3. Design Section

3.1 Design Context

3.1.1 Broader Context

Area	Description	Examples
Global, cultural, and social	Our project fits in the broad global and cultural scope of athletic performance. Currently only track athletes at the professional level have access to the track lighting system that aids in workout pacing. But once we deliver the Rabbit, access to high level training will be given to more athletes who are younger and will have more time to train in that space before they reach the age of most professional athletes. This could very well rebalance what the landscape of track competitions look like as more and more people will be able to increase their training efficacy and reach significant benchmark goals sooner in their career. (Might we unlock the sub 4 minute mile?)	A young athlete starts their high school track career with the Rabbit, and by the time they are a senior have trained with such accuracy that their performance rivals that of a seasoned veteran who has trained for twice as long without the aid of a pacing device.
Public Health	The Rabbit may very well be useful for more than just an athletic workout. The rabbit could also be used	

	for personal workouts, or potentially for a rehabilitation program for someone who is relearning to walk or run. With the advent of telehealth, an automated pace car on a track could be a feasible way for a physical therapist to prescribe individualized workouts for patients who are retraining their legs to walk or run, and the rabbit would be able to guide them through a session without the need for the PT to be there in person.	
Environmental	Since the rabbit is a small product, we do not anticipate large impacts to the environment. However we will be using some form of battery to power the rabbit, and potentially as the market for our device opens up, selling them in mass could increase the amount of batteries floating around out there which would in the long run lend itself to a negative impact based on how well our users handle their batteries	A College buys ten Rabbits, and after a few years throws away the old batteries instead of disposing of them in the proper manner.
Economic	When a new product like ours enters the market there is always potential for positive economic growth. We anticipate that the benefits that come from utilizing a rabbit in an athletic workout will be desirable at all levels of athletic ability from grade school, to collegiate, to	A college puts in an order for 10 Rabbits. After one or two seasons of use, the noticeable results drive other colleges to purchase and use the Rabbit which in turn creates higher demand that stimulates the market and leads to other innovative athletic training advancements.

	professional. As such we would expect to not only sell a lot of Rabbits which would be good for the economy as it would create a solid flow of money, but it may also pique interest in the area of athletic performance in general and could generate even more market activity in the form of other workout enhancing solutions or parallel products that would all serve to increase athletic ability overall.	

3.1.2 User Needs

Track athletes need a way to monitor their training so they can train as consistently as possible throughout the whole training routine.

Track coaches need a way to tailor workouts to their athletes so that each athlete can excel and reach their full potential.

Grade school and collegiate athletic programs need a cheaper and more accessible solution than a track lighting system to allow their athletes to train and compete at a higher level.

3.1.3 Prior Work/Solutions

Track lighting system: The Problem With 2020 World Records -WAVELIGHT PACING- With Joshua Cheptegei And Jakob Ingebrigtsen
https://youtu.be/vYy-DIdcp0k?t=43

3.1.4 Technical Complexity

Component	Subsystem	Applicable fields
Vehicle Hardware	Power,electrical,	Safety standards, electrical

		equations,
Line following	Computer vision, movement	Advanced computer vision and pathing
Real time communication from app to car(s) and car to app	Communications, App	Signal communication, parsing signals

As there are very few current solutions, comparing the rabbit to them is a little tricky as their functionality have similar goals, but are carried out in completely different ways.

3.2 Design Exploration

3.2.1 Design Decisions

What car to use?
How to handle line tracking
How to interface with the car? (likely two questions)

3.2.2 Ideation

The design decision we spent a lot of time deciding and ideating on was the communication between the user and the car. The following ideas were ideated:

1. Bluetooth
2. Bluetooth Low Energy
3. Exterior device to send RF signals
4. Sound
5. Cellular communication
6. Server to host all the cars that the app can connect too

