ECE 445

Spring 2025
Senior Design Project Proposal

Antweight Combat Robot

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1. Introduction

1.1 Problem

The constraints for Professor Gruev's competition are as follows:

- Must weigh less than 2 lbs
- Must be 3D printed in PET(G), ABS, or PLA(+)
- Must have controlled movement
- Must be controlled over bluetooth or wifi by a PC
- Must have a fighting tool to use against other bots

The main challenges involved in this are making a custom control solution and designing a combat robot that will not only survive the 2 minute matches but actually win them by immobilizing the other robot.

1.2 Solution

To meet these constraints, I plan to build a 2 lb walking combat robot with a shell spinner. To control it I plan to create a custom PCB that has a PCA9685 servo driver to control all 12 servos used in the legs, uses a STM32WB55 microcontroller to communicate with a PC over bluetooth and run the walking code that controls the servo driver over I2C, interfaces with 1 brushless electronic speed controller (ESC) to control the weapon motor. For the actual robot design I plan to build a shell spinner which usually performs well in this weight class. The shell will be spun by a brushless motor and the robot will move by precisely controlling 12 servos across 6 legs allowing the robot to translate on 2 tripods. My robot's main feature will be this novel walking mechanism. This will contain 6 legs with 2 servos each, 1 for rotation and 1 for lift. By having 6 legs my robot will be able to walk forwards by translating 3 legs at a time giving it the 3 points of contact it needs for stability. To protect the fragile legs, I have chosen a shell spinner as the "tool" which will provide a lot of protection to the internal components.

1.3 Visual Aid

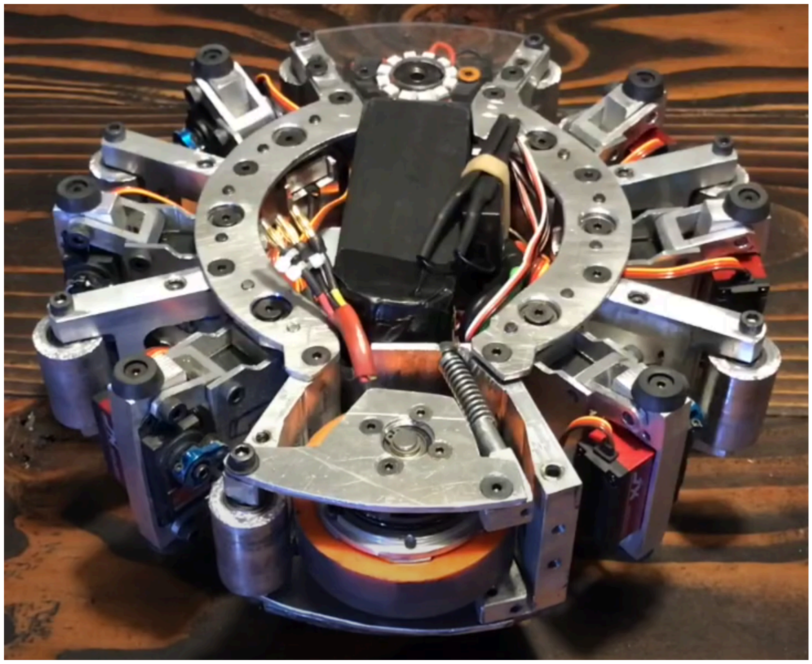

Figure 1: Sample chassis of a 30-lb walking robot

The picture above features the walking mechanism I aim to replicate in this much smaller weight class. It has 6 legs arrayed in a circular pattern with each controlled by 2 servos 25 kg servos. I plan to use 9g micro servos as my robot will be significantly smaller but the concept will be very similar. This bot also uses a metal ring spinner whereas mine has to be plastic so I will be using a shell spinner as it has more structural integrity at lower weight classes. Credit for the above robot goes to dapperrogue on YouTube [1].

1.4 High Level Requirements

1. The robot upon powering up should be able to pair with the computer in under 15 seconds.
2. The weapon should have a maximum tip speed of at least 100 mph and should be able to recover to that speed within 10 seconds after a collision.
3. The robot must be able to move controllably for a whole match (2 minutes) and be able to cross the arena in under 10 seconds.

