Team 8 - Nissan Leaf Driving Simulation Project Proposal

Michael Mollica, Chase Colotta, Brett Harden, Ethan Powers, Gerardo Mateo
ECE Department
Tennessee Technological University
Cookeville, United States

mamollica42@tntech.edu, cdcolotta42@tntech.edu, bpharden42@tntech.edu, espowers42@tntech.edu, gjmateolar42@tntech.edu

I. INTRODUCTION

The Nissan Leaf Vehicle Simulator project has been an ongoing senior design project in the Mechanical Engineering (ME) department at Tennessee Technological University for several years. Most recently, the project goal was to create a real-time driving simulation using external controls. Now, the Electrical and Computer Engineering (ECE) department has been asked to collaborate with the ME department to re-implement the driving simulation using the hardware of a 2014 Nissan Leaf.

Given the alarming number of casualties from automobile accidents each year, an accurate driving simulation has the potential to teach and prepare new drivers without the risk of injury to themselves or others. As of 2016, the National Highway Traffic Safety Administration (NHTSA) reports an average of 95 fatal accidents per day [1]. A product of this nature could be implemented in high schools, driving schools, and DMVs across the nation. With proper use, insurance claims and fatalities behind the wheel could decrease significantly in the coming years [2].

Team 8 intends to replace the controllers that interface with the simulation to the Nissan Leaf's hardware which includes, but is not limited to the steering wheel, petals, and shifter. The use of this hardware will still provide real-time and accurate inputs into the simulation to provide the most realistic driving experience possible to its user. In order to achieve this goal, the car must be powered and tested for the data outputs from the Controller Area Network (CAN) bus, Nissan sensors already inside the vehicle, and external sensors installed by the team. The CAN bus is the highway for all data being communicated between different systems of a vehicle. Thus, the CAN bus contains useful information about steering angles, throttle position, gear position, and brake status. The team will not pull data from the CAN bus because data will not be able to be decrypted, but the team will still read its outputs. The Nissan sensors and external sensors will be the target for data acquisition. To extract data from the sensors and interpret their outputs, the team shall connect the outputs of each sensor to a microcontroller via General-Purpose Input/Output (GPIO) ports. Due to the real-time constraint, this microcontroller will have a clock frequency of no less than 16 MHz to read and write data quickly. Sending data to the simulation is beyond the scope of this project, but the data will still be collected and stored for future capstone teams in an excel spreadsheet.

II. BACKGROUND

Currently, the simulator has five main sections as depicted in Fig. 1.

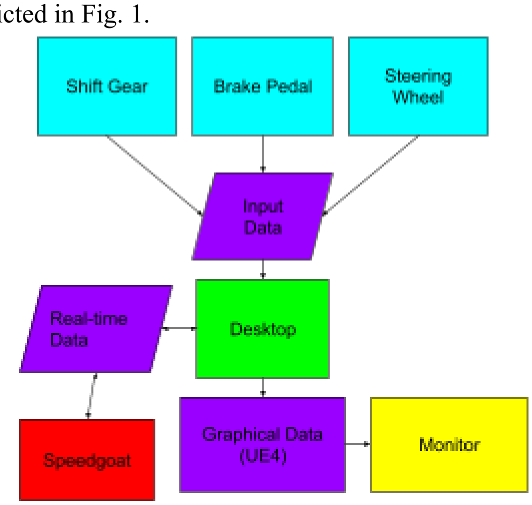

Fig. 1. Current Data Flow of Driving Simulation

The input controls are Logitech G29 steering wheel and petal and a compatible Logitech shifter device [3]. These devices are connected into the personal computer (PC) via a USB port. Once the PC receives the inputs from the devices, they are fed into the Speedgoat, which runs a real-time MATLAB script to calculate accurate driving physics [4]. The output calculations of the Speedgoat are then reintroduced to the PC to create the graphics for the simulation based on the original inputs from the controls. Finally, the graphics are displayed on a high-definition monitor via an HDMI output.

