Autonomous Lawnmower High Level Design

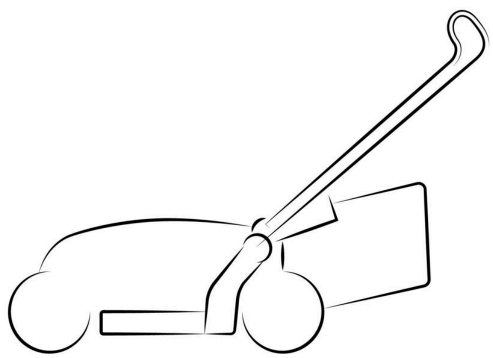

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Table of Contents

Introduction

Problem Statement and Proposed Solution

System Requirements

System Block Diagram

- Overall System
- Subsystems and Interface Requirements
- Future Enhancement Requirements

High Level Design Decisions

Known Unknowns

Major Component Costs

Conclusions

References

1 Introduction

As time goes on, automation becomes more and more common. On a quick inspection, it is easy to see why: it is often very convenient. Automation has been brought to all manner of industries and applications, one popular household example is with vacuums. However, some appliances have not taken as quickly to automation.

One of these appliances is lawn mowers. Despite acting in a similar manner to a vacuum, autonomous lawn mowers have not seen the same popularity. Both an automated lawn mower and automated vacuum primarily solve a similar problem, one of convenience. As a general theme, convenience is a major reason for many examples of automation.

This project seeks to bring the same convenience to lawn mowers as automation has brought to other tasks. The proposed system plans to incorporate several systems with the overall goal of being versatile and durable. The versatility and durability of the system will establish it as a practical and logical introduction to future lawn maintenance.

2 Problem Statement and Proposed Solution

Mowing a lawn can be a time consuming and inconvenient task. The inconvenience is compounded by factors such as the weather or the size of the lawn. There are also a large number of elderly lawn owners for whom it is more difficult physically to mow their lawn with a traditional lawn mower. There is an inherent risk operating such equipment needed to mow a lawn, often putting limbs near fast moving blades. At the same time, more technology is available now to automate tasks such as these. However, autonomous lawn mowers are not widely used or available.

Our solution is to use this technology to create a practical autonomous lawn mower. With automation, users can let this device mow their lawn without supervision, so that they can use their time as they please. Distancing users from this task also saves them from the risks involved and elderly users no longer have to struggle to keep their lawn looking clean. To keep the system adaptable, our solution involves a remote control element so that the lawn mower can still be used for unexpected circumstances and difficult terrain too complex to handle by a program.

3 System Requirements

- Battery operated motors
- GPS location and navigation
- Remote Control through RF
- Built in Programs for Automation
- Safety Features
- Overall durability of electronics and robustness

The first requirement is battery operated motors. This requirement exists to ensure that our system can interact with itself easily, particularly with the electrical control components. With battery operated motors, there is not a need to have another power source specifically for the motors such as gasoline, taking up space, and weight.

The system needs GPS location and navigation in order to determine its location on the lawn. This method provides the mower with a sense of direction so that it knows where it is and where it can go. GPS will allow the mower to understand the bounds of the lawn and distance it needs to travel.

Remote control through RF is required in our system because it is unrealistic to predict every circumstance which the mower may encounter in our automation program. Remote control provides the end user a means to continue using the mower when the automated portion cannot tell what to do. This requirement avoids the user needing to use a traditional mower anyway to mow areas that the program has difficulty reaching.

