DIVIDE AND CONQUER
Senior Design 1
Group 13

Self-Propelled Robotic Car with Voice Command and Object Recognition

Group Members:

- Jorge Bulnes (Computer Engineering)
- Ryan Penland (Computer Engineering)
- Paola Londono (Computer Engineering)
- Dylan Rivera (Electrical Engineering)

Sponsor:

Professor Ying Ma

Customer:

Senior Design Professors (Lei Wei and Samuel Richie)

Motivation and Project Description:

There are many robots in the market that are able to navigate various landscapes through the use of sensory or visual detection. They can be expensive and many of them use their platforms for programming, or they are already programmed. A lot of them such as the Roomba allows for traversing environments, but do not have a full understanding of the environment around them enough to efficiently navigate the area around them without failure. Additionally, many of them don't have the capability of following voice commands to recognize a specific object.

Our group would be building a self-driving robot able to perform the following functions:

1. Navigates around any environment while avoiding obstacles
2. Takes simple voice commands using an integrated microphone
3. Successfully finds the point of interest that is mentioned in the voice command with the help of a camera and artificial intelligence.

Main Goal:

To build a functioning self-driven robotic car that can move front, back, left, and right, with the capability of following a basic and specific voice command that asks about finding a target and locating it while avoiding any fixed obstacles in its path. We must successfully apply machine learning and algorithms to be able to achieve our result.

Basic Goal:

To build a functioning self-driven robotic car that uses visual language navigation in a simple environment.

Stretch Goal:

To build a functioning self-driven robotic car with visual language navigation technologies that can avoid dynamic obstacles in a more complex environment.

Objectives:

1. Plan logistics pertaining to the project development, by identifying the necessary types of tools required to build our robot. These required tools include the investigation of hardware tools, such as types of chassis, tires or track systems, mechanical systems, sensors, circuits, etc., and software tools, like robotic programming languages, simulators, libraries, and middleware frameworks, among others. Planning will happen during the beginning of Senior Design 1
2. Investigate in depth the hardware and software technologies to be used for the development of the project. This step will include research from technology companies, academic papers, questions to experts on the topic, courses, videos, among others with the purpose to define specific tools, costs, and time requirements, among other constraints. This objective will happen during the first half of this semester.
3. Develop the software and design the hardware components of the robot based on the investigation results to test and correct any possible design error before incurring additional costs. This activity would happen during the second half of this semester.
4. Build the robot and integrate the software designed and developed during the design and development stage, identifying errors, and making corrections. This objective will happen mostly during Senior Design 2.
5. Test the programmed robot to identify necessary corrections and improve performance.

Requirements and Specifications:

There are many tools required to complete this project. We have concluded that we need to learn more about the types of sensors that could be used. The sensors include a type to help with the obstacle avoidance part of the robot, a camera, and a microphone. On the software side, we also need to start identifying the different libraries, languages, and platforms that can help us integrate all these functions into one program. Here is a short summary of what we have found so far with respect to the previously mentioned tools.

Obstacle Avoidance Sensors:

It is very important to have a really good sensor for our project. Something accurate and effective, but also affordable. There are many types of sensors in the market and some of the most common are light sensors, sound sensors, and proximity sensors. This is how they work:

<u>Light Sensors:</u>

Light sensors are used to identify changes in light or voltage. The two primary light sensors are photoresistor and photovoltaic. A photoresistor is a kind of resistor that changes with light intensity. That means the more light that's shined the less resistance. While photovoltaic sensors are mostly used to convert solar energy into electricity.

Sound Sensors:

This sensor (usually a microphone) identifies sound and, in return, sends a voltage that's equal to the sound level. If designed properly, a basic robot can navigate from the sound it receives.

Proximity Sensors:

They can identify the presence of a nearby object without any physical contact. These sensors work by transmitting electromagnetic radiation and examining the signal for any interferences. The three most common types used in robotics:

- Infrared Transceivers
- Ultrasonic Sensor
- Phototresister

The sensor we would need to use after this research is a proximity sensor because we want to build a robotic car that can detect objects around it and these types of sensors will be perfect to achieve this result.