The Speedgoat is a real-time simulation device that runs MATLAB seamlessly [4]. This external device connects to the PC to retrieve inputs to be processed on the CPU and provides the corresponding outputs from the MATLAB script to be fed back into the PC or any other I/O connected

A. Existing Solutions

A Nissan Leaf driving simulation does not yet exist and can not be purchased on any consumer market. However, there are many advanced videogame driving simulations that exist for various gaming consoles and gaming computers for games such as *Forza Horizon 5* and *Gran Turismo 7* [5]. These simulators can include racing seats, gas petals, brake petals, clutch petals, steering wheels, paddle shifters, and manual shifters. For a gaming experience, they provide an immersive feel for the user, but without a gaming system to connect to, the simulators are simply useless hardware. Additionally, the driving simulators that exist for gaming do not have true brand specific parts. That is, there exists no driving simulation that uses the exact hardware of a commercially produced vehicle from any manufacturer.

For non-gaming experiences, there exists many realistic vehicle driving simulations using actual vehicle manufactured hardware, but they are not for commercial use. These existing simulations are solely for use by the manufacturers of the vehicle. The Nissan simulator designed by the team could be used in the consumer market, unlike these existing simulators.

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III. SPECIFICATIONS

The overall goal of the complete capstone project is to test and collect all data from the four targets of the driving simulation inputs. This includes: using the Nissan's hardware, providing the simulation with real-time inputs and outputs, and maintaining the look and feel of being inside of a stock Nissan Leaf. To maintain the look and feel of the Nissan Leaf, the team shall use the original hardware of the vehicle and prevent the external devices from being in plain sight while sitting in the front seat. The hardware in use includes the steering wheel, brake petals, gas petals, Controller Area Network (CAN) bus, On-Board Diagnostics (OBD), shifter, and the Heads Up Display (HUD). Data acquisition is to be from the OBD and CAN bus as much as possible, given the constraints from Nissan's encryption on their data. All other data that must be obtained to have the simulation function properly shall be from external sensors installed by the team on the appropriate Nissan hardware.

In order to power the vehicle and its surrounding components, an external power supply will be used. The power supply is to be a 12V supply that connects to a standard 120V outlet. In the event the use of an external sensor is necessary, a DC voltage amplifier with a negative gain will be used to step down the 12V signal to an appropriate voltage required for the sensor(s).

A. Constraints

The specifications of this project contain three major constraints: time to reach the solution, real-time speed of processing, and Nissan's data protection. The data acquired from the CAN bus will be encrypted and therefore will not be able to be used to send inputs into the simulation. Attempting to decrypt the CAN bus could take over three months. This may prevent sending the outputs of the sensors and hardware to the simulation. However, the data can still be tested and organized for the future teams to use in order to finish the overall simulation. In regards to real-time, some sensors or data processing within the OBD may not meet the desired speeds to be considered real-time. Real-time speed shall be no more than 20 milliseconds. The goal to overcome this constraint is to use the fastest and most efficient parts within the budget of the project. With clever engineering solutions, the team is confident that real-time data transfer can still be done. Finally, Nissan's data protection most likely can not be overcome unless an authorized personnel from Nissan gives the team and its associates permission. In the event data from the CAN bus is unobtainable due to their protection protocols, the team will continue with using additional external sensors and other hardware to acquire appropriate data.

IV. PROPOSED SOLUTION

The following Figure contains a step-by-step roadmap to achieve the proposed solution.

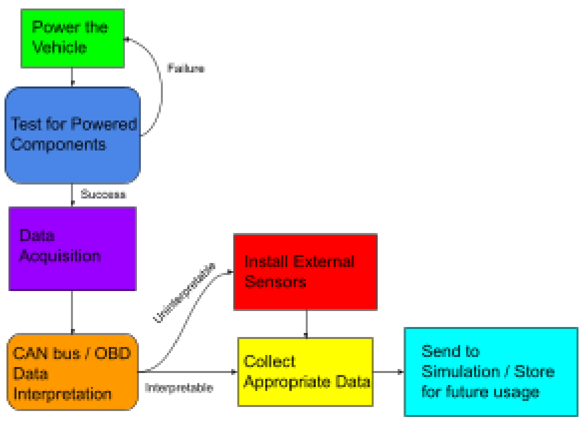


Fig. 2. Project Roadmap

As seen in Fig. 2, the first step toward the solution is properly powering the vehicle and its components that must be used in the simulation. Once the power supply is connected to all appropriate hardware, each device will then be tested for functionality to ensure it receives the correct amount of power. Upon success or failure of the components to be powered properly, a different approach to the supply of power shall be taken.

