Vehicle Model: First Semester Report

Autonomous Golf Cart Project

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May 2020

Contents

1 Abstract

This report describes the Simulink model for a golf cart accomplished in the first semester of the Autonomous Golf Cart Project, which has the long term goal to modify an ordinary golf cart into a fully autonomous vehicle. This report will focus on the first version of the vehicle model, designed to be integrated with a ROS network (group of nodes that are interconnected and communicating, allowing the exchange of information between different components of a robot system) and a MatLab App (interface between user and computer/network), both designed by other project members throughout the semester.

2 Introduction

2.1 Basic Approach

To simplify the modeling process and make it more efficient, the vehicle is divided into subsystems. Each subsystem is modeled individually and the respective models are subsequently combined to form the full cart model. Considering the golf cart specifications and the early stage of the project, the main subsystems implemented were “Vehicle Body”, “Braking” and “Motor/Motor Controller” (Figure 1). The goal of this primary approach is to build a model for a vehicle that accelerates and brakes successfully, following values provided through the ROS network and returning information (such as instantaneous velocity and acceleration) as feedback. Once this basic model for the cart is accomplished, subsystems for “Steering”, “Sensor Data Processing” and “Output Processing” will possibly be added.

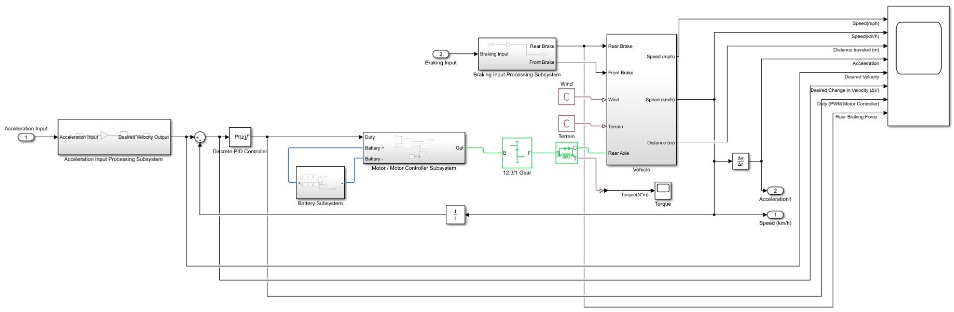

Figure 1: Full vehicle model and subsystems

2.2 Simscape Implementation

Using block diagrams, Simulink allows modeling, simulating and analyzing systems. Within Simulink's environment, Simscape is an added feature that enables the modeling of physical systems by using blocks that represent physical components with physical connections. Two options were considered when deciding how to approach vehicle modeling on MatLab: taking a strictly equation based approach using basic Simulink blocks or taking a physical modeling approach by integrating Simscape and Simulink. Since using Simscape was significantly more intuitive and allowed a more accurate representation of the actual golf cart systems, the second approach was chosen.

3 Current Vehicle Model

3.1 Vehicle Subsystem

The main component of this subsystem (Figure 2) is the "Vehicle Body" block (highlighted in Figure 3), which allows the customization of a set of parameters (such as mass, number of wheels, height and frontal area) in addition to having inputs for headwind speed and road inclination angle. This block represents a two-axle vehicle and accounts for weight distribution due to acceleration, road incline and aerodynamic drag, while providing outputs for horizontal motion, front and rear normal forces and velocity of the vehicle.

