MRSD Project Course

Team I – AIce

Autonomous Zamboni Convoy

Individual Lab Report 6

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Sep 8, 2022

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1. Individual Progress

In spring semester, we demonstrated our project concept on the RC car as follower and Husky as leader. We got Zamboni at the start of August, so over the last one week and a half, we worked on finalizing the functional requirements with zamboni in focus for the project. Another major task we completed was finalizing how the approach for drive-by-wire conversion will be and did some sizing for these options.

As our backup platform for Zamboni is ATV with AirLab, we also worked on understanding the software stack of the system and analyzed how our autonomy stack can be combined with the ATV autonomy stack.

1.1. Updated Functional requirements :

In the spring semester, we faced the issue of very tight functional requirements and had to alter them based on the RC car performance.

Based on the spring valid demonstration experience, we reworked our functional requirements. As we haven't finalized the drive by wire components, we changed the functional requirements to accommodate some error in following the leader, based on the size of the Zamboni and estimated accuracy of the drive by wire components.

I brainstormed with team members and categorized the functional requirements into 2 sections: Drive by Wire functional requirements and Follower Autonomy software requirements.

Here are the new functional requirements for the 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

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 ±0.50 m/s
	PR.A-5	Follower will detect the lateral velocity of the leader to within ±0.50 m/s
State Estimation	PR.A-6	Follower will estimate its yaw to within ±1°
	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

Table 1. Functional requirements

1.2. Drive by Wire system evaluation

1.2.1. Steer by Wire

My other major work till now was doing trade study for different types of non-invasive steer by wire system available in the market. I met with suppliers and understood their product details, analyzed their compatibility with our vehicle and got the necessary quotation. The OEMs that I contacted were AB Dynamics, Kistler, Kairos Autonomy and Delphi Automotive. However the quote received from them was way more than the budget.

So I brainstormed and researched possible solutions that can be built in house. We had a meeting with ISUZU Usa to discuss the same.

Potential steering system solutions discussed with Isuzu are follows and illustrated in figure below:

1. Place the motor and other components outside of the panel
2. Extend the shaft to go through the steering control part and place the motor inside the vehicle

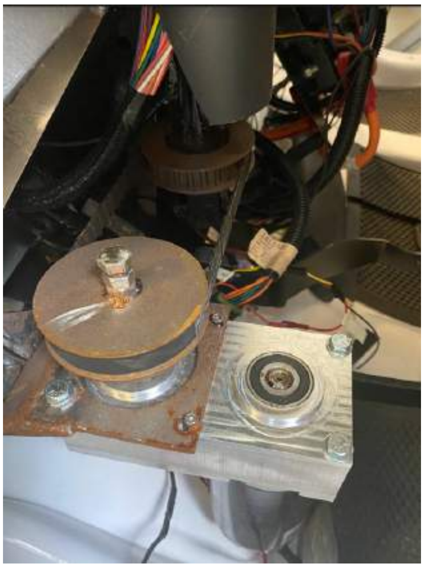

Figure 1. Steer by Wire concept

1.2.2. Throttle by Wire

I also worked on understanding the current throttle system on zamboni to command the necessary speed and torque from the motor on the vehicle. I identified two ways to control the throttle:

a. Using analog signals to emulate the voltage signal from the potentiometer of the throttle body. The throttle body on the zamboni is a Sevcon series electric throttle pedal. The potentiometer on this throttle generates a signal from 0.5 V for 0% throttle to 4.5 V for 100% throttle.
b. Another method that I studied was by using a CAN based signal that can demand the throttle directly from the Motor. The zamboni's motor controller uses openCAN to communicate with the peripheral devices. It has an object dictionary 2650h dedicated to RPDO that contains a throttle signal. So I was able to figure out the type of CAN message and the content of its data bytes to send the necessary throttle signals to the motor controller.

2. Challenges

One of the biggest problems faced was getting zamboni on time, there were many logistics issues and I had to spend a lot of time coordinating between CMU, Pittsburgh Penguins and the CMU facilities to get the vehicle on campus.

Also as we haven't finalized the actuators for drive by wire, finalizing the functional requirements for the Zamboni was tricky. We had to estimate the accuracy we can achieve and update the functional requirements accordingly.

Another technical challenge faced was sizing of the motor for the steering system. As we did not have a torque wrench to measure the actual torque required to turn the steering wheel, we had to estimate the torque by analyzing a similar system used on passenger cars like Ford Raptor.

3. Teamwork

a. Kelvin Shen

Kelvin worked on majorly updating the functional architecture based on ATV autonomy stack.

b. Nick Carcione

Nick also worked on updating performance requirements and also brainstormed potential drive by wire steering design. He also worked on ATV autonomy stack.

c. Yilin Cai

Yilin also worked on reviewing the ATV autonomy stack, concepting the transferring and fusion of previous autonomy codebase to ATV

d. Jiayi Qui

Jiayi majorly worked on the collaboration with Isuzu, updated potential drive by steering and brake by wire designs, reviewed ATV autonomy stack and installed dependencies to build the repository.

4. Future Work/Plans

Following is the plan for the coming weeks:

1. Get transportation to Isuzu arranged and Zamboni shipped
2. Visit the ATV at the Gascola facility
3. Integrate current perception subsystem into ATV software stack
4. Begin initial performance testing on the ATV