ECE 445
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Senior Design Project Proposal

Project #1: Ant-weight, 3D Printed Battlebot

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1. Introduction

1.1 Problem

The issue at hand is an Ant-weight, 3D Printed Battlebot Competition in which each team wants to win. There are certain constraints of the Battlebots' design in order to be eligible and win. To win the competition, the goal of a battlebot is to outlast or destroy the opponent team's battlebot. Different teams will have different designs, meaning a battlebot designed for winning must take into account as many factors to withstand and outlast the competition.

1.2 Solution

We decided upon developing a 3D Printed Bluetooth-controlled battle bot powered by an STM32 microcontroller. The Battlebot communicates with a PC via a Bluetooth module, enabling wireless command and control. It is equipped with two DC motors driven by H-bridge circuits for precise movement and a ramp-shaped weapon system for engaging in battles. The STM32 manages motor control using GPIO and PWM, while the weapon system utilizes GPIO or I2C protocols for activation. The bot integrates real-time communication, robust motor control, and weapon functionality, offering an engaging and functional design. My goal is to create a responsive and competitive robot for dynamic competitions.

1.3 Visual Aid

1.4 High-level requirements list

The Battlebot will be controlled wirelessly via Bluetooth with a response time of under 100ms.

● The drivetrain will consist of two high-torque DC motors powered by an H-bridge circuit, enabling precise movement and speed control.

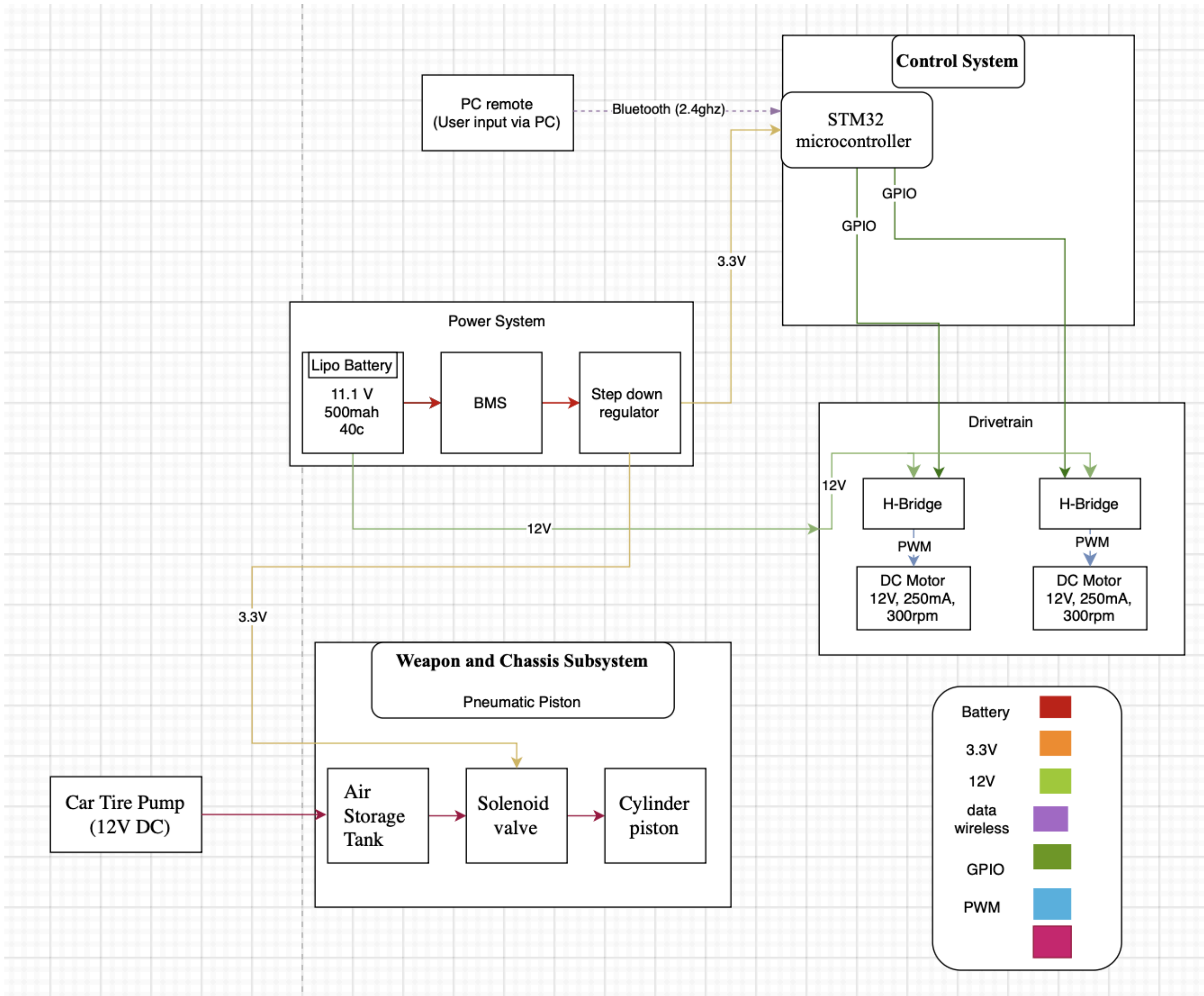
● The weapon system will be a Skid Bucket mechanism controlled via a pneumatic actuator, capable of flipping or destabilizing 2 lb opponents.

