MRSD Project Course

Team I – AIce

Autonomous Zamboni Convoy

Individual Lab Report 02

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1. Individual Progress

In the past week, I have identified some preliminary hardware solutions for converting the Zamboni into a drive-by-wire (DBW) vehicle. Converting the Zamboni to a DBW vehicle requires that three main functions can be controlled via an electrical signal: accelerating, braking, and steering. After doing some research, it appears as though the first two of these, accelerating and braking, can be accomplished by the current Zamboni. The ice resurfacer comes equipped with a Sevcon Gen4 controller that is connected to the accelerator pedal and controls the electric motor used to drive the Zamboni. After reading through the reference manual for the controller, I found that a switch or analog input signal can be sent to the controller as a footbrake input. The controller uses CAN communication, so by sending the correct CAN commands, we should be able to control the velocity of the Zamboni.

Implementing steering-by-wire proved to be more difficult. As it is designed now, the Zamboni uses power hydraulic steering to turn the front wheels. This system is shown in Figure 1 below. The most noteworthy component in Figure 1 is the steering control valve attached to the end of the steering column (item 6). This valve directs fluid flow to different sides of the steering cylinder as the wheel is turned and requires the mechanical input of turning the wheel to do so.

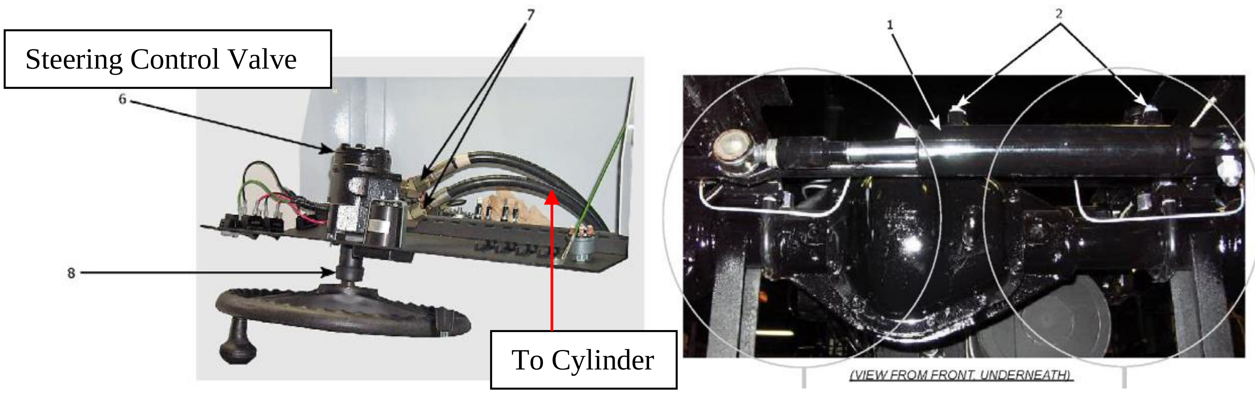

Figure 1: Hydraulic powered steering of Zamboni [2]

After doing some research on converting existing vehicles to steer-by-wire, I came across a line of electrohydraulic steering valves from Danfoss. These valves operate on the same principle as the hydraulic steering valve above but use an electrical signal to turn the valve instead of a steering wheel. By replacing the existing steering control valve with an electrohydraulic one, we would be able to send commands from our controller to turn the Zamboni. To make sure that the electrohydraulic valve I chose would be capable of turning the wheels, I first set out to identify which valve was already on the Zamboni. After looking through Danfoss hydraulic steering catalogs and comparing the size, shape, and appearance of the options listed with the picture above and dimensions of the CAD part I had been provided, I was able to determine that the Danfoss OSPE electrohydraulic steering valve should have ability to steer the

Zamboni. This valve is shown below in Figure 2. It has a flow capacity of up to 50 L/min and can reach steering pressures of up to 210 bar, both of which exceed the specifications of the valves similar to the pre-existing one. It also communicates using CAN.

Figure 2: Danfoss OSPE electrohydraulic steering valve [1]

I, along with Rathin, have also identified and acquired a backup platform for demonstrating and testing our software stack until the Zamboni is available. Initially, we targeted an open-source platform called F1TENTH. Importantly, this platform is designed to be ROS compatible and has Ackermann steering geometry, making it compatible with our ROS software stack. The car also comes with some useful additions included; these include on-board computing, a camera, lidar, and packages for waypoint following. However, after inquiring about how to purchase one, Rathin and I found out that they are currently not being sold. We then worked to find another platform that is available now so that we can begin testing our algorithms and sensors in the real world. We identified the RC car used by the MRSD project team Delta Autonomy in 2019, pictured in Figure 3 below. Like the F1TENTH, this RC car is ROS compatible and has Ackermann steering. It also has the benefit of being available and I have been able to acquire it for our team to use.

