MRSD Project Course

Team I – AIce

Autonomous Zamboni Convoy

Individual Lab Report 06

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1. Individual Progress

This past week, I largely focused on updating and rewriting our performance requirements. The largest changes in the performance requirements revolved around the drive-by-wire (DBW) conversion. Previously, this conversion was only captured by 2 performance requirements that specified a system wide latency and a maximum operating speed. Now, the DBW system is broken into its 3 main components (acceleration, braking, and steering), and each component is given requirements. These new requirements are shown in Table 1 below. The latency requirements were carried over from the previous requirements, but now each component has a requirement more directly related to its intended function.

Table 1: Updated performance requirements for the DBW system

Drive-by-Wire Performance Requirements		
Acceleration	PR.D-1	Follower will have a maximum latency of 50 ms for acceleration commands
	PR.D-2	Follower will achieve desired velocity ±0.10 m/s within 1.00 s / m/s
Braking	PR.D-3	Follower will have a maximum latency of 50 ms for deceleration/braking commands
	PR.D-4	Follower will come to a complete stop from 4.34 m/s within 2.00 m
Steering	PR.D-5	Follower will achieve desired steering angle to within ±10°
	PR.D-6	Follower will have a maximum latency of 50 ms for steering commands

The remaining performance requirements relating to the autonomy stack were also updated, although many of these requirements stayed the same from last semester. These are shown in Table 2 below.

Table 2: Updated performance requirements for the autonomy stack

Autonomy Performance Requirements		
Leader Detection	PR.A-1	Follower will detect the leader in 95% of frames within a distance of 8 m from the follower's front and a field-of-view of 60°
	PR.A-2	Follower will detect the longitudinal position of the leader to within ±0.10 m
	PR.A-3	Follower will detect the lateral position of the leader to within ±0.10 m
	PR.A-4	Follower will detect the longitudinal velocity of the leader to within ±0.20 m/s
	PR.A-5	Follower will detect the lateral velocity of the leader to within ±0.20 m/s
State Estimation	PR.A-6	Follower will estimate its yaw rate to within ±5°/s
	PR.A-7	Follower will estimate its position to within a 0.10 m radius
	PR.A-8	Follower will estimate its velocity to within ±0.10 m/s
Leader Following	PR.A-9	Follower will generate necessary control commands within 450 ms
	PR.A-10	Follower will follow the leader with a head-to-tail longitudinal distance of 6.00 m ±1.00 m
	PR.A-11	Follower will follow the leader with a center-to-center lateral offset of 0.98 m ±0.50 m
Obstacle Detection	PR.A-12	Follower will detect obstacles larger than 0.25 m in height within a distance of 2 m to 10 m from the follower's front and a field-of-view of ≥180° 90% of the time
	PR.A-13	Follower will detect the longitudinal position of obstacles to within ±0.10 m
	PR.A-14	Follower will detect the lateral position of obstacles to within ±0.10 m

There were two main additions to this set that better specified detection rates and ranges for the leader and obstacles. The leader detection range was set to be farther than the leader would be if the following distance requirement is satisfied, and the field of view was set to be within that of the RealSense camera used during the spring. The obstacle detection range was set to have a minimum distance matching the required braking distance from full speed. The minimum obstacle height was set to be below many of the common objects that would be found on an ice rink (e.g., humans, goals, buckets). Additionally, anything below this height will be able to pass under the ice resurfacer and will be caught by the safety guards in front of the conditioner. The following distances were also updated to better reflect the desired separation between machines given their size.

I also spent some time brainstorming different ways to achieve a steer-by-wire system given the current hydraulic steering setup of the vehicle. One potential idea I had was to mount a motor connected to a rubber wheel onto the frame or dashboard of the resurfacer and using a tension element to preload the rubber wheel against the steering wheel. By electrically activating the motor and causing the rubber wheel to spin, the steering wheel would then also spin. However, there are a few issues with this, major ones being the potential for slip to occur (and no way to measure that it has happened) and the lack of direct position control in the motor position (this is especially true in the off-the-shelf solutions which do not include encoders). After further research and discussing with Isuzu, the team has settled on a stepper motor connected to the steering wheel shaft using a belt. An example implementation of this is shown in Figure 1.

