MRSD Project Course

Team I – AIce

Autonomous Zamboni Convoy

Individual Lab Report 07

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Teammates

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1. Individual Progress

My largest individual technical contributions this sprint have been designing all the mounts we will need for our sensors for both the ATV and the Zamboni resurfacer. Currently, the ATV does not use a RealSense camera, so we need to add our own to it. The camera should be placed high enough and forward enough such that it has an unobstructed, far-seeing view. The camera should also be rigidly attached to the ATV frame to avoid any unnecessary vibrations. Ideally, the camera is mounted in a place with an easily measurable distance from the forward facing lidar on the ATV so that calculating the calibration extrinsics between the camera and lidar is easy. The final design is shown in Figure 1 below. This mounting plate is attached to the lidar mast on top of the ATV using the existing lidar mounting hardware. This makes mounting easy, gives the camera a good view of what is in front of the ATV, and places the camera a known and measurable distance from the lidar. The vertical plate is included to ensure the camera is oriented as directly forward as possible.

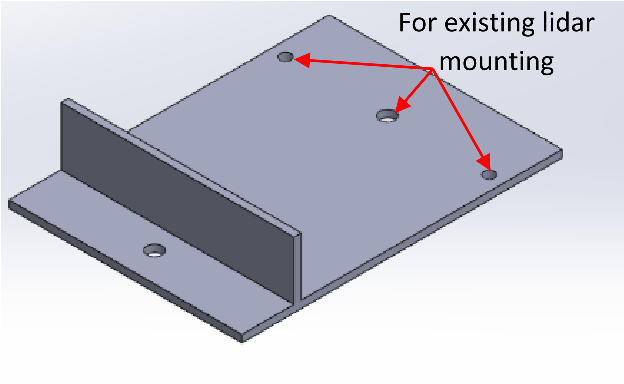

Figure 1: Mounting plate for mounting the RealSense D435i onto the ATV

On the Zamboni resurfacer, the cameras and lidar should be as forward on the vehicle as possible, ideally on the front face, to give the sensors as clear and unobstructed view as possible (placing them further back would cause part of their field of view to be obstructed by the vehicle body). Additionally, per Zamboni's request, the sensors need to be mounted in a temporary and non-destructive way. The final concept for the lidar mount is shown in Figure 2 below. This utilizes existing bolt holes on the front bumper and places the lidar close to the ground so that it can detect shorter obstacles (like young children or buckets) at a closer distance. It also provides a >180° view of what is in front of the vehicle.

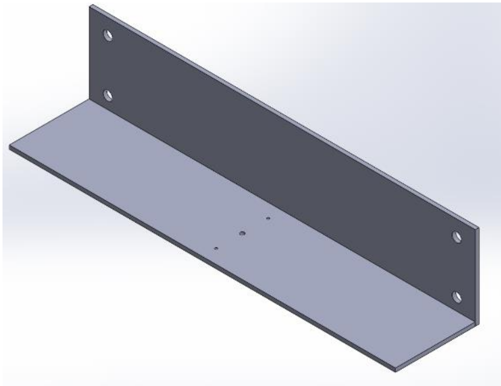

Figure 2: Lidar mount for the Zamboni ice resurfacer

The cameras should be mounted closer to mid-height on the vehicle to better align with where the ArUco board will be. However, there are no existing holes anywhere on the front of the vehicle outside of the 4 already used for the lidar mount (and trying to use these holes would likely lead to unwanted cantilever beam effects). After searching around the vehicle, a bracket with unused holes was found inside the side doors. This bracket is near a gap that exists in the vehicle's front about halfway up the face. The final mount design was made to utilize these holes and is shown in Figure 3 below (the mount shown is for the left side, the right side is simply the mirror image). It should be noted that these mounts will need to be removed if the snow tank ever needs to be opened, since the tank pinches the gap closed when opening. However, since we are only focused on driving for now, this will not be a problem.