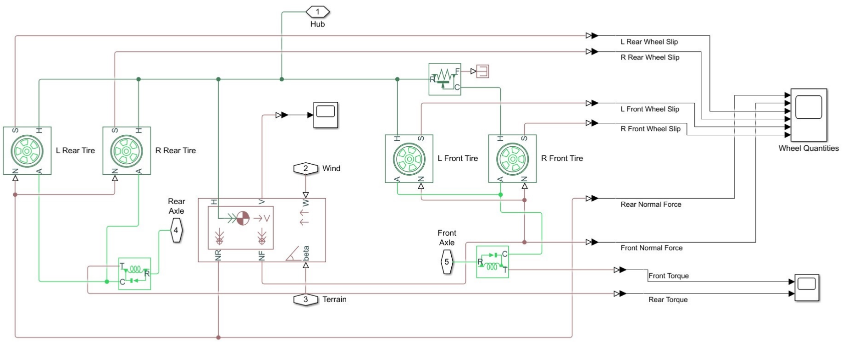

Figure 2: Vehicle subsystem

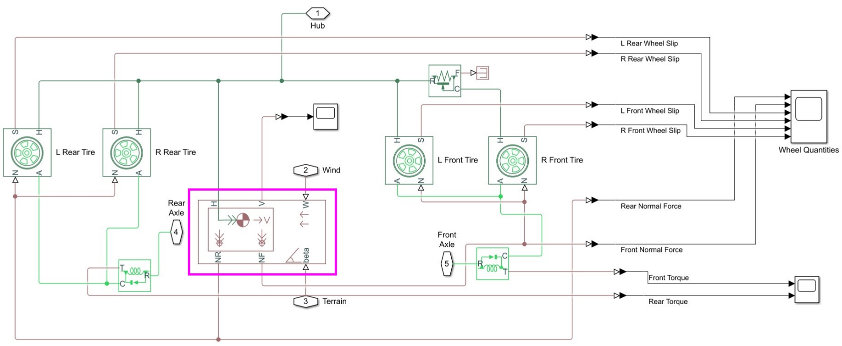

Figure 3: Vehicle Body block

Connected to the "Vehicle Body" block and receiving the values respective to front and rear normal forces are four "Tire" blocks, two for each axle (highlighted in Figure 4). The tires follow the "Magic Formula" tire model, which rely on a series of mathematical formulae and the tire's coefficients to calculate the interaction between tire and road, publishing the tire slip and the transnational motion of the wheel to their respective outputs.

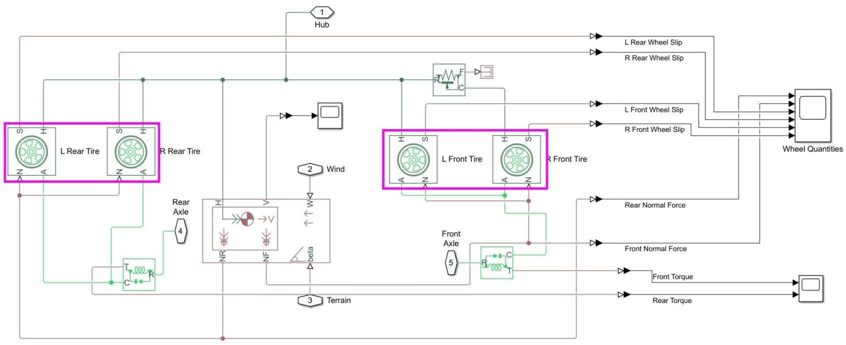

Figure 4: Tire blocks

3.2 Braking Input Processing and Braking Subsystems

Connecting the ROS network and the model, the braking input forwards information regarding the percentage change in the braking pedal position. In this setting, 0% means that the braking pedal is not pressed (no change in position) and 100% means that the braking pedal is fully pressed. This percentage is multiplied by the maximum braking force (in Newtons), resulting in the braking force applied being proportional to the braking pedal position (Figure 5).

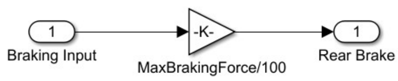

Figure 5: Braking input processing

The respective braking force desired is then supplied to the cart's braking subsystem (Figure 6), which consists of a "Double-Shoe Brake" block for the rear part of the vehicle. Several parameters can be determined within the "Double-Shoe Brake" block (as drum radius, shoe span angle and friction coefficient) and the resulting drum shaft rotation is subsequently directed to the vehicle body subsystem, more specifically to the wheels.

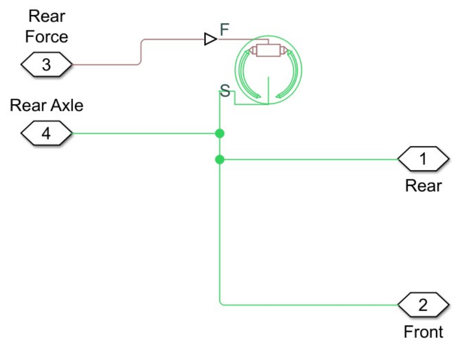

Figure 6: Double-Shoe Brake block

3.3 PWM Motor Controller

Pulse Width Modulation (PWM), is a technique used to control the speed of a DC motor by regulating the voltage across its terminals. The method consists of turning the power source on and off repeatedly and at a high frequency, which creates a square wave with maximum value being the maximum voltage provided by the battery and the minimum value being zero. The proportion between the amount of time the voltage provided is maximum in contrast to when it is 0 determines the duty cycle and the average voltage supplied.

The first model designed for the PWM motor controller (based on a switch mechanism) is not ideal to implement because, although resulting in an accurate representation of the system, its compilation is extremely time-consuming (Figures 7 and 8). As an attempt to overcome this problem, the second design of the PWM controller consists of a mechanism that supplies a voltage proportional to the duty cycle inputted and it is undoubtedly faster to compile but not accurate (Figures 9 and 10).

