Shadow Cart – Spring 2024

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MAKE WAVES.

Abstract

Our project is to design an **AI-driven** vehicle that will follow a user, allowing the user to store items in an area on the top, essentially creating a cart-like experience. To track the user's location, the user will hold a phone that transmits a **Bluetooth signal** to the cart. The AI will use the signal strength to determine the user's proximity. Additionally, ultrasonic sensors in front and behind the cart will provide information to the AI, helping it detect obstacles for safety. As for powering the cart a battery bank composed of **lithium-ion batteries** will be used. The power is regulated through a custom **buck converter** which lowers the voltage coming from the batteries. The buck converter is controlled using an Arduino that calculates how much power the batteries have left and maintains a constant voltage. That converted power then enters a motor driver which powers the cart’s motors.

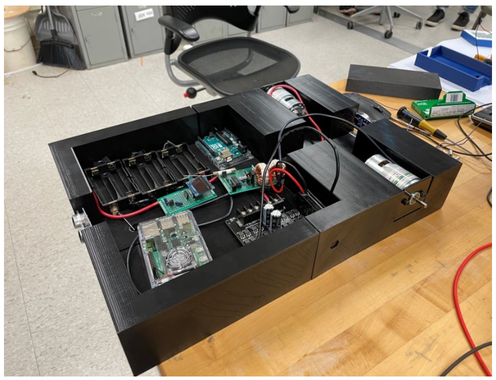

Figure 1: Overview of Cart

Background

We wanted to create something using AI learning that could help people. We are fascinated by how AI can find shortcuts to achieve goals, so we aim to develop a device that can do that. We also wanted to make our own battery pack and basic control system to test our knowledge

References

[1] sentdex, “Creating A Reinforcement Learning (RL) Environment - Reinforcement Learning p.4,” *YouTube*, Jun. 06, 2019. https://youtu.be/G92TF4xYQcU?si=0TpYiRiDMrMQBS9O (accessed Jun. 06, 2024).

Methods

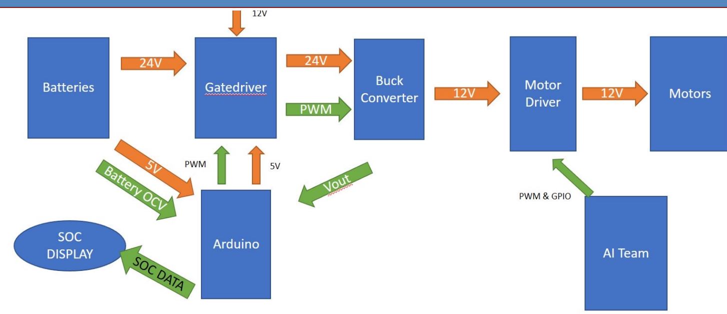

Figure 2: Block Diagram of Power System

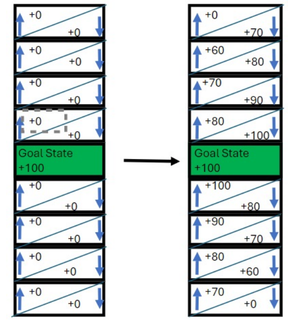

Figure 3: Q-Learning Table

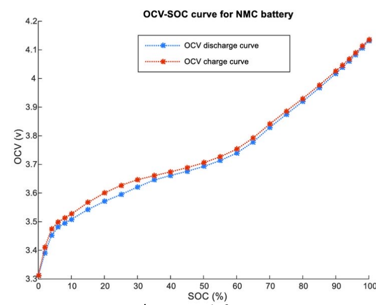

Figure 4: OCV/SOC Graph for NMC Batteries

Power System:
The system uses a battery pack made of 21700 lithium-ion cells, arranged in 6 series for a nominal voltage of 23V. This voltage is reduced to 16V for the motor driver via a buck converter, which uses PWM signals to chop the power and smooths it with inductors and capacitors. An Arduino adjusts the PWM duty cycle to maintain the desired voltage by measuring the output voltage. Increasing the duty cycle raises the output voltage, while decreasing it lowers the voltage. This voltage mode control adapts to varying motor loads due to changes in speed, direction, and resistance, such as when climbing a hill.

SOC:
The Arduino also calculates the SOC (State of Charge) by measuring the battery voltage and referencing an OCV/SOC curve.

Artificial Intelligence:
We aim to create an AI that can learn how to drive using a **reinforcement learning** (RL) algorithm called **Q-learning**. By using RL, the AI can learn from an increasing amount of data as we add more sensors. To enhance our AI, we can expand the Q-table to include more dimensions, accommodating each new sensor and potential movement.

Q-learning:
It is a reinforcement learning algorithm that iteratively calculates the value of potential actions in each state to determine **optimal behavior**. It does this by maintaining a **Q-table**, which stores the calculated values and learns the best one to take based on the highest valued option it has. The algorithm then chooses the action with the highest value from the Q-table, thereby aiming to maximize the cumulative reward over time

Results

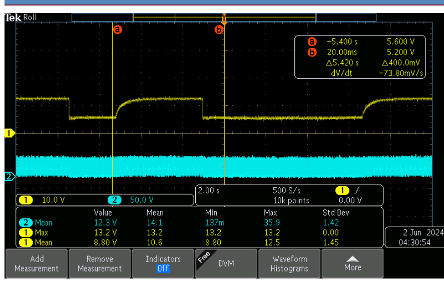

Figure 5: Voltage Control Test w/ Motors

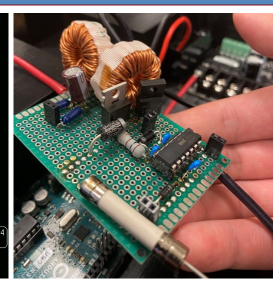

Figure 6: Buck Converter

In Figure 8, the buck converter’s output voltage is shown in yellow, and its PWM signal is shown in blue. During the test, the motors were turned on in the entire system. The voltage drops as the motors turn on and takes roughly a second to recover. The second voltage drop occurs when both motors were turned on simultaneously. When testing the cart on the ground, it takes about a second to start moving from a standstill. To address this, we increased the PWM frequency and raised the motor voltage to 16V. Our SOC estimation appears to be close to the SOC shown on our charger.

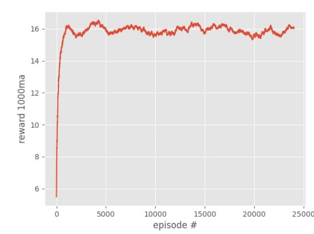

Figure 7: Ai- Results

Figure 7 shows the reward received by our AI over 25,000 episodes. Initially, it starts low, indicating the AI is performing poorly. However, there’s a sharp rise, suggesting the AI learns quickly and approaches around 16. This higher reward is sustained for the remaining episodes, signifying the AI has achieved a successful learning outcome and maintains its performance.

Future Direction

We can build a working cart that can drive itself around but only in a straight line. If we were given more time and a bigger budget, things we would want to add/change would be:

- Have a microcomputer with AoA (angle of arrival) so that we know what direction the user is in a 2D environment
- Include a proper charging system using wall power
- Improve the accuracy and efficacy of filter components and transient response time
- Use one computer to control both the AI and the power control

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