Once the CAN bus and/or OBD is powered, data acquisition will begin. The CAN bus data will be the primary target for the team to interpret and use for sending information to the simulation via the Speedgoat. Decryption will be necessary in order to accurately read the data from the CAN bus. The team's approach to decrypting the CAN bus will be to meet with faculty members in the ME department who have done research on the Nissan Leaf model in the past or attempt to gain contact with a Nissan representative who will supply the team with a method to decrypt/interpret. In the event decryption of the CAN bus is infeasible, the secondary target for data acquisition will be the OBD.

Theoretically, the OBD contains most of the data necessary for the simulation to function. However, concerns arise with the time it takes for the OBD to supply information versus the CAN bus. There are three possible outcomes using the OBD as the target. The first possible outcome is that the OBD contains all information necessary in a real-time manner. This means the speed, the gas pedal position, brake position, gear, and steering wheel position can be read quickly and successfully. The second possible outcome is that all relevant data can be read, but the time of acquisition is too slow to be considered real-time. The last possible outcome is that the data can not be read whatsoever. In the cases of the last two outcomes, the team shall resort to the use of external sensors as the target for data acquisition.

In conjunction with the ME team, the ECE team will have to install sensors on the vehicle in the case where the other options of data acquisition fail. These sensors will most likely be angle sensors to detect the position of the steering wheel, brakes, and gas. The ECE team shall select the appropriate sensors for each component of the simulation and collect the data retrieved by the sensors. The ME team will assist in the mounting and installation of the sensors to ensure they are appropriately positioned on each component and capture the motion of the components correctly.

In any case the ECE team is able to retrieve data, some form of data management must be done. Ideally, the team will have enough time to gather and input data into the simulation in which storage is unnecessary. In reality, the time frame will be too limited to do so. When data is collected from our target, it shall be stored in an excel sheet with highly detailed descriptions of its origin, its values, its size in bits, and its destination for future work on this project.

A. Broader Implications and Ethics

The Nissan Leaf Driving Simulation does not involve many ethical concerns. There is minimal risk of endangerment for users of the simulation or bystanders. One primary concern arises with the pivoting of the front wheels when the steering is turned. To eliminate this risk, the team will install a barricade between the front of the vehicle and bystanders to prevent contact between them and the wheels. Both the ME team and the ECE team will experience the most risk while working with the vehicle. Primarily, it is of utmost importance to take all precautions necessary when dealing with potentially hazardous electrical equipment such as the power supply as outlined in the Institute of Electrical and Electronics Engineers (IEEE) National Electrical Safety Code [6].

Future work on this project can lead to a fully implemented driving simulation using all the available peripherals of the Nissan Leaf. A driving simulation of this type is highly reminiscent of an actual on-the-road experience. Therefore, it could significantly assist the training process for new drivers before they ever operate a real vehicle. In doing so, fatalities behind the wheel and other minor car accidents may see a large decline [2]. The current team's work will leave the next several capstone groups with useful data to pull from the sensors from the vehicle. The goal is to leave future capstone groups with organized and readily available data to transfer into the simulation to complete the customer's request.

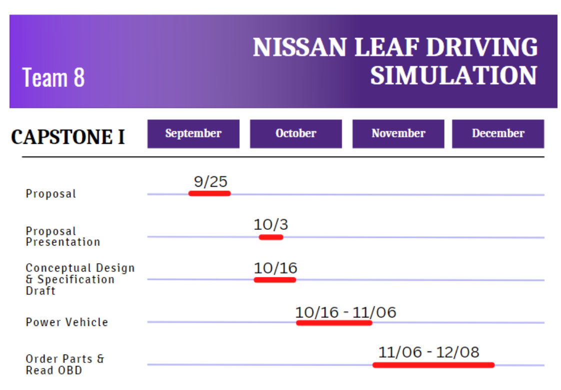
B. Measure of Success

Several steps must be taken to appropriately measure the scale of the team's success. In order to keep track of progress within the objective, the team shall conduct a plethora of tests in each phase of the project. The first testing that will occur will be to ensure the power supplied to the vehicle and its components is appropriate and safe for normal usage. This shall be done by testing each component with a voltmeter. If the voltage read by the voltmeter is incorrect in any manner, the team shall reconfigure the voltage supply and/or install other circuitry to ensure the voltage supplied to each component is appropriate.

