Running Track Pacing Assistant

ECE 445 Project Proposal - Spring 2021
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1 Introduction

1.1 Objective

One of the biggest problems that new distance runners face is learning to pace themselves. Whether you are a high school track or cross country runner or just a casual 5K runner, you have probably experienced this issue. The most effective way to run a distance race is to keep a constant speed the entire time, and if you are not doing this, it will dramatically hurt your performance [1]. A lot of beginners will end up running too fast at the start of the race and have to slow way down by the end. While this issue affects beginners more dramatically, even very experienced runners have trouble with this as well. When you are looking to shave every possible second off of your time, perfect pacing matters a lot.

Our solution will create a device to help distance runners pace themselves perfectly along a standard running track. Our proposed solution is to create a miniature car that can maintain a precisely constant and adjustable speed on any standard running track in the world. It would utilize IR sensors to follow the lines around the track, and have an interface where the user could input distance, pace, or time. The runner would then run behind this car in order to maintain a constant pace throughout their run. We may also implement an option for more advanced users to start or finish their workout at a faster speed, in order to simulate an actual race.

1.2 Background

One of the members of our group, David, was a cross country and track runner throughout all of middle school and high school. He has first hand experience with the issues that beginner runners face, as well as experienced runners. Even after seven years of running, pacing was still an issue that was faced every single day. The runners at a track meet that sprinted out fast at the beginning of a race were rarely the ones who won it in the end.

Extensive research has been done on the subject, and researchers unanimously agree that maintaining a mostly constant speed throughout a distance race will lead to the fastest times [1]. There may be some slight exceptions depending on the race length and strategy, such as starting and ending the race faster than the middle [1]. Nonetheless, if a runner can develop the muscle memory for their desired race pace prior to the actual race, they can give themselves the best chance to run their fastest times.

In an effort to understand how important pacing is, even for olympic level runners, we can analyze Haile Gebrselassie's world record attempts for the marathon. At the 2007 Berlin marathon, Gebrselassie broke the world record with a time of 2 hours 4 minutes and 26 seconds [2]. He boasted he could run even faster, and planned to do it at the 2008 Dubai marathon. Well, he started off fast and completed the first half of the race in 61:27 which was 30 seconds faster than he ran in Dubai [2]. Unfortunately, this had detrimental effects on his second half of the race, and he ended up finishing in 2 hours 4 minutes and 53 seconds [2]. This goes to show that improper pacing dramatically affects the outcome of a race. On that day in Dubai, Gebreselassie may very well have had the aerobic capacity to break the world record again, but his eagerness to go out too fast hurt him in the end. Luckily for him, he was able to learn from this mistake and break the world record again at the 2008 Berlin marathon [3].

This example shows why GPS watches are so popular today, among serious and casual athletes alike. However, GPS watches can't provide very instantaneous feedback and are sometimes inaccurate, especially going around turns [4]. They also can't provide visual motivation like having a pace car in front of you would. These are the two issues our group is trying to solve with our pacing assistant.

There is no shortage of athletes that could benefit from this technology. The NCAA estimates there are over 800,000 high school track and cross country athletes in the U.S. alone [5]. Aside from that there many more college and professional runners, not to mention the casual 5K runner that just wants to run their fastest times. Our pacing assistant would be an incredibly helpful tool to many thousands of runners across the world.