● The chassis will be 3D-printed using PLA+ plastic, ensuring durability while maintaining a low center of gravity for stability.

● The power system will utilize a 3S 11.1V 500mAh LiPo battery with a 40C discharge rate (20A max continuous discharge) and 3C charge rate (1.5A max) (Flex Innovations, 2025). The system includes voltage regulation and short-circuit protection to ensure reliable performance throughout the match.

2. Solution

2.1 Block Diagram



2.2 Subsystem Overview

Subsystem Analysis

1. **Drivetrain Subsystem:**

The drivetrain is responsible for the Battlebot's movement and maneuverability. It utilizes two high-torque DC motors (Pololu 3204, 2025), which provide 11 kg·cm of torque and a no-load speed of 300 RPM. These motors drive the rear wheels, enabling precise movement with enhanced torque for pushing against opponents. The motors are controlled via an H-bridge circuit, allowing bidirectional movement and speed control with improved efficiency. The circuit ensures the motors can dynamically adjust speed and direction for quick and strategic maneuvers. The battlebot employs PWM (Pulse Width Modulation) signals from the STM32 microcontroller, ensuring variable speed control with smooth acceleration and deceleration.

The rear wheels are equipped with high-friction tires to maximize traction, enabling the bot to push against opponents effectively. The front wheel is omni-directional, ensuring smooth directional changes and enabling pivoting maneuvers. This combination optimizes the bot's agility and defensive capabilities while maintaining stability during combat.

2. **Weapon and Chassis Subsystem:**

The primary weapon is a Skid Bucket system, designed for flipping opponents. The weapon operates through a pneumatic actuator that connects to a gas tank with 120psi. Which allows controlled the piston to flip the opponent. The system's solenoid valve is controlled by the microcontroller for each release.

The chassis is 3D-printed using PLA+ plastic, which offers a balance between durability and weight efficiency. PLA+ is selected over standard PLA due to its increased impact resistance and reduced brittleness. The chassis design features structural reinforcements in high-stress areas, ensuring it can withstand repeated impacts without compromising integrity.

The low center of gravity of the bot further improves stability, preventing easy flipping by opponents. Additionally, weight distribution is optimized to ensure consistent movement and controlled aggression during combat.

3. **Power System Subsystem:**

The power system ensures consistent and reliable power delivery to all components. A 3S 11.1V 500mAh LiPo battery (Flex Innovations, 2025) provides power to the drivetrain, control, and weapon subsystems.

The Pololu 3204 motors operate within a 6V-12V range, and since a fully charged 3S LiPo battery outputs 12.6V, the system can efficiently power the motors without additional voltage regulation. The battery voltage will naturally decrease during operation but will remain within the acceptable range.

A voltage monitoring circuit is integrated to track power levels and ensure the motors do not receive excessive voltage beyond their rated limits.The power system also includes overcurrent and short-circuit protection mechanisms, ensuring safety in case of electrical faults.

4. **Control System Subsystem:**

The STM32 microcontroller serves as the central processing unit of the Battlebot, handling real-time control inputs, motor operation, and weapon activation. The microcontroller is programmed to interpret Bluetooth commands from a PC controller, ensuring precise movement and attack execution.

The control system leverages PWM for speed modulation, GPIO for directional control, and I2C communication for sensor data (if applicable). The microcontroller processes commands with a response time of under 100ms, ensuring low-latency execution during battles.

The Bluetooth module is optimized for high-speed, interference-free communication, ensuring real-time command execution without signal drops. Extensive testing is conducted to mitigate latency issues and improve responsiveness.

2.3 Subsystem Requirements

Drivetrain Subsystem

- Each motor produce roughly 11kg * cm amount of torque (no load)
- Each motor can reach 300 RPM with no load, with load at least 160 RPM

Weapon and Chassis Subsystem

- Have a solid building structure of PLA+ plastic that can withstand the force of ramming 2lbs
- Have a gas tank that can withhold 120psi for the weapon

Power Subsystem

- Can supply a continuous 4.5A of current to all subsystems when under load (Check Tolerance Analysis)
- Have enough capacity to last 2 minutes of continuous usage to last the battle (our current battery is 500mAh)

Control System Subsystem

- Be able to connect via bluetooth from the computer we intend to use as a remote to our STM32 microcontroller and control/send signals to the different subsystems
- Be able to control the direction of the battlebot with given signals

2.4 Tolerance Analysis

An aspect of our design that may pose a threat to the successful completion is if our battery depletes before the end of the 2 minute time limit with the assumption that it is an endurance fight. In order to counteract this, we have decided to find a battery that will supply enough voltage to the different components while also having enough amperage such that it can sustain throughout the whole fight with extra power to spare.
To calculate the amount of amperage required of our battery, we need to calculate the power usage of all the subsystems based on a given time.