Once the components of the vehicle are properly powered, data collection must occur. The second testing phase will be to acquire the data from the CAN bus, OBD, and/or sensors and interpret them accordingly. This will involve several stages of trial and error when reading inputs from the data sources. When inputs are collected, the team will create some form of test case to compare each input with its expected outputs. This will include applying all possible combinations of inputs to the sensors and deciphering all outputs read from the OBD or CAN bus in the vehicle. When sufficient data is collected from the sensors, CAN bus, and/or OBD, the testing will cease until the data can be transferred to the simulation appropriately.

Given the complexity of this project and the amount of data collection and reverse engineering that must be done in order to fully implement the driving simulation, the team's measure of success will have limits. Realistically, the goal will be to install all necessary sensors and retrieve all necessary data to feed into the driving simulation. For the data to be considered successful, the data must be sent in a real-time manner of no more than a 25 millisecond communication speed. This communication speed should be no issue with modern sensor technology and a 16 MHz processor. The implementation of the data into the simulation itself is beyond the scope of the project in this timeframe of approximately seven months. However, if data acquisition proceeds quicker than expected, the team may be able to begin the process of transferring data into the simulation. Overall, the success of the team will be measured on how much data can be retrieved and how accurate the data from the Nissan Leaf and its surrounding sensors are.

The team expects the powering of the vehicle phase to span only within the first month of embarking on the project. Data acquisition and writing the algorithms to the microcontroller for sensor data interpretation will take the majority of the time frame given for the project. The team estimates approximately three to four months. However, those three to four months will include all troubleshooting and external sensor installation if need be.



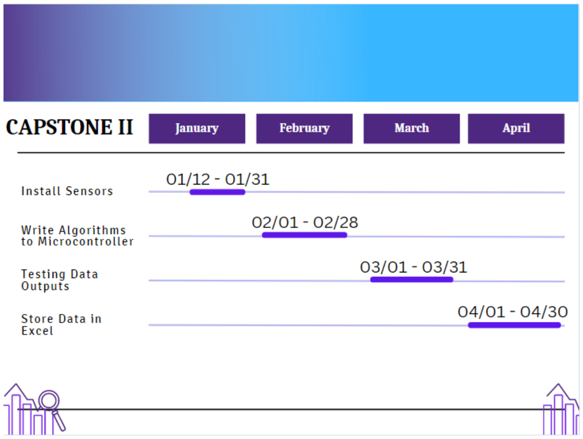


Fig. 2. Tentative Timeline

V. RESOURCES

Tools and resources necessary for project completion include, but are not limited to the following:

- OBD reader
- 12 V DC power supply
- Angle sensors
- Distance sensors
- Mounting tools for sensors
- Software tools
- Speedgoat modifications
- Multimeter

Some of the tools required are already in possession of the team or the university, which will save on the overall budget of this project. The table below outlines an approximate budget and total cost for the project.

TABLE I. PROJECT BUDGET

Resource	**Expected Quantity**	**Estimated Unit Price ($)**	**Total Cost ($)**
OBD Reader	1	100	100
Angle Sensor	3	20	60
Distance Sensor	1	10	10
Mounting Equipment	4	2	8
Software Tools	2	50	100
Speedgoat Modification	1	100	100
Multimeter	1	40	40
Microcontroller	1	100	100
TOTAL			**518**

A. Personnel

The project will require a multitude of skills that intersect both electrical engineering (EE) focuses and computer engineering (CmpE) focuses. Power is the first step in the process of completion and will be dependent on the EE students. The power supplied in this project will be DC and may include some form of voltage stepping down to meet the specifications of the hardware in use. Skills such as circuit design and knowledge of voltage amplifiers will be required. For the CmpE students, low-level programming may be necessary to communicate between the sensors and the components used for testing. Additionally, an external processor and accompanying peripherals may be used to collect data via I/O pins and then store in memory for future usage. Most of this work will require some experience working with embedded systems.

VI. REFERENCES

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