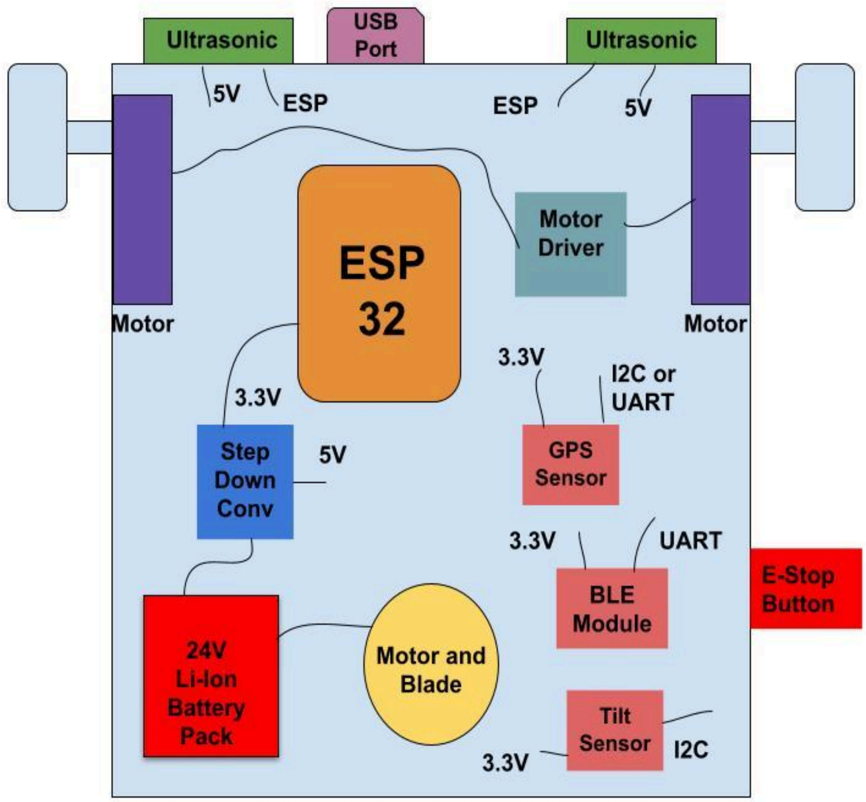
The main purpose of this system is to be automated, not requiring direct user input to operate while mowing the lawn. The built in programs must be versatile enough to appeal to a wide range of lawns to save the user from the trouble of creating their own program for their specific lawn. The main purpose of this system is for its convenience, so the better the automation program is, the better it is for any user.

An inherent part of mowing a lawn in the traditional way is the risk. While the users are not expected to be close to the lawn mower at all times, there will likely be cases where they are at risk of being hurt by the mower. To prevent injuries, the system will need to have safety features like an emergency stop and automatically stopping the blades when the lawn mower is lifted. These safety features must be functioning properly to mitigate the most possible risk.

The system needs to be durable since it is intended to work in an outdoor environment. This environment means that it will be exposed to weather and sometimes unpredictable ground. To overcome these obstacles, the housing must be durable and the system should be built to last so that users will not face broken machines a short time after getting it. The more often that the lawn mower breaks or is damaged, it is inconvenient for the user, going against the system's main purpose.

4 System Block Diagram

4.1 Overall System:



4.2 Subsystem1 and Interface Requirements: ***Power Management***

Description: Supplies power to all components in the system.

Requirements:

- 24V lithium-ion batteries supply power
- Step-down converters provide 5V and 3.3V outputs for MCU, sensors, and BLE

Interfaces:

- **Input:** Lithium-ion battery pack
- **Output:** Power to ESP32, motors, GPS module, BLE, and sensors

4.3 *Subsystem2 and Interface Requirements:* ***Navigation and Obstacle Detection***

Description: Enables autonomous movement and obstacle avoidance

Requirements:

- GPS Module maps yard boundary and tracks lawnmower position
- Ultrasonic sensors detect obstacle from a distance

Interfaces:

- Input: GPS signals and ultrasonic sensor data
- Output: Motor control commands sent to motors via driver motors

4.4 *Subsystem3 and Interface Requirements:* ***Remote Control and Communication***

Description: Allows lawnmower to be controlled via a mobile app

Requirements:

- BLE communication for real-time control and data exchange
- Mobile app displays GPS position, battery and mower status

Interfaces:

- Input: Remote control commands from the app via BLE
- Output: Motor commands and status feedback

4.5 *Subsystem4 and Interface Requirements:* ***Safety Controls***

Description: Ensure safe operation of lawn mower

Requirements:

- E-Stop button immediately stops all motors
- Tilt sensor stops blade when mower is lifted or tilted

Interfaces:

- Input: Physical E-Stop button, tilt sensor
- Output: Motor shutdown signals

4.6 Future Enhancements Requirements

- Weather sensing sensor
- AI integration for better obstacle detection and path planning
- Solar charging

5 High Level Design Decisions

Power Management
The 24 V battery will be the source of power for the mower. Being 24 V, the battery pack will have enough voltage to directly power the motors and power the other electrical components through the use of voltage regulators.