The motor we selected (at 12V) has a max efficiency of 0.82A draw with a 5A stall current.

Average and Peak Current Draw of both motors:
$I_{motors} = N_{motors} * I_{motor} = 2 * 0.82A = 1.64A$

$I_{peakM} = N_{motors} * I_{motor\_peak} = 2 * 5A = 10A$

Our Pneumatic system has a rough average current draw of 3A with a peak current draw of 5A. Additionally, our STM32 and related components have an average current draw of 0.15A and a peak current draw of 0.2A.

The calculation of how much our battery capacity need as well as tolerance can be calculated as follows:

Total and Peak Current Draws:
$I_{total} = I_{motors} + I_{pneumatic} + I_{IC} = 1.64A + 3A + 0.15A = 4.79A$
$I_{peak} = I_{motors\_peak} + I_{pneumatic\_peak} + I_{IC\_peak} = 10A + 5A + 0.2A = 15.2A$

Capacity of Battery Wanted = I_{total} * Total Time = 4.79A * 2min = 4.79 * 2/60 h = 0.1596 Ah
Peak current of battery = 15.2A

Because actual consumptions with batteries will vary, we need to make sure that the battery can handle 15.2A of peak load draw as well as have a total capacity of at least 0.1596Ah. This will ensure that the battery can handle the components we are using as well as last the total battlebot round of 2 minutes. The battery we have opted for has a capacity of 500mAh - which satisfies the capacity of battery wanted by a lot to ensure even with not optimal conditions it will work - as well as discharge rate of 35C and max discharge rate of 70C. To ensure that the peak current and current ratings are within this discharge rate, we take the amperage divided by the total capacity of the battery (4.79A/500mAh = 9.58C and 15.2A/500mAh = 30.4C), both of which are within limits: 9.58C < 35C and 30.4C < 70C.

3. Ethics and Safety

Ethical Considerations:

Our project adheres to the **IEEE Code of Ethics** (IEEE, 2023) and the **ACM Code of Ethics**(ACM, 2023), ensuring responsible design and ethical considerations throughout development. Ethical concerns specific to this project include: fair competition, Safety of Participants and Bystanders and Transparency in Development. We will ensure compliance with competition rules and avoid unauthorized modifications that provide an unfair advantage. Also, Adhering to **Occupational Safety and Health Administration (OSHA) regulations** (OSHA, 2023) is crucial to preventing unintended harm during development and testing. This includes ensuring all team members wear appropriate personal protective equipment (PPE) such as safety goggles and gloves while handling electrical components, following lockout/tagout (LOTO) procedures to prevent accidental activation of the battlebot, and enforcing strict safety zones around active testing areas to protect bystanders from potential hazards. All hardware and software components will be documented to ensure project integrity and reproducibility.

Electrical Safety:

From **IEEE safety guidelines** and **NFPA electrical safety standards** (NFPA, 2023) we know that wires and power components will be insulated and tested to prevent short circuits or electrical hazards.Wires and power components will be properly insulated and undergo continuity and resistance testing to detect any potential faults before deployment. The 11.1V LIPO battery will follow **IEEE 1725-2011 battery management guidelines** to prevent overheating and damage.The 11.1V LIPO battery battery will be housed in an impact-resistant, ventilated enclosure to prevent overheating and mechanical damage.

Mechanical Safety:

The battlebot's chassis and weapon systems will undergo finite element analysis (FEA) to predict stress distribution and deformation under impact conditions.Simulated combat tests will be conducted to ensure structural integrity and resistance to high-force collisions.The battlebot's weight distribution and center of gravity will be optimized to enhance stability and prevent tipping during combat.

The weapon actuation system will include redundant fail-safes to prevent unintended activation, ensuring safety during handling and maintenance.

Wireless Communication Reliability:

Since the bot relies on Bluetooth control, we will ensure low-latency response times and test for interference risks to avoid unintended loss of control.

Lab Safety Compliance:

Our development and testing will take place in University of Illinois laboratories, requiring strict adherence to campus safety policies. This includes compliance with **University of Illinois Lab Safety Guidelines**, **OSHA electrical safety protocols**, proper handling of PCB components, and adherence to lab-specific regulations to minimize hazards. Safety measures such as PPE usage, workspace organization, and risk assessments will be strictly followed to maintain a secure testing environment.

4. Reference

IEEE. "IEEE Code of Ethics." 2023. https://www.ieee.org/about/corporate/governance/p7-8.html

ACM. "ACM Code of Ethics and Professional Conduct." 2023. https://www.acm.org/code-of-ethics

OSHA. "Occupational Safety and Health Administration Regulations." 2023. https://www.osha.gov/

NFPA. "National Fire Protection Association Electrical Safety Standards." 2023. https://www.nfpa.org/

University of Illinois. "Division of Research Safety." 2023. https://www.drs.illinois.edu/