2. Design

2.1 Block Diagram

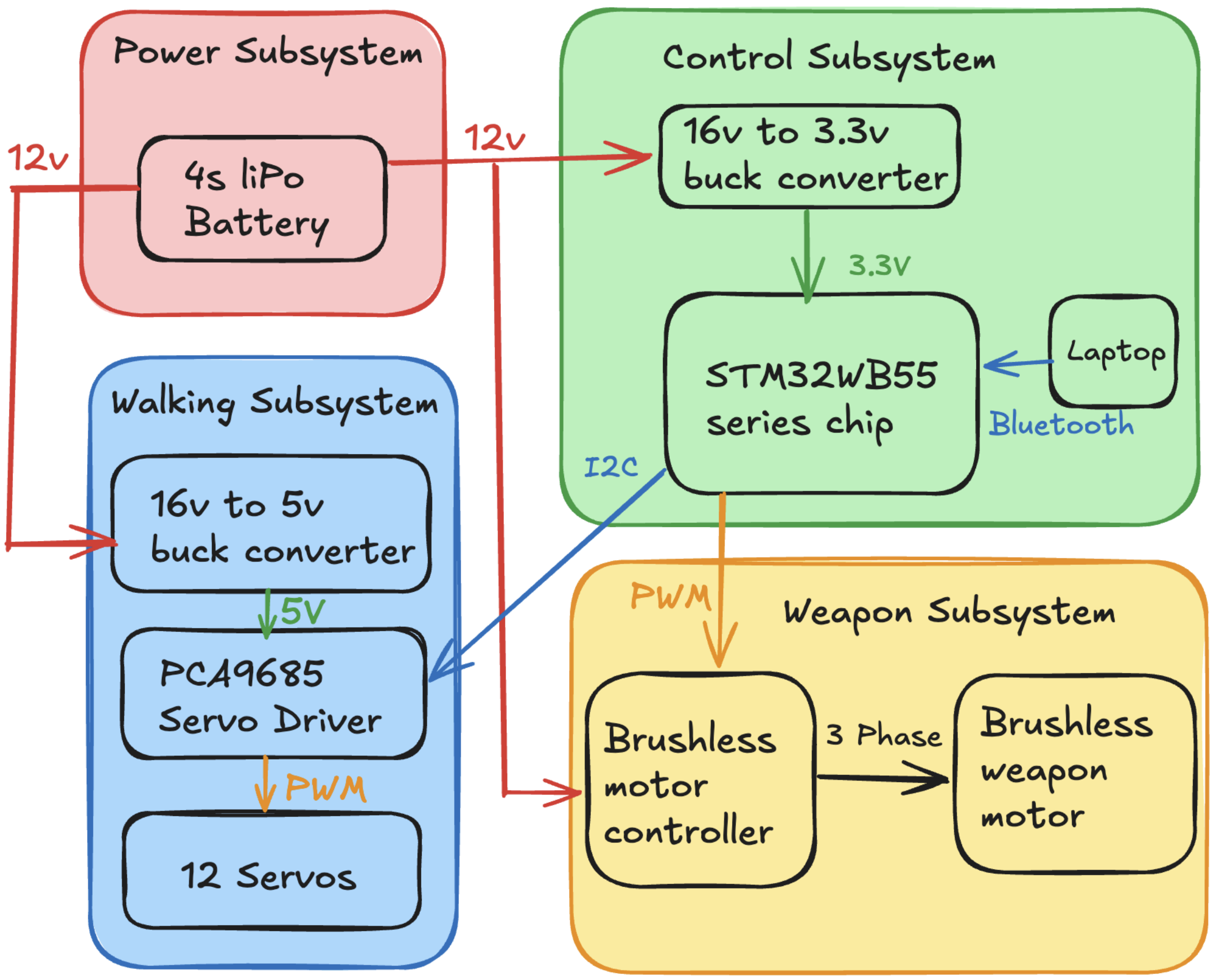

Figure 2: Block Diagram for Combat Robot

2.2 Subsystem Overview and Requirements

2.2.1 Power Subsystem

<u>Description:</u>

The power subsystem is in charge of powering all the electronics in the robot for the duration of the match. The robot will use 3 different voltages across it's electronics: 16V, 5V, and 3.3V. 16V will be supplied to the brushless esc and the brushless motor to achieve a high tip speed. 5V will be used by the servo driver and all 12 servos. 3.3V will be used by the microcontroller. I will use buck converters (switching regulators) to reduce the battery voltage to 5V and 3.3V because they are more power and heat efficient than other options like a linear regulator.

Interactions:
The power subsystem will interact with every other subsystem by providing them with power.

Requirements:
1. Provide 10 A continuous current
2. Provide 30 A peak current
3. Provide stable 5V and 3.3V for the servos and microcontroller

2.2.2 Walking Subsystem
Description:

Interactions:

Requirements:

- 12v to 5v buck converter to bring 12v from battery down to 5v for the servo driver
- Servo driver to take instructions from the STM32 chip and control the 12 servos so the bot has a fluid walking motion
- 12 servos for the 6 arms of the walking mechanism.

