EEL 5666C

DAN Robot

Formal Report 1

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Abstract

This report serves to formally and thoroughly introduce the project I intend to complete during this semester. Named DAN Robot, the autonomous machine will work to dynamically navigate a pre-constructed course while actively looking for and responding to visual signals. The succeeding sections will include a detailed list of the sensors and actuators that will be on the robot and a breakdown of the planned behaviors.

Introduction

We are on the brink of a major societal shift due to the current progress that has been made with self-driving cars. It will change the relationship that people have with automotive vehicles and in turn, how people and things are transported. This technology accomplishes its goal using a multitude of sensors constantly gathering information (at an estimated speed of 1 GB per second[1]), while simultaneously utilizing pre-gathered GPS data to assist in path planning and navigation.

The robot I intend to build will attempt to replicate some of the functionality present in self-driving vehicles. Using a pre-defined track which the robot will have some knowledge of (simulating roads and GPS data), the robot will navigate the course from one pre-determined point to another. The robot will have its path planned out, but when presented with obstructed or restricted roads, the robot will reanalyze the course to determine and take the next best path to its destination. In addition, the robot will utilize computer vision to be on the lookout for 'street' signs that it will detect and appropriately respond to. This will include stop signs, turn signs mandating the direction the robot must take at the next intersection, and speed limits.

Integrated System

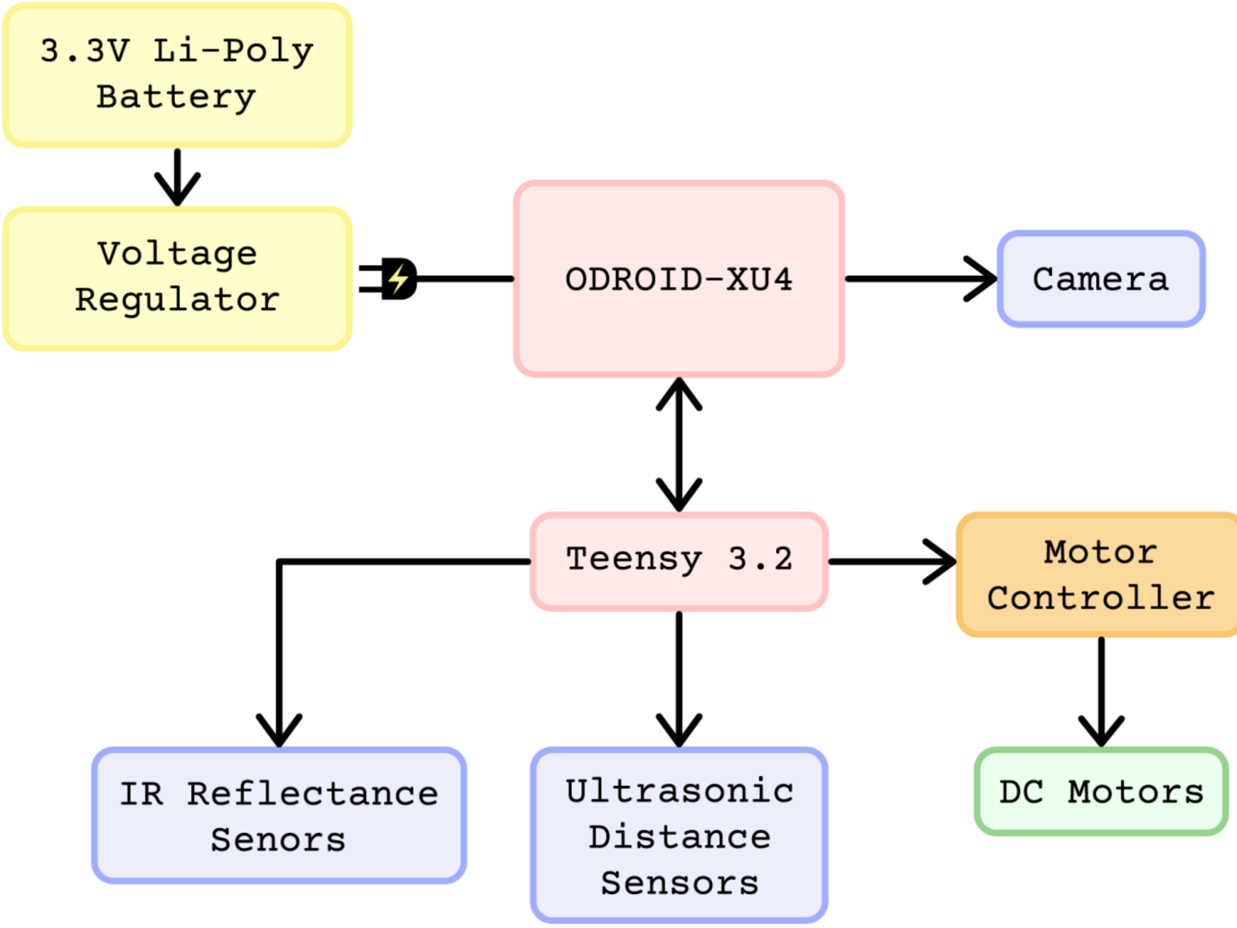

Figure 1

The robot will be entirely self-contained, not relying on any external device for processing or directing. The central processing device will be an ODROID-XU4 that will dominantly be utilized for capturing and processing visual data through the attached camera. The ODROID will also be responsible for planning the path using the knowledge of the course in conjunction with gathered data about the dynamic obstacles. The Teensy microcontroller will be responsible for the lower level sensors which include the IR reflectance sensors and the distance sensors. Also, the Teensy will be controlling the two DC motors via the motor controller. This will all be powered with a 3.3V, single celled, lithium-polymer battery stepped up to the necessary 5V.