Microcontroller:

The microcontroller is a smaller chip that has inputs and outputs which will be programmed to control our circuit and make it do various tasks that we will employ. There are many microcontrollers in the market and we are looking to possibly use the Arduino Uno R3 USB microcontroller as it is one of the more recommended ones in robotics development.

Microphones:

We are considering a few options. These are some of them:

UMA-8: (Price 105$ plus shipping):

The UMA-8 could potentially be a microphone that would be used for the project, this microphone has a beam-forming running across 7 microphones, which improves voice detection while having echo cancellation and noise reduction to reduce the effects of non-voice sounds(Like music playing, traffic noise, ambient noise, etc.). The ability for the UMA-8 is that you don't have to configure anything, you only need to connect it to the raspberry-pi and it works. It is a potential candidate since we have to find out which microcontrollers it is compatible with.

ReSpeaker 2-Mics Pi HAT (Price 35.39$ plus shipping):

The ReSpeaker 2-Mics Pi HAT is a speaker with two microphones on both sides of the circuit board to collect sound, it provides 3 APA 102 RGB LEDs, 1 user button, and

2 onboard Grove interfaces for expanding applications. It has a width of 30mm and a length of 65mm which is a great small-size microphone board. This is a great microphone used for IA assistance making it great for our product.

Adafruit Voice Bonnet for Raspberry Pi (Price 24.95$ plus shipping):

This specific microphone contains 2 microphones and two one-watt speakers, having an on/off privacy switch to deactivate audio for safety features, two analog microphones, two 1W speakers outputs, a 3.5mm stereo headphone or line-out audio for testing and it plugs into the Raspberry Pi, a 3 pin JST STEMMA connector as an extension for larger devices, and a push-button to change modes or activate the audio assistant.

Camera:

The use of the camera will be necessary for teaching the AI locations that the car will be navigating to, as well as identifying any obstacles it may need to overcome. For this, we feel that it is necessary to have a camera that has decent quality and a stable framerate. This is so the car does not have difficulty depicting obstacles at the speed at which it will travel. It is important to keep a low weight on the camera as well as a smaller form factor to make for an easy implementation onto the car. The camera must also be compatible with our microcontroller board. We are currently exploring camera options and will have to discuss with Dr. Ma to figure out what our budget can be for this camera as they tend to fluctuate in price depending on variables of weight, quality, and framerate.

Development Framework:

Due to the complexity of the robot, our team is considering the use of middleware that allows the connection of sensors, communication, mapping capability, machine learning, etc. There are many of these frameworks that can be used, even knowing that one of the most popular options is ROS. The advantage of using a robotic framework is that we can integrate the different aspects of the robot. The disadvantage is that we would require some additional training and that is time-consuming. Regarding cost, some of these frameworks are open source, so the expense would be more associated with the hardware part of the project.

Some of the names found for possible development frameworks are YARP, POCOLIBS, OROCOS, ROCK, and ROS. More middlewares are used in robotics, but we would need to review them before choosing the best option.

Libraries:

Based on the language, many robotic libraries can be used. For example, if our team decides to use Python, there are many libraries, for example Robot Framework, Pyro, DART, PyRobot, PyDy, SOFA, Klamp't, Pybotics, Siconos, iDynTree. If C++ is chosen, an alternative is Robotics Library.

One very popular name is PyTorch, being big in the research world. Another very popular name is TensorFlow. They are popular because they are free, open source, and are libraries for machine learning, which we would need for this project. One of the advantages of TensorFlow, for example, is that it can be integrated with ROS, and it can be used for different programming languages, such as C++, Java, and Python.

Project constraints to consider:

- Time
- School
- Work
- Knowledge of topic /Learning Curve
- Cost
- Emergencies
- Deadline
- Benefits
- Scope
- Implementation of software/hardware

Project Standards to consider:

- Safety
- Testing
- Communication
- Documentation
- Design
- Programming Language and Libraries
- Development Frameworks
- Data Formats

Block Diagrams:

Software Block Diagram:

