is continuously update by the server on-board. The VR headset will display this information. The status is green when on and red when off.

9.7.2 Source

Brainstorming

9.7.3 Constraints

N/A

9.7.4 Standards

N/A

9.7.5 Priority

High

9.8 The system shall support the Oculus Rift S VR headset

9.8.1 Description

The 360 video feed will go from the client computer to the Rift S

9.8.2 Source

Brainstorming

9.8.3 Constraints

N/A

9.8.4 Standards

N/A

9.8.5 Priority

Moderate