ECE 445

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

ABCD

Antweight Battlebot Champion Destroyer

Team No. 30

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September 19, 2024

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1 Introduction

We provide details as to the problem we aim to address, along with our proposed solution, in context.

1.1 Problem

We will be designing and building a PC-controlled battlebot as per the instructions provided by Prof. Gruev. Battlebots is an elimination style competition where uniquely designed robots under very clear restrictions combat in 2-minute rounds. However, several constraints need to be met, which introduce challenges to the design process. These restrictions include:

- The battlebot must weigh under 2 lbs.
- Only 3D-printed parts made from PET, PETG, ABS, or PLA/PLA+ are allowed for the chassis and weapon.
- The robot must be wirelessly controlled via a Bluetooth or WiFi-enabled microcontroller.
- It must demonstrate visible mobility and have an indicator light showing when power is on, and an optional secondary light for wireless connection.
- The battery voltage must not exceed 16V, and the system must include a manual disconnect for safety.
- If a pneumatic weapon is used, the pressure must remain under 250 psi, and the system must have an easily accessible bleed valve. It would also be heavier than a plastic option due to the need for a metal pressurized tank.
- If a spinning weapon is employed, it must come to a complete stop within 60 seconds of power being disconnected.
- A custom PCB must be implemented.

1.2 Solution

Adhering to the above restrictions, our proposed solution involves the development of a battlebot using an STM32 microcontroller paired with a WiFi module for wireless control using a laptop. The bot will utilize three gear motors: two for the drivetrain and one with higher RPM for the weapon, a horizontal spinning blade. The battlebot's chassis will be constructed with 3D-printed PETG filament min-maxing for weight and durability, with ramps on all sides enabling it to lift up opponents. The wheels will be 3-D printed to be as light as possible and coated with Plasti-dip to provide both traction and boost defense. The weapon will also be 3D printed with a durable material that can tolerate >= 1000 rpm without breaking apart on impact.

1.3 Visual Aid

The following is a diagram similar to the bot we will be aiming for

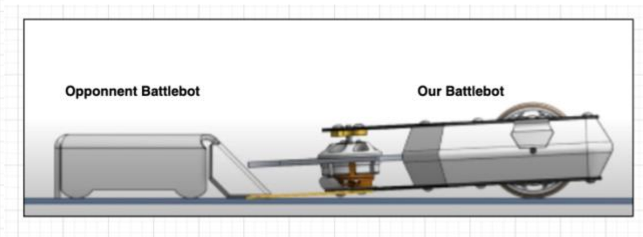

Figure 1: Top view of Battlebot connected via a WIFI receiver to the laptop.
Figure 2: Lateral view of how the battle bot will attack an opponent. The highlighted yellow piece is a protruding bottom ramp.

1.4 High-Level Requirements

To be considered successful, we aim to hit the following goals.

1. The Proper wireless communication must be established and the bot should respond precisely (acceleration increases smoothly with joystick controls) and swiftly (500-1000 ms).
2. The entire battle bot should meet the 2lb weight requirement, be made of strictly permitted materials, and be powered the entire battle duration.
3. The battlebot's weapon should operate according to rules and be able to maintain structural integrity at rpm > 1000 including on impact.