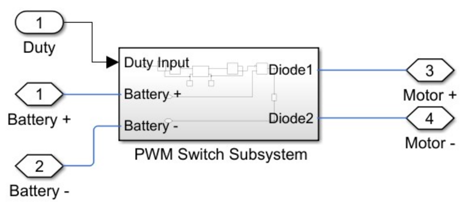

Figure 7: PWM Switch Mechanism

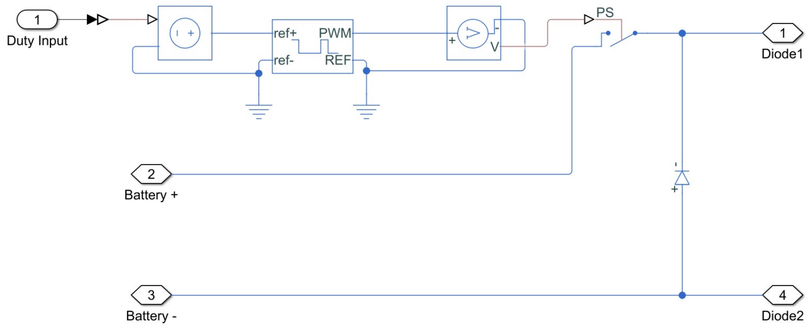

Figure 8: PWM Switch Mechanism Subsystem

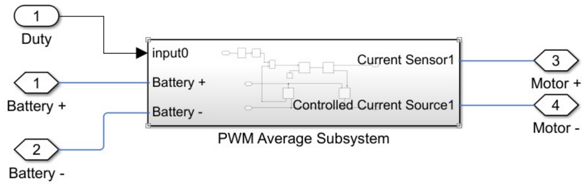

Figure 9: PWM Average

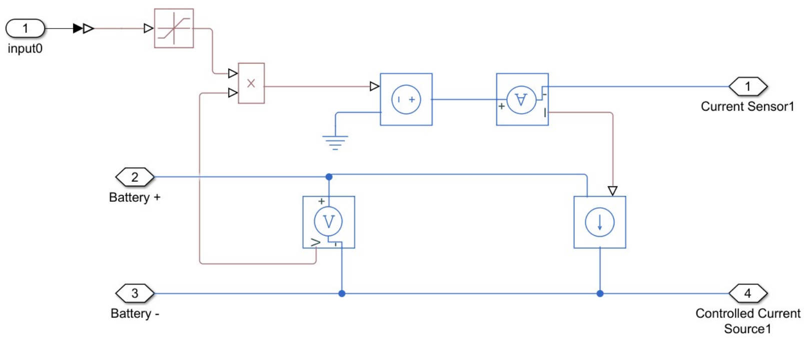

Figure 10: PWM Average Subsystem

3.4 Motor Subsystem

Prioritizing simulation efficiency, the average duty cycle based PWM motor controller was chosen and implemented in the "Motor/Motor Controller" subsystem, which receives voltage from six 8V batteries and delivers it to a 48 volts DC motor. The motor is connected to a transaxle consisting of double reduction helical gears with 12.3/1 direct drive axle and the new rotation is subsequently directed to the vehicle body subsystem. Because Simscape's and Simulink's libraries do not include a transaxle block, a "Simple Gear" block was used in the model, with gear ratio set to 12.3/1 (Figure 11).

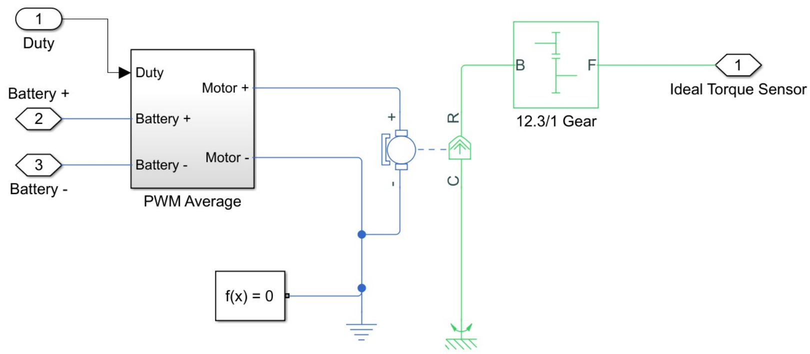

Figure 11: Motor Subsystem

4 Conclusion and Next Steps

Although the original goal for the semester was to adapt the golf cart and implement a drive by wire system, COVID-19 pandemic and its repercussions forced the group to take a different approach and scale down the semester's objective for the project. The new objective was to successfully design and integrate a ROS network, a vehicle model and a MatLab App.

The current vehicle model successfully accelerates and brakes, following the inputs supplied through the ROS network, set by the user/driver while using the App. The main issue encountered was the inefficiency of the model in reaching the golf cart's maximum speed (the model reaches only 16km/h while the golf cart reaches approximately 24 km/h). Moving on, the goals for this vehicle model include integrating new subsystems (as steering and sensors) and readjusting the current components to more accurately and effectively represent the golf cart (allowing it to reach the maximum speed, among other things). Additionally, the goals for the project are to adapt the golf cart to implement a drive by wire system and to improve the app, providing a more appealing interface.