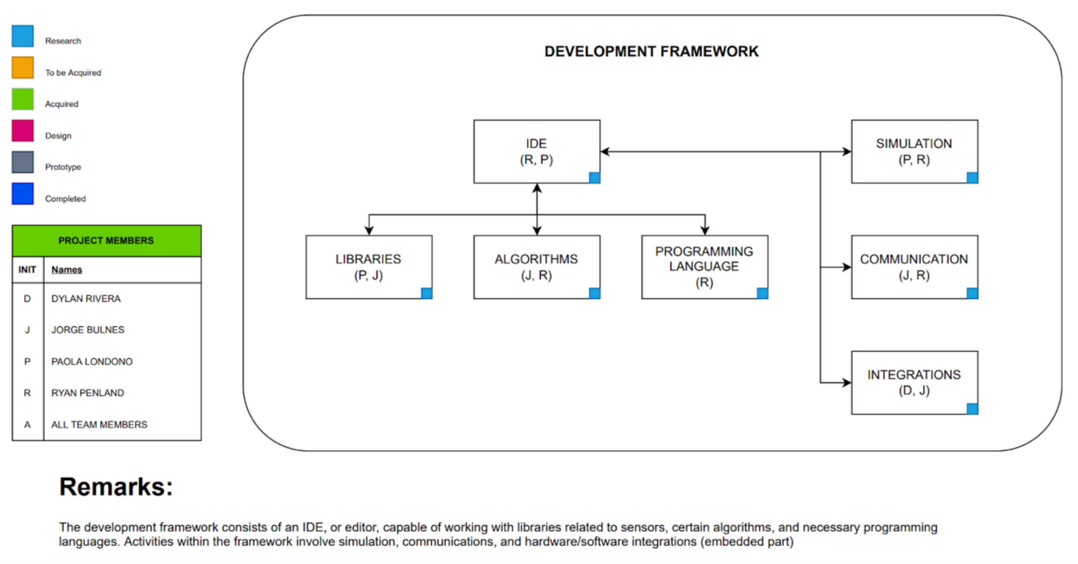

Figure 1: Software Block Diagram

Hardware Block Diagram:

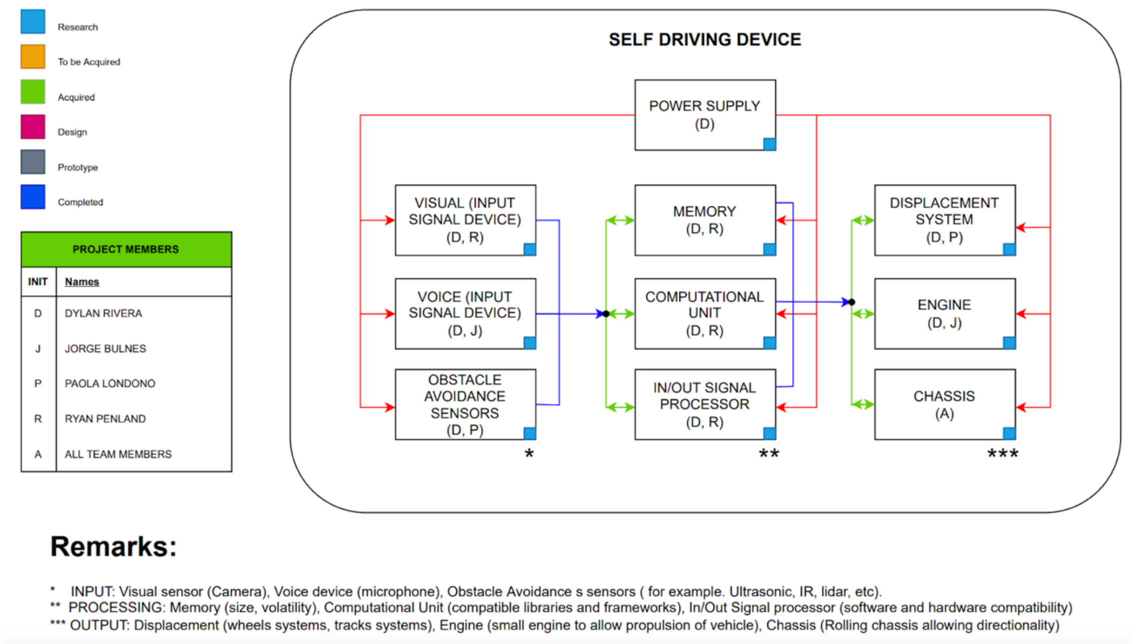

Figure 2: Hardware Block Diagram

Budget and Financing:

All of the materials will be paid for by our sponsor, Dr. Ying Ma. To receive our funding, we have to organize a BOM and submit a proposal to her with valid reasoning for the parts we are requesting to order. This needs to be done relatively early, as the prices of these materials as well as their availability are changing rapidly in this climate.