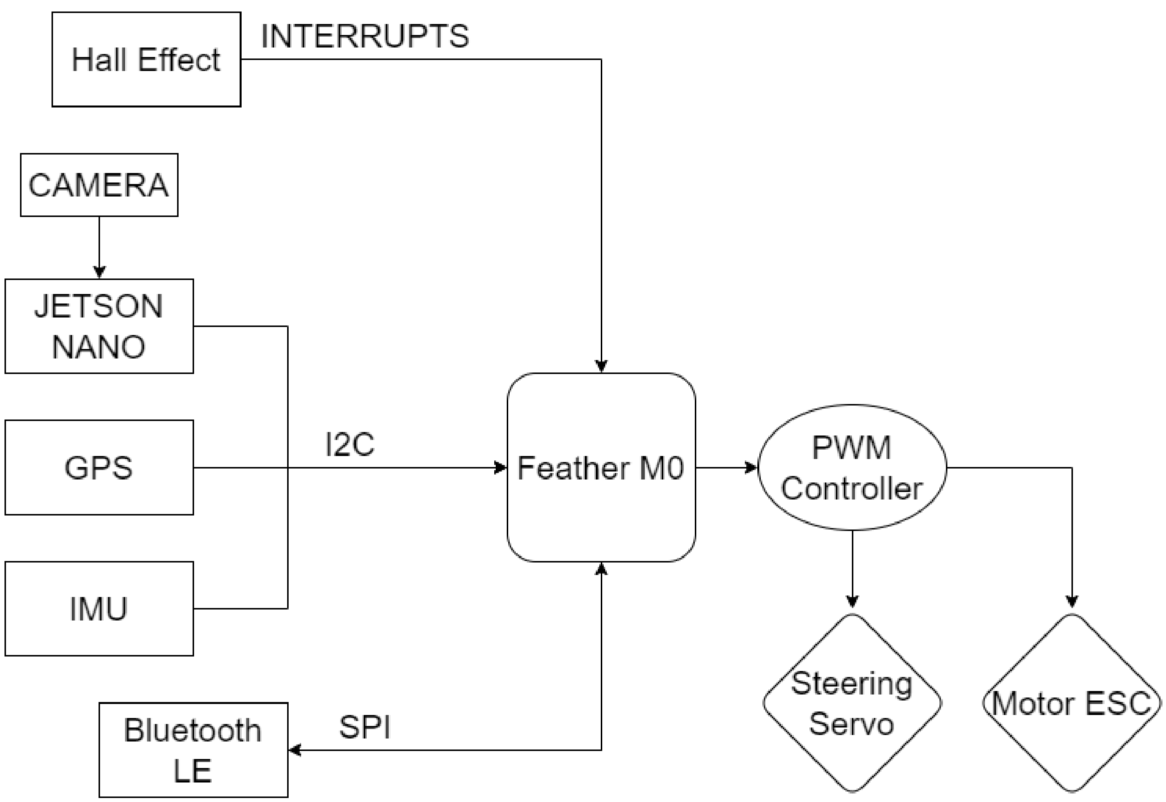
3.2.3 Decision-Making and Trade-Off

Criteria	Weighting	Bluetooth		Bluetooth LE		External RF		Sound		Cellular	
		Score	Total	Score	Total	Score	Total	Score	Total	Score	Total
Range	5	2	10	1	5	7	35	2	10	9	45
Cost of implemetation	2	7	14	8	16	5	10	9	18	1	2
Ease of implementation	3	4	12	7	21	2	6	3	9	5	15
Speed	4	6	24	6	24	3	12	7	28	1	4
Data bandwidth	1	7	7	6	6	3	3	1	3	4	4
			67		72		66		68		70

3.3 Proposed Design

Our design is as follows: a purchased RC car serves as the base of the design attached to the car will be a platform for additional equipment we need such as a camera and boards for decision making this will be controlled via a smartphone app for both ios and android where a user can set distance and time settings and the car will automatically figure out speeds and acceleration. Once the user sends the go command the car will execute these commands following the track through use of computer vision.

3.3.1 Design Visual and Description



The Adafruit Feather M0 accepts input from a variety of sensors, including speed data calculated from interrupts caused by a hall effect sensor, acceleration data from the IMU, and redundant speed data from GPS. The Jetson Nano is responsible for determining the position of the car within the lane, and then sends this corrective data to the Feather. Using sensor inputs and based on the workout plan delivered from the app, the Feather will then control the steering and speed outputs through a PWM module using a PID model. By comparing sensor data to the desired goals, a corrective error model can be generated continuously as the car makes its way around the track.