2 Design

2.1 Block Diagram

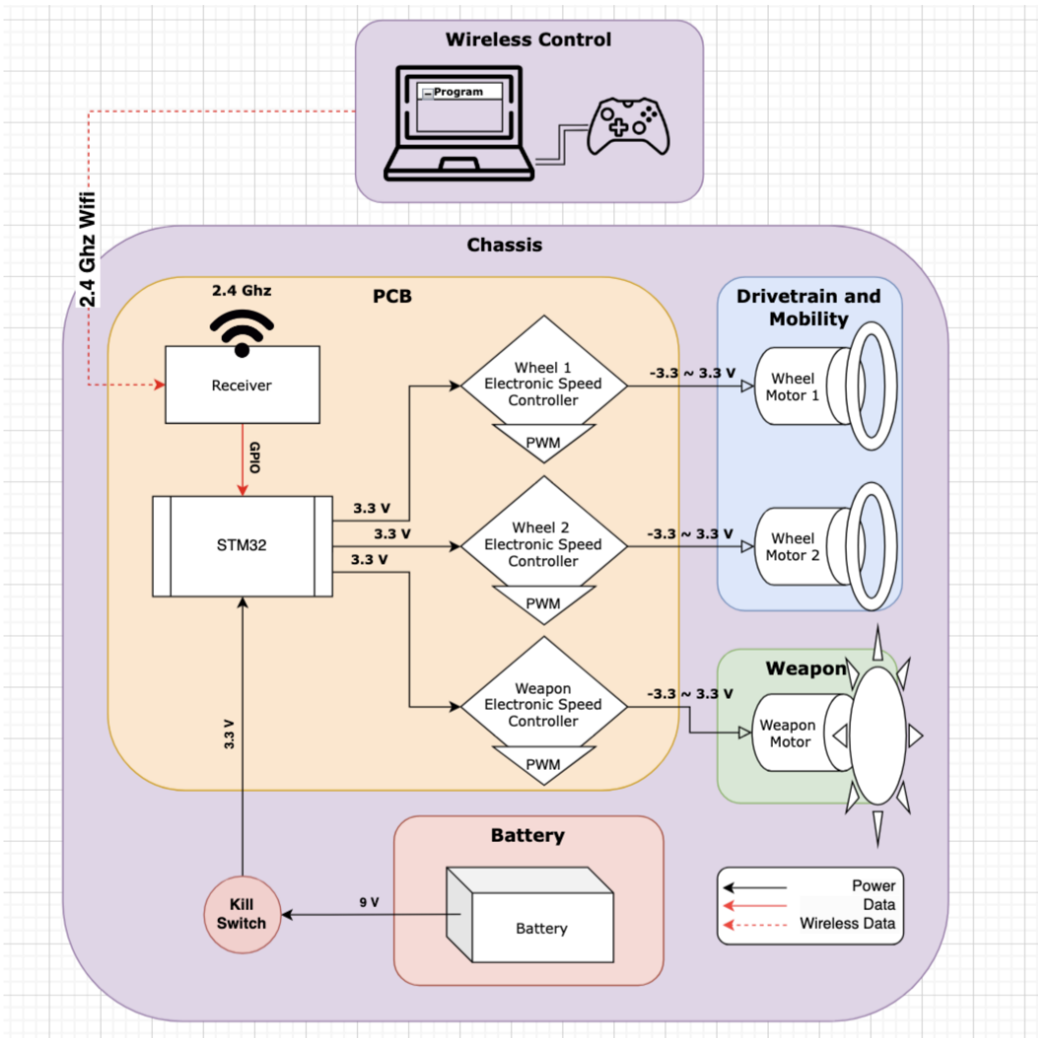

Figure 2: Block Diagram for Battlebot
**PWM – Pulse Width Modulator*

2.2 Subsystem Overview

Our design is divided into five subsystems, which are implemented in both hardware and software.

1. **Chassis/Frame of the Battlebot:** We have chosen to incorporate a combination of PLA+ and PETG. PLA+ is lighter and cheaper to use as compared to PETG which is stronger and more expensive. Our weapon will use PETG while the frame of our bot will use PLA+.

2. **Mobility and Drivetrain:** We plan to use low-torque gear motors with enclosed gearboxes to drive the wheels. The wheels will be approximately 3 inches in diameter and 3D-printed. For improved traction and mobility, we are considering coating the wheel treads with Plastidip or exploring the use of a more suitable material for better grip in the future. A key point of discussion is the gear ratio. We are targeting a motor speed of around 600-750 RPM to achieve a balance between speed and maneuverability.

3. **Wireless Control:** The main purpose of the wifi module attached to the microcontroller is to wirelessly communicate with the battlebot via our laptop. We plan to use a controller plugged into a laptop that transmits each joystick forward and backward to one motor, thus controlling left and right movements when one is forward and the other is backward.

4. **Weaponry:** The weapon is designed to attack, disrupt, and disable other bots we will be competing against. We will use a 3rd motor to power a downward leaning blade (3D Printed) aimed at the base of any opponent bot in an attempt to flip it over. We will design the blade to have prongs on the ends that can carry weight and do more damage.

5. **Power:** The current plan is to rely on a 9v battery to power every subsystem on the robot. We will upgrade to a higher voltage battery or one that can provide a higher current draw if it is needed. The main reason for a smaller battery is weight as we aim to find the sweet spot when it comes to high performance while still being under the limit of 2lbs for the whole robot.

2.3 Subsystem Requirements

Chassis:

- Material: 3D-printed PETG for superior strength and durability
- Design features: Protective ramps on front and sides, widened base to shield wheels
- Function: Structural foundation supporting all components
- Key benefits: Adheres to weight restrictions while maximizing protection
- Potential alternative: PLA+ if weight/cost becomes an issue
- Metrics:
    - Total bot mass: 0.9 kg ± 0.05 kg
    - Width: 0.18 m ± 0.01 m

Mobility and Drivetrain:

- Configuration: 2-wheel drive system

- Components: Two strong brushless motors, 3D-printed wheels with rubber treads, 3D-printed drivetrain
- Additional feature: Anti-friction pads at the front for smooth turns
- Design goal: Quick and accurate arena traversal, enhanced maneuverability
- Metrics:
  - Turning rate: 2.5 rad/s (as used in gyroscopic calculations)
  - Motor power: Sufficient to overcome 0.795 N·m ± 0.04 N·m weight moment

Wireless Control:

- Core component: WIFI module attached to microcontroller
- Control setup: Laptop with plugged-in controller
- Operation: Joystick inputs are transmitted to individual motors for differential steering
- Advantage: Precise wireless control for responsive maneuvering
- Metrics:
  - Latency: Low enough to achieve a 2.5 rad/s turning rate (specific value will be found with further testing)

Weaponry:

- Type: Downward-leaning blade
- Construction: 3D-printed with pronged ends for increased damage potential
- Power source: Dedicated powerful motor with high responsiveness
- Target: Designed to attack the base of opponent bots, aiming to flip them
- Control: Integrated with the wireless control system for coordinated attacks
- Metrics:
  - Blade mass: 0.15 kg ± 0.01 kg
  - Blade radius: 0.09 m ± 0.005 m
  - Rotation speed: 493 RPM, with a tolerance range of 425-575 RPM
  - Impact force: 30 N ± 2 N

Power System:

- Power source: 9V D-cell battery, Potential upgrade: 15V LiPo battery
- Chosen for: Balance between size and power output
- Consideration: Power system directly impacts overall performance and endurance
- Upgrade conditions: Increase performance if weight limits allow.
- Consideration: Power system directly impacts overall performance and endurance
- Metrics:
  - Voltage: 9V (current) / 15V (potential upgrade)
  - Capacity: Sufficient to power blade motor at 493 RPM and drive motors for full match duration (specific value in mAh needed)

- Weight: Must fit within overall bot mass limit of 0.9 kg ± 0.05 kg

2.4 Tolerance Analysis

Parameters:

- Maximum bot mass (M) = 0.9 kg
- Blade mass (m) = 0.15 kg
- Blade radius (r) = 0.09 m
- Desired impact force (F) = 30 N
- Bot width = 0.18 m

Analysis:

1. Moment of inertia (I) of the blade: $I = (1/2) * m * r^2 = 0.5 * 0.15 * 0.09^2 = 0.000608\ kg \cdot m^2$
2. Angular velocity (ω) required for the desired impact force: $F = m * r * \omega^2$ $\omega = sqrt(F / (m * r)) = sqrt(30 / (0.15 * 0.09)) \approx 51.64$ rad/s Converting to RPM: $51.64 * (60 / (2\pi)) \approx 493$ RPM
3. Angular momentum (L) of the blade: $L = I * \omega = 0.000608 * 51.64 \approx 0.0314\ kg \cdot m^2/s$
4. Gyroscopic precession torque (τ) when the bot turns: Assume a turning rate (Ω) of 2.5 rad/s $\tau = L * \Omega = 0.0314 * 2.5 \approx 0.0785\ N \cdot m$
5. Compare the gyroscopic torque to the bot's weight: Bot's weight moment = $M * g * (width/2)$ Weight moment = $0.9 * 9.81 * 0.09 \approx 0.795$ N·

Tolerance range:

- Lower bound: 425 RPM (to maintain sufficient impact force)
- Upper bound: 575 RPM (to limit gyroscopic effects)

Feasibility: The calculated optimal speed of 493 RPM falls within our new tolerance range. The gyroscopic torque (0.0785 N·m) is still significantly less than the bot's weight moment (0.795 N·m), suggesting that the bot should remain stable during turns, even at this smaller scale.

Considerations:

1. Motor selection: We need a small, light motor capable of reaching higher RPMs (425-575 RPM range) to maintain effectiveness at this scale.
2. Control system: The control system must be more precise to manage the higher rotational speeds within the tolerance range.
3. Structural integrity: With the mass available for structural components, we need to ensure the chassis can withstand the forces generated by the faster-spinning weapon.

4. Heat management: Higher RPMs may generate more heat, so we need to consider cooling solutions for the motor and control systems.
5. Power supply: We must select a battery that can provide sufficient power for the higher RPM motor while staying within the weight constraints.

Conclusion: The battle bot having a maximum mass of 2 lbs presents challenges, particularly in terms of maintaining weapon effectiveness while ensuring stability. Our analysis shows that a blade speed of 425-575 RPM should provide a good balance between impact force and controllability.

The higher rotational speeds required at this scale introduce additional considerations for motor selection, control precision, structural design, heat management, and power supply. However, with careful component selection and design optimization, creating an effective battlebot at this scale is feasible.

To mitigate risks to project success, we should:

1. Prioritize lightweight yet durable materials for construction
2. Invest in high-quality, precise control components
3. Conduct thorough testing of the weapon system at various speeds
4. Optimize the chassis design to maximize stability and protection with minimal weight.

3 Ethics & Safety

Our battlebot project involves several ethical and safety concerns, primarily around the spinning weapon and wireless control. To address these, we will ensure the weapon stops within 60 seconds of power disconnection, as competition guidelines require, and include a manual disconnect switch for emergency shutdowns. We will also implement safety lights to indicate power and wireless connectivity, preventing accidental operation. These measures align with the IEEE Code of Ethics, which emphasizes prioritizing public safety and welfare in engineering projects.
From an ethical standpoint, we will adhere to the IEEE and ACM Codes of Ethics by maintaining fairness, transparency, and respect for competition rules. We will follow all safety regulations for battery handling, voltage limits, and material usage as outlined by the competition while ensuring that our design cannot be misused outside of the intended controlled environment. By meeting these standards and adhering to industry best practices, we will minimize risks during development and operation, promoting both ethical conduct and safety throughout the project.