1.3 Physical Design

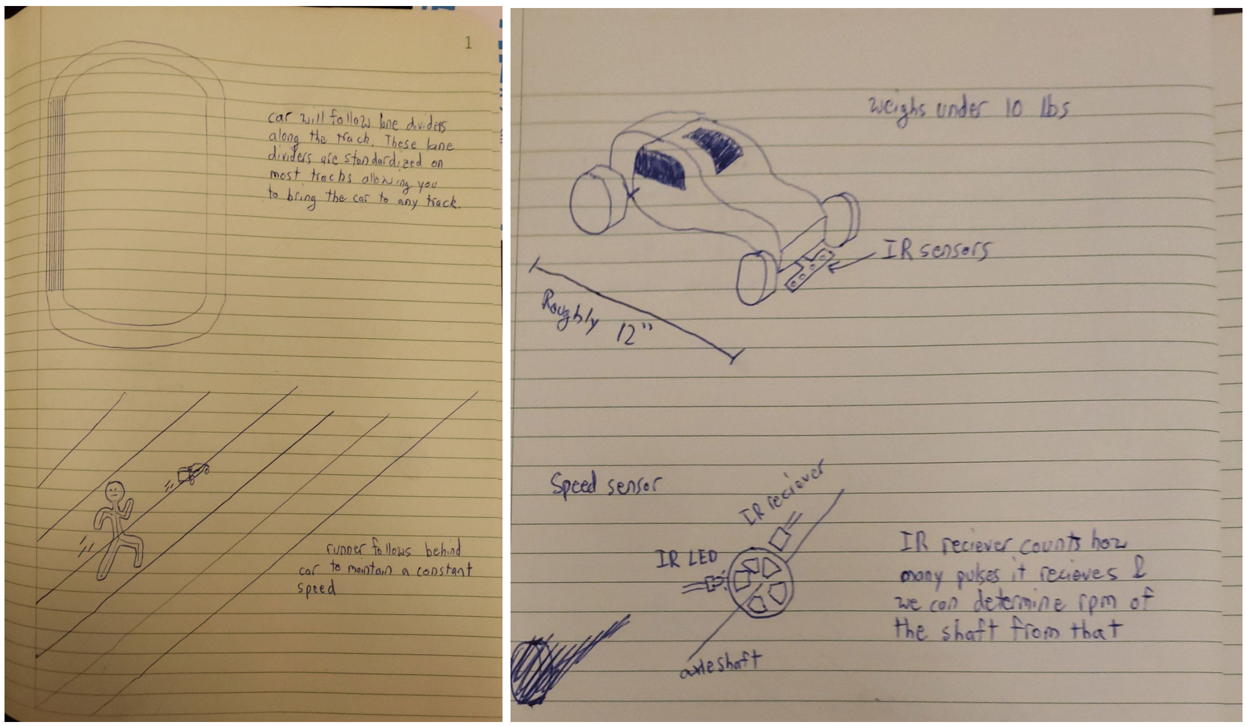


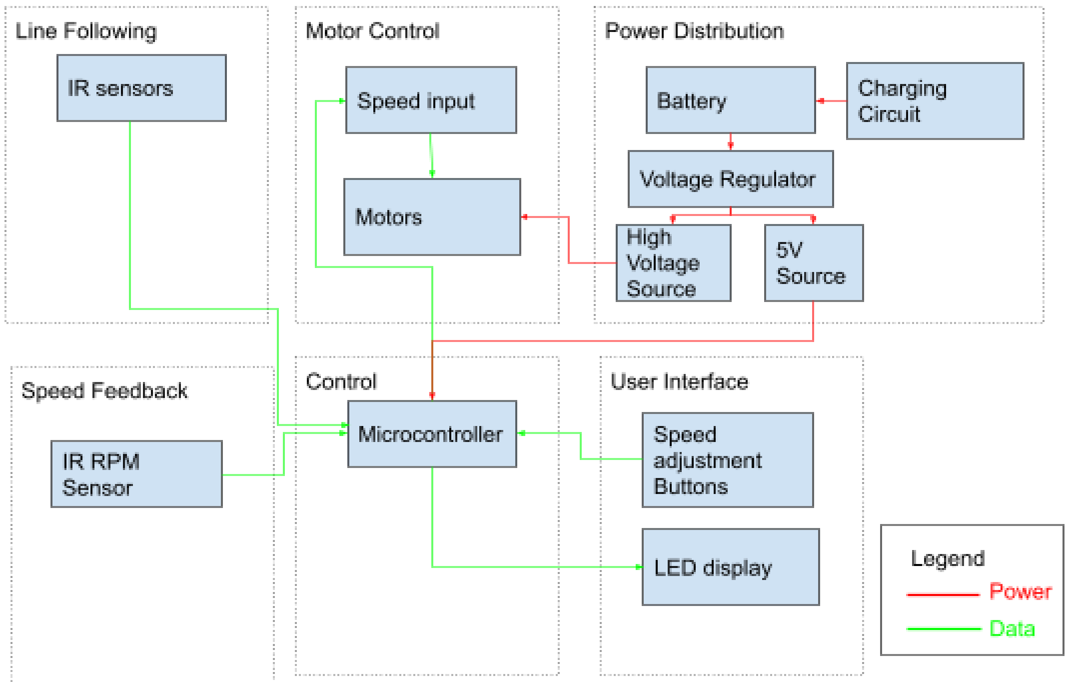
Figure 1: Running Pace Assistant Robot

1.4 High-level requirements list

- The robot must have adjustable speed ranging from between 1 mph and 10 mph.
- The robot must follow all typical Olympic track lane markers at all times.
- The robot must have a display showing set speed, distance travelled, and time elapsed. Distance, pace, and time must each be correctly displayed within an allowable percent error of 5%.

2. Design

2.1 Block Diagram



2.2 Functional Overview

<u>Line Following Module:</u>
The main function of this module is to drive the robot to follow a particular path. This achieves the second given high level requirement and is done with the help of IR sensors that will detect/follow one of the 8 white lines present on a standard running track. Data picked up by the sensors will be sent to the microcontroller which will determine the direction of the robot.

<u>Motor Control Module:</u>
This module works to accomplish the first and second high level requirements we proposed by acting as the speed controller for the robot. The module receives data from the microcontroller and this data is used to control two aspects of the robot.
The first part which satisfies the first high level requirement is setting the speed. The microcontroller will receive information from the used interface, based on speed values inputted by the user, which is then sent to the Motor Control module which sets the pace of the robot.

The second aspect is the direction. This along with the Line Following module satisfy the second high level requirement. Using data from the IR sensors, the microcontroller will inform the robot when and where to turn.

<u>Power Distribution Module:</u>
There are three main parts to this module: the charging circuit that provides power to the battery allowing the robot to last longer, the main battery that powers the whole project and the voltage regulator that powers the motor and microcontroller with their required specifications.

<u>Speed Feedback Module:</u>
This module allows the user to track his workout in real time. Using an IR RPM, the current speed and total distance travelled can be calculated. This information will then be sent through the microcontroller and outputted onto an LED screen so the user can keep track.

<u>Control Module:</u>
This is the most important module for this project. It is connected to every other module and all the data is processed here. There are three data paths that run through this module:
The first path is Line Following - Control - Motor Control. This data path is used to determine the direction the robot will follow. The data input comes from the IR sensors and is sent to the speed input which adjusts the direction and speed of the wheels.
The second path is User Interface - Control - Motor Control. This path allows the user to set the pace they want to follow. Using adjustment buttons the user sets and speed, this data is sent through the microcontroller to the speed input which adjusts the speed of the robot.
The final path is Speed Feedback - Control - User Interface. The input for this data path comes from the IR RPM sensors. It is then processed in the microcontroller and current speed and time elapsed values are sent to the LED display. This cycle allows the user to track their real time progress.

<u>User Interface Module:</u>
This module works to fulfill the third high level requirement. There are two parts to this module. The speed input buttons and the workout progress screen. The speed adjust feature allows the user to set their desired pace for the workout. This data is processed by the microcontroller and finally reaches the wheels for any speed changes. The second aspect involves a LED display that lets the user track their current progress. Using input from the Speed Feedback module, the microcontroller determines current speed and time elapsed and outputs it onto the user’s screen.

2.3 Block Requirements

Line Following Module:

Must be able to detect specified white lines on the running track. Must be able to differentiate between horizontal and vertical white lines (So robot does not get confused by extra markings on the track). Line deviation greater than 45° should not be considered.

Motor Control Module:

Must be able to regulate the speed of the wheels between 1mph and 10mph. Must be able to change direction of the robot when needed.

Power Distribution Module:

Must be able to deliver 5V +/- 0.1V to the microcontroller. Must be able to deliver specified power to the motor.

Speed Feedback Module:

Must be able to measure the RPM of the wheels, data used to calculate robot's current speed. Must be accurate to +/-0.25mph.

Control Module:

Must be able to interpret data from IR sensors to steer the robot toward the right path. Must be able to analyze data from the IR RPM sensor to determine the current speed of the robot. Must be able to pass the correct user specified speed to the motor control.

User Interface Module:

Must be able to accept an input speed and send to the microcontroller. Must be able to display current speed and time elapsed provided by the microcontroller.

2.4 Risk Analysis:

Due to the autonomous nature of our project, the greatest risk would be a malfunction of the motor control. The robot must be able to navigate a track field on it's own. As a result, the robot may continue moving if the user does not tell it to stop. It could cause an accident with other people on the track field if the robot does not stop properly to avoid collision. By installing an ultrasonic sensor to the front of the robot we can create an early warning system to tell the robot to stop when there are obstacles within 2 meters in front of it. Other failsafes would include stopping if the IR sensor no longer detects the white line that the robot is supposed to be following, which will prevent the robot from running off of the predesignated path.

3. Ethics and Safety

There are inherent risks to having a project which utilizes its own power system. The biggest of which is the method in which we store power for the operation of our robot. We will be using a Lithium-Ion battery, however, these batteries come with inherent risks if precautions are not taken [6]. Lithium-ion batteries may explode if handled improperly. In order to reduce risks, we will test our charging circuit to ensure that the battery does not achieve voltages above manufacturer specifications. The battery will be placed in such a way that padding will reduce impact if the robot were to run into objects or people, in order to prevent damages due to physical impact. Other problems may arise if the battery reaches extreme temperatures which may lead to battery failure or fire. In order to mitigate this risk, we will monitor the temperature of the battery to ensure that the temperature does not exceed 45C. Low temperature changing may also lead to battery damage. A warning will be posted to warn users that charging at low temperatures may lead to battery failure.

Although the design is autonomous, it will not utilize machine learning or artificial intelligence, instead it will solely rely on predefined use cases. However, this is still an autonomous vehicle and we must mitigate harm [7]. The biggest consideration is to prevent the vehicle from running into other people that are also running on the track. To do this, we implement ultrasonic sensors to tell the robot to stop if it detects anything within 2 meters in front of it.

We try to follow IEEE's code of ethics #1: "To uphold the highest standards of integrity, responsible behavior …" [8]. In doing so we must try to mitigate inherent risks of autonomous vehicles but we hope that our precautions will reduce chances of injury.

References

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