3.3.2 Functionality

For an average user they will open the app, set up a connection to the car on their phone then set the distance, time and number of sets. After this is done they will ensure the car is in an appropriate position then once the runner is ready the user will hit the start button at which point the car accelerates in a manner similar to an average runner and follows the track with the runner following behind using the car as a guide for distance. Once the set is done the car shall come to a stop and be able to be retrieved and reset.

3.3.3 Areas of Concern and Development

Computer vision is an incredibly complex topic and perfecting the system for our use presents unknown challenges and feasibility we plan to solve this by finding established research and ustalizing tutorials

3.4 Technology Considerations

Using the Jetson Nano:

Pros:

- We will be able to have high accuracy and efficiency with making driving decisions.
- We will be able to quickly and easily make changes to the code if need be
- We have the option to add other features if necessary

Cons:

- The Jetson Nano needs a large amount of power and we may run into issues with powering the entire rabbit off of one battery.
- The Nano is also very large and will pose issues when it comes time to mount it onto the rabbit body.

Solutions:

- A solution for powering could simply be having a separate battery for the Nano.
- We also plan on creating a shroud to hold all of the components and keep them secure during operation.

Using Opencv:

Pros:

- We can use the prebuilt libraries to detect lines and implement tools that already exist.

Cons:

- We may spend time wrestling with getting Opencv to work properly and we do need a higher level of processing power to analyze the data.

Solutions:

- Go back to implementing Opencv in python instead of cpp alleviate some of the more complicated aspects of the libraries.

Using the Traxxas:

Pros:

- High Durability
- Open source design and easy to incorporate microcontroller functionality

Cons:

- Original gear ratio was too low
- Unsure of battery life

Solutions:

- We were able to upgrade our gear ratio
- Buy multiple batteries so we can swap them out if needed

Coding our app in React Native

Pros:

- App is portable to both android and iOS

Cons:

- React hasn't been taught to any of us in our classes

Adafruit Feather M0 Bluetooth

Pros:

- Capable microcontroller with built in Bluetooth LE
- Existing libraries with examples
- Stackable additional modules

Cons:

- Open source requires making code open source
- No software UART support
- Libraries often lack thorough documentation

3.5 Design Analysis

While we have not fully completed our full design yet, it is coming together very well. Specifically our microcontroller system to control the car has operated and performed exactly as we anticipated it to. We have succeeded in establishing a high fidelity connection via bluetooth from a phone to the adafruit feather which we can sync to the pwm signals of the Traxxas car allowing us complete control over the car via our app. We have been able to send a list of commands as well as live driving instructions to the car.

Our computer vision design has gone slower than we were hoping, but not slower than expected. We mainly have had blocker issues with getting Opencv properly installed on the Jetson nano. We recently cleared these issues up and plan on continuing forward with our original design implementation. The good news is that our design idea holds up to what we already have implemented with the RC car. We expect that once we have driving instructions generated from the Jetson Nano based on live video data, the driving instructions will successfully be followed by the RC car based on the testing we have already done through driving the car via bluetooth.

3.6 Design Plan

Currently our design plan will continue forward without much modification. We will work out a way to interpret lines viewed by the Jetson Nano camera into meaningful driving instructions and then easily incorporate the Nano into our system flow by feeding its output to the adafruit feather input. Our overall progress will be governed by the success of the computer vision piece and as such we will plan on working through computer vision as much as we can over break so that when our spring semester starts we will give ourselves the best chance possible to start off on an even footing with a system that is ready to be fully integrated.

Something that can help speed up our computer vision development is recording a video of a camera moving around a full lap of a track. We can then take this test data and use it as dummy input for our computer vision program. That way as we develop our solution for extrapolating driving instructions from the line data we will be able to retest and verify the success of our code over this data instead of needing to run the full rabbit over and over again. This will greatly increase the speed of testing and overall development.