Navigation and Obstacle Detection
GPS systems will be used to determine the lawn mowers location owing to its availability and easier integration compared to more advanced techniques. Using GPS to outline the mowing area will also be more accessible to users, who are likely more familiar with GPS than other electronic methods of locating the system. This fact would allow users to troubleshoot more easily.
Ultrasonic sensors were chosen to avoid collisions that could not be predicted by a GPS mapping. Such obstacles may be garden pots or soccer balls, where these sensors would be able to detect an object which may not have been present when the initial mapping of the lawn was conducted. Using ultrasonic sensors also allows the system to detect the obstacle before colliding with it, improving the mower's longevity and limiting the risk of damaging the object.

Remote Control and Communication
For this system, we will use the ESP32-S3 due to its dual core. This will allow for more processing power where the mower may be communicating with the app through BLE and keeping track of its position and status concurrently.

Safety Controls
A tilt sensor is included to provide a more instantaneous and automatic method of detecting whether the blades should continue spinning. There are cases where reaching an emergency stop button would be dangerous, so having the mower be able to detect itself adds to the safety of the system.

6 Known Unknowns

Battery Life:

- We know that the lawn mower will be powered by a 24V Li-ion battery; however, we are not exactly sure of exact battery life, as this will depend on factors such as terrain, power consumption of sensors, motor efficiency, etc.

GPS Accuracy:

- We know that the GPS will provide location data; however, we are unsure of the accuracy of the data, especially in small cluttered environments such as small back yards, where there might be signal interference from buildings and trees that might affect performance

Obstacle Detection:

- Ultrasonic sensors will help with obstacle detection. Currently we are thinking of integrating 2-3 sensors into our design; however, we are unsure whether this number of sensors will provide sufficient coverage and reliability, particularly in difficult terrain

Communication Range of BLE:

- BLE will be used for communication, but we are unsure of its effective range in our lawnmower design, particularly when there are obstacles or potential interference

Software Behavior in Face of Uncertainty:

- We are confident that we will be able to make software behave well under regular events; however, we are unsure how well our software will handle unexpected events, such as sudden obstacles, interference with GPS, etc.

Durability of Overall Design:

- For the structure of the lawn mower, we have decided to use wood; however, the electronics will need to be housed in waterproof enclosures, but we haven't decided on whether they will be necessary or if other protective measures will be needed.

7 Major Component Costs

Component	Quantity	Cost
ESP32-S3	1	$8
Electric Motor (Blades)	1	$57
Electric Motor (Wheels)	2	$15 (each)
Wheels	4	$15 (total)
Body Materials	NA	$60
RF Antenna	1	$10
GPS Antenna	1	$5
24 V Battery Pack	1	$60
Total	**11**	**245**

Table 1. Cost of Major Components

8 Conclusions

This system is designed to be a practical implementation of an autonomous lawn mower. The system's final versatility and durability will make it a solid step and proof of concept toward making autonomous lawn mowers commonplace. In addition to the primary automated program of the lawn mower, the remote control option allows for adaptation where automation currently fails. The GPS and sensing systems allow the lawn mower to work efficiently and with minimal collateral damage. The app will make the lawn mower accessible so that the user can understand what their lawn mower sees. Through the combination of these systems, the lawn mower comes together to be a clear choice for lawn maintenance. Ultimately, these systems are made to alleviate the work that a person has to do to care for their lawn, giving the user their time back.

References:

DigiKey
DC Gear Motor
Blade Motor
Battery Packs
DC-DC Step Down Converter (24V to 5V)
DC-DC Step Down Converter (24V to 3.3V)
UltraSonic Sensors
Tilt Sensor

GPS Sensor