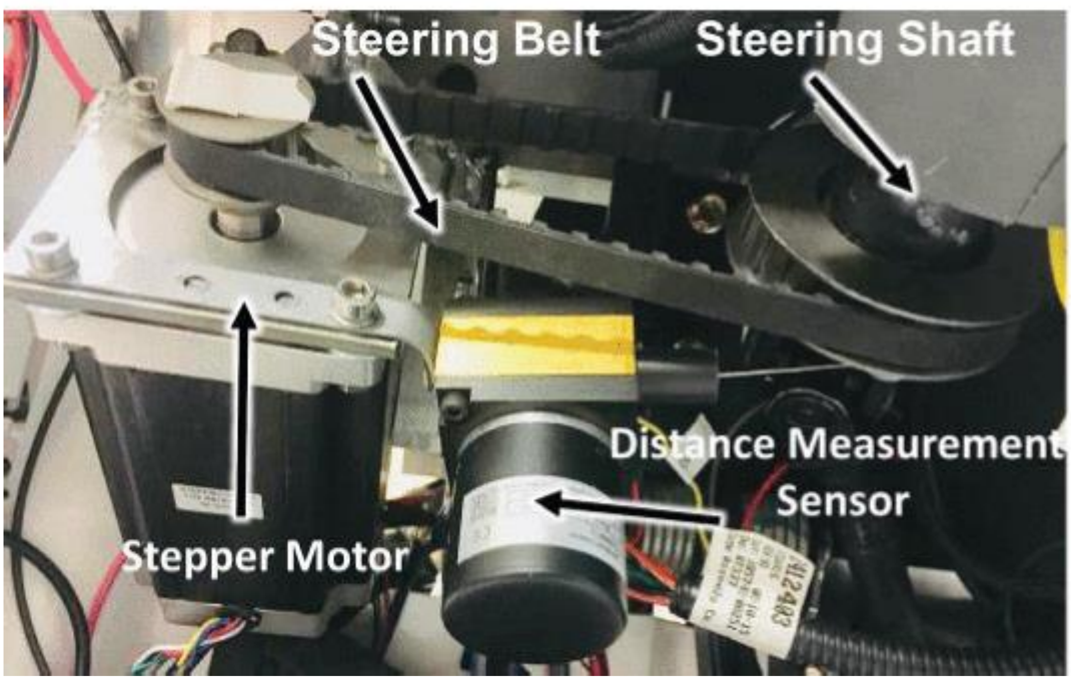

Figure 1: Example of steer-by-wire system implementation[1]

I took some time to familiarize myself with the basic functionality and operating procedures of the ATV that we will be using this semester for testing and development while the Zamboni ice resurfacer is brought up to speed. This involved reading through the documentation that the AirLab team sent over and beginning to parse through their large code base. Finally, I received some basic training on how to operate our Zamboni ice resurfacer so that we can drive and test it as necessary.

2. Challenges

There have not been many challenges during this opening week of the semester. The major challenge I have faced regarding the drive-by-wire conversion has been the request that anything we do to the Zamboni ice resurfacer is temporary and minimally destructive, if possible. This limits the steering components to be external and will require some potentially unique mounting schemes. Another challenge I have faced is the size of the ATV repository. There are many different files and making sense of all of them will take some time and potentially some guidance from the team that developed the code.

The final challenge faced this week is a team wide challenge; the process of adding Isuzu as an extra partner has required some corporate and legal proceedings that have slowed down progress. These blockers should be cleared in the coming weeks.

3. Teamwork

<u>Rathin Shah</u>

Rathin worked with me to brainstorm and research different potential designs for the steer-by-wire system. He also worked on the acceleration piece of the drive-by-wire system and identified the voltage range of the electric throttle and the CAN commands for throttle control.

<u>Yilin Cai</u>

Yilin worked on learning and reviewing the current ATV autonomy stack. Using his knowledge of how their code works and what topics are published, he began to conceptualize the procedure for transferring our code onto the ATV and fusing parts of our code with what is already on the ATV.

<u>Jiayi Qiu</u>

Jiayi started the collaboration discussion with Isuzu and has continued to be our main point of contact with their team. She also participated in the drive-by-wire discussions and contributed to the steering and braking designs. Finally, she reviewed the ATV's existing autonomy stack and installed all the necessary dependencies to build the repository.

Kelvin Shen

Kelvin took this past week to refamiliarize himself with our codebase from the spring as well as some ROS usage fundamentals to prepare for any updates, additions, or changes that we will make to the codebase this semester. He also reviewed the ATV's autonomy stack and updated our functional architecture to merge in some of their architecture elements (namely, using lidar point clouds in localization).

4. Plans

Over the course of the next week, I plan on updating and further fleshing out the team's work breakdown structure (WBS) and schedule for the upcoming semester to better reflect the work that needs to be done given the ATV and Isuzu developments that occurred over the summer. Doing so should also help reveal what technical work I will individually need to take on before the next progress review. Outside of these project management activities, I plan to join my teammates in going to Gascola to see the ATV and begin initial testing to see how well our code from the previous semester works on the new platform. I anticipate a considerable amount of work will need to be done to make our code compatible with their interface and hardware.

5. Citations

[1] K. Tian, K. Kobayashi and K. C. Cheok, "Agile Development Process of a By-Wire Electric Vehicle for Intelligent Ground Vehicle Competition Self-Driving Challenges," *2020 IEEE/SICE International Symposium on System Integration (SII)*, 2020, pp. 726-730, doi: 10.1109/SII46433.2020.9026232.