2.2.3 Weapon Subsystem
Description:
The weapon subsystem will have a brushless esc and the brushless motor it controls. The weapon motor will connect to and spin the shell of the shell spinner. This motor will have to have a high enough kv rating to reach the desired tip speed of 100 mph and have enough torque to recover from impacts in under 10 seconds. The brushless esc will be a 45A esc capable of handling the current and voltage required to power such a motor.

Interactions:
The esc is powered by the 4s battery in the power subsystem and controlled by the STM32 chip in the control subsystem.

Requirements:
1. Must be able to spin the shell fast enough to reach 100 mph tip speed
2. Must recover from impacts and get back up to speed in under 10 seconds
3. The esc must be rated to handle the current and voltage requirements of the motor so it will not get burnt out during operation

2.2.4 Control Subsystem

Description:

The control Subsystem contains the STM32 chip that will run the walking code and my laptop which the chip will connect to over bluetooth and will be used as the controller. When the walking code is running, the STM32 chip will communicate with the PCA9685 servo controller telling it what to do so my robot can walk. It will also send a PWM signal to the brushless esc when my laptop tells it to spin the weapon motor.

Interactions:

The STM32 chip is powered by the power subsystem and controls the brushless esc and servo driver. It also connects to my laptop over bluetooth to receive instructions.

Requirements:

1. Run the walking code well enough that the robot can walk in a straight line and cross the arena in under 10 seconds
2. Send the desired PWM signal to the brushless esc to the weapon motor spins at the correct speeds
3. Provide a stable and fast bluetooth connection for my laptop to connect to

2.3 Tolerance Analysis

Weapon Subsystem Analysis

I think the weapon subsystem poses the greatest risk as it will have to be powerful enough to damage the other robots and thus will be powerful enough to harm someone. I have a requirement of reaching a tip speed in excess of 100 mph or 44.704 m/s. To accomplish this I need a motor with a high enough KV rating. Since the entire shell of my robot will be the weapon, I have a very high weapon diameter. I will estimate this to be 150mm and my battery will be 4s or 16V.

$$\frac{44.704m/s}{0.15m \times \pi} = 94.8648RPS \times 60s/min = 5691.89RPM \times \frac{1}{16V} = 355.743KV$$

I am planning to use a 750 KV motor which is comfortably above 356 KV so hitting 100 mph tip speeds should be very achievable even if my shell diameter ends up being a bit smaller than my estimate.

3. Ethics and Safety

3.1 Ethics

As outlined in Section I of the IEEE Code of Ethics [2], I will be disclosing any factors that could pose a risk to the public or the environment, as ensuring safety is of the utmost priority. One of the major risks our robot poses is having a lethal weapon that can harm humans. It's my responsibility to only turn on the robot during competition settings in the allowed zones or in contained testing environments, as well as guaranteeing a weapon lock is used properly.

3.2 Safety

With a dangerous robot, safety is the utmost priority. I will follow safety procedures similar to that of other competitions. First I will never power the robot when it's not inside of a safe and approved test box. This ensures that no body part of mine or anyone else is in the way of the spinning weapon. Second, I will follow the standard protocol for turning on the robot when entering the arena/test box.
1. Place robot inside of test box
2. Turn on the transmitter/computer
3. Turn on the robot
4. Ensure robot is connected to transmitter/controller and that robot does not have any motors that are actively trying to spin
5. Remove the weapon stop
6. Close arena doors
7. Move robot to check functionality

By following these procedures, I should be able to create a safe environment. These procedures are based on NHRL (combat robotics competition) procedures [3].

Our competition spec also contains some specific safety-related rules that we must implement:

1. If WiFi or Bluetooth connection is lost between the robot and PC, the robot will automatically go into shutdown mode: it will stop moving and the fighting tool will stop rotating.
2. All electrical power to fighting tools and drive systems must have a manual disconnect that can be activated within 15 seconds without endangering the person turning it off.
3. Spinning blade must come to a full stop within 60 seconds of the power being removed using a self-contained braking system.

4. References

[1] "How Scuttle Walks," dapperrogue, https://www.youtube.com/watch?v=U8zYyy_4mZI (accessed Feb. 12, 2025).
[2] IEEE. "IEEE Code of Ethics." (2024), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (accessed Feb. 11, 2025).
[3] "Safety," NHRL, https://wiki.nhrl.io/wiki/index.php/Safety (accessed Feb. 11, 2025).