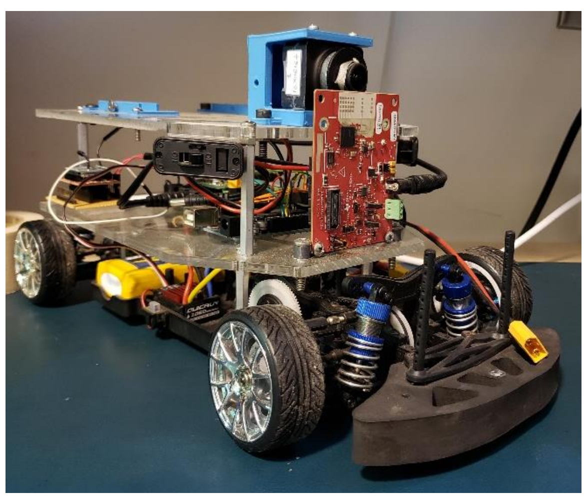

Figure 3: RC car that will be used as the backup platform

In terms of work done for the project course, I wrote the tests for validating the overall system in simulation and validating the pose estimating algorithm on hardware. I also created the presentation describing our project management style.

2. Challenges

As mentioned above, a big challenge in identifying a suitable steer-by-wire replacement for the current steering controller was the lack of information regarding the current part. Without any information about the displacement, flow rate, pressure, or type (e.g., open center vs closed center, reaction vs non-reaction), it was difficult to assess whether a potential replacement would be suitable. Another (ongoing) challenge with the electrohydraulic valve is the procurement of the valve. According to the vendor I spoke with, electrohydraulic valves are not widely used and thus not commonly stocked. As a result, these valves are expensive (an estimated $3500-$4500) and have a lead time of 12-14 weeks, which would push steer-by-wire integration into the fall.

The main challenge faced when procuring the backup platform was the unavailability of the F1TENTH platform. Currently, there is nowhere on their website to place an order. When Rathin messaged a Slack group of members of the F1TENTH community, he was informed that they are not being sold at the moment due to a parts shortage. As noted earlier, the solution to this was to use the RC car from a previous year's project that fits our needs and is available in storage.

3. Teamwork

<u>Rathin Shah</u>

Rathin worked on integrating the pose estimation and localization algorithm with the Gazebo simulation and was able to validate its performance. He also finished integrating the pure pursuit controller that he developed in Simulink with the simulation environment in ROS and Gazebo. Additionally, he helped me identify suitable backup platforms for us to use if/when the Zamboni is not available. Outside of the project, he worked on creating the schematic for the team's Power Distribution Board.

<u>Yilin Cai</u>

Yilin expanded the capabilities of the simulation by adding a second Zamboni to the Gazebo environment. He setup the simulation so that both Zambonis can be individually controlled using teleoperation. Also, Yilin helped to develop and test the robot_localization package by developing the wheel odometry for the follower and integrating the package with the simulation.

Jiayi Qiu

Jiayi focused on developing the team's ability to control the path that the leader Zamboni will follow during simulation testing. This included familiarizing herself with ROS navigation including teb_local_planner plugins and the move_base package. She was also able to load predefined waypoints into the simulation and visualize the resulting path. Finally, she solved a ROS version conflict that the team was having when trying to launch the URDF model of the Zamboni.

Kelvin Shen

Kelvin continued his work on the perception subsystem with a focus on developing the Zamboni's perception capabilities in the simulation. He has integrated and imported the RealSense camera that we will be using into Gazebo and tested the robustness of this camera's ability to detect a board of ArUco markers in simulation. Using the board of ArUco markers, he was able to retrieve an estimate of the pose of the board, a transform from the board frame to the camera frame, and the depth of the board. These capabilities will be used later to detect the leader Zamboni and estimate its pose relative to the follower.

4. Plans

During our next meeting, I will present the information I gathered on the electrohydraulic steering valve to our sponsors for feedback. If they approve the selection, I will begin the process of ordering one. However, as mentioned in the "Challenges" section, these valves are quite expensive, so I will work with our sponsors to see if there are any other cheaper options that would take up less of the team budget. Also, now that we have acquired the RC car, I will begin to familiarize myself with it. A major part of this will be developing a function that maps a desired slip angle for the RC car into a desired angle for the servo motor that controls the Ackermann steering mechanism. Additionally, I will begin designing and printing mounts for integrating our sensors onto the platform.

5. Sources

[1] Danfoss, "Electrohydraulic steering," OSPE datasheet, Jun. 2016.

[2] Zamboni, "Model 552AC Electric Parts List," Pgs. 1.4-A, 1.4-B, [Revised Aug. 2021].