Some of the parts that are needed to build our robot are listed below. Once the further investigation has been completed, we will be able to determine a more accurate budget amount to present to Dr. Ying Ma:

<u>Sensors connections:</u>
Obstacle avoidance sensors
Microcontroller(s)
Microphone
Camera

<u>Car:</u>
Tires or tracks
Chassis
Cables
Pins
Battery
Mechanical System
Maybe a controller for the emergency stop button

<u>Tools:</u>

Multimeter
Oscilloscopes
Probes
Screwdrivers
Hammer
Solder
Soldering station

Initial Project Milestones:

For Senior Design 1:

We must have all of the schematics and design-related documents in order so that senior design 2 can begin smoothly. It is also necessary that we start acquiring the parts that are necessary for the development of the car as early as possible. This will be important so that there are no last-minute issues, or surprises when we get back from winter break. These things are in addition to the final paper that we will be submitting.

For Senior Design 2:

Our main Milestone is to build a fully functional robot effectively and efficiently (time and cost). Week by week we will need to benchmark any work that has been done to the project as well as test each part we implement. Stress tests will be necessary for the algorithm.

Team Organization:

The project responsibilities will be mostly shared except for very specific tasks that would be assigned to a specific member. At the beginning of the project, all members will be investigating existing technology sources, and during development, the workload will be divided in the following way:

Dylan Rivera (Electrical Engineering):

- Build car
- Design Circuit
- Solder Circuit
- Test Circuit
- Make appropriate connections

Jorge Bulnes(Computer Engineering):

- Help Building Car
- Micro-Controller setup
- Microphone setup in the car
- Deep learning implementation

Ryan Penland(Computer Engineering):

- Help with the design of the car
- Building of the car
- Deep learning algorithm implementation
- Microcontroller configuration

Paola Londono (Computer Engineering):

- Help build the car
- Microcontroller configurations and sensors connections
- Deep learning algorithm implementation
- Algorithm Testing

House of Quality Diagram:

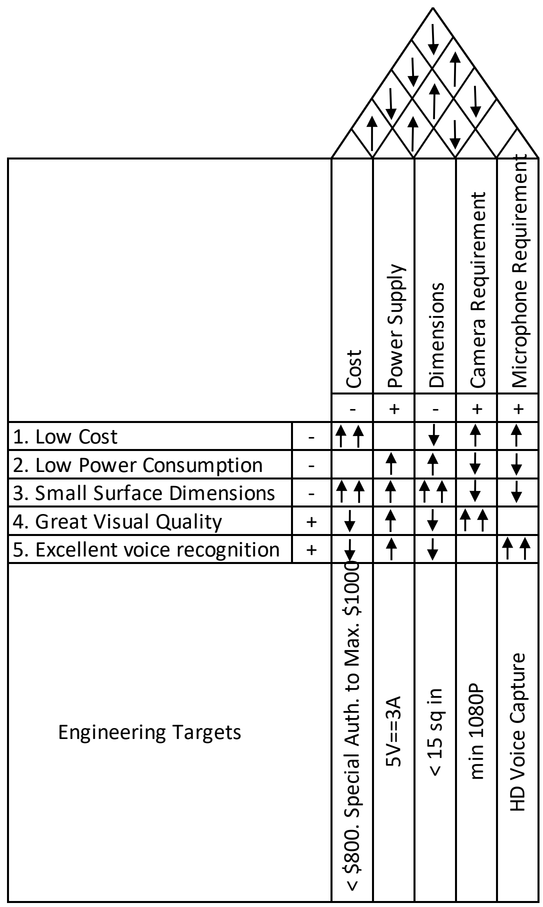

Figure 3: House of Quality Diagram.

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