Mobile Platform

I intend to construct the chassis of the robot with acrylic, it will be rectangular (currently planned at 115mm x 82.5mm) and will be at least two layers. My main goal for the overall construction is to make the robot as small as I can, chiefly for convenience in transporting both the robot and the track, but additionally, the size of the robot is inversely proportional to the complexity that I can make the course within a fixed area, so minimizing the robots size will also allow for a more complex course. The robot will have two independently driven, 32mm wheels and a single ball caster wheel.

Actuation

The actuation of the robot is minimal in that it only utilizes two DC motors for differential driving. The motors I have are Pololu high-power brushed DC motors with a 150.58:1 metal gearbox capable of up to 200 RPM with a 40 oz·in stall torque[2] (figure 2).

The only additional actuation that I may potentially need would be a servo motor that would have the camera or a distance sensor mounted on it. This would give the sensor a wider field of view, but I don't anticipate this to be necessary.

Figure 2

Sensors

For detecting obstacles, I will be utilizing the HC-SR04 ultrasonic distance sensor (figure 3). This sensor has a 30-degree field of view and can sense ranges between 2cm and 400cm[3]. The final iteration of my robot should only need a single forward facing distance sensor, but I may use three for the obstacle avoidance test.

Figure 3

To stay on the course, I will be utilizing multiple QTR-1A IR reflectance sensors (figure 4). They have an optimal sensing distance of 3mm and a maximum distance of 6mm[4]. While four of these sensors is ideal for line following, the design of the course may only require three sensors since the current plan is to only use intersecting straight lines.

Figure 4

Lastly I will be using a camera and OpenCV for the sign detection. The specific camera model is not yet determined, I have both a Logitech C270 and a PS3 Eye, and a final decision will be made based on a performance comparison between the two. Both are about the same size, and the Logitech camera has a higher resolution at 720p, but I will likely be scaling down the image anyway, so I will be leaning towards using the PS3 Eye since it is cheaper and thus I would have less reservations about dismantling it.

The computer vision technique I will use will also be the result of testing, as there are multiple methods of doing object recognition. Potential candidates include ORB (Oriented FAST and Rotated BRIEF), FLANN (Fast Library for Approximate Nearest Neighbors) feature matching, and HOG (Histogram of Oriented Gradients).

Behaviors

The robot has three main behaviors:

1. Stay on the course following the shortest path to the destination
2. Dynamically redetermine the shortest path when obstructions or restrictions are detected
3. Detect and appropriately respond to signs along the path

Behavior one requires the IR sensors to detect and stay on the track, essentially line following, and requires knowledge of the course as a whole to determine the shortest path. The course is planned to be a set of straight intersecting lines, so we have straight paths and intersections. Internally, the course will be represented by a 3D array. Each index of the array will represent an intersection on the track, each item in that array will be an array of three to four entries, each representing a possible direction at that intersection. For each direction, there will be two values, one indicating the distance to the next path (relative to other paths, so there will be path lengths of 1, 2, or 3), and the other value being the index of the intersection it leads to. This 'map' design may change depending on the final design of the course or to better accommodate the path planning algorithm. I plan to use Dijkstra's algorithm for solving the shortest path problem.

Behavior two requires both the distance sensor and the camera to determine if a given path is closed or obstructed. Once this is determined, the 'map' will be adjusted and Dijkstra's algorithm will be used again to determine the next shortest path.

Behavior three requires the camera and computer vision techniques to first detect and then identify and finally respond to signs. The robot will be familiar with all of the utilized signs so internally-held images can be used for feature matching with input images. Multiple object detection methods exist and potential candidates were explored in the final paragraph of the sensors section.

Conclusion

I believe that the current plan for DAN Robot is well realized. Once the chassis is constructed and parts are mounted, I can begin to use the sensors and actuators together as planned in the integrated system diagram (figure 1). The first step will be object avoidance which will demonstrate the autonomous interaction between the sensors and actuators. At that point, once the course is designed, I will begin working on the path planning, and once that is working, I will focus on computer vision.

I anticipate the computer vision to be the most difficult part of the project, so I will be working to quickly get the first two behaviors working so that I have ample time to achieve the third. I also believe that actually designing the course will be difficult because I want to make the course as complicated as possible to exhibit the robot’s intelligence, but I don’t want the course to be too large where it is difficult to fabricate or cumbersome to transport.

Overall, the plan for this robot is not to make a directly usable device, but to prototype behaviors and functionality that can then be applied to larger and more complex projects. With that said, I believe the functionality that I will achieve by the end of the semester demonstrate intelligence and a respectable feature set compared to the self-driving cars that I am attempting to model.

Documentation

1. Rayej, S. (2013, June 3). How do self-driving cars work? Retrieved January, 2016, from http://robohub.org/how-do-self-driving-cars-work/

2. Pololu - 150:1 Micro Metal Gearmotor HPCB. (n.d.). Retrieved January, 2016, from https://www.pololu.com/product/3066

3. Cytron Technologies. (2013). HC-SR04 Product User’s Manual (Vol. 1.0).

4. Pololu - QTR-1A Reflectance Sensor. (n.d.). Retrieved January, 2016, from https://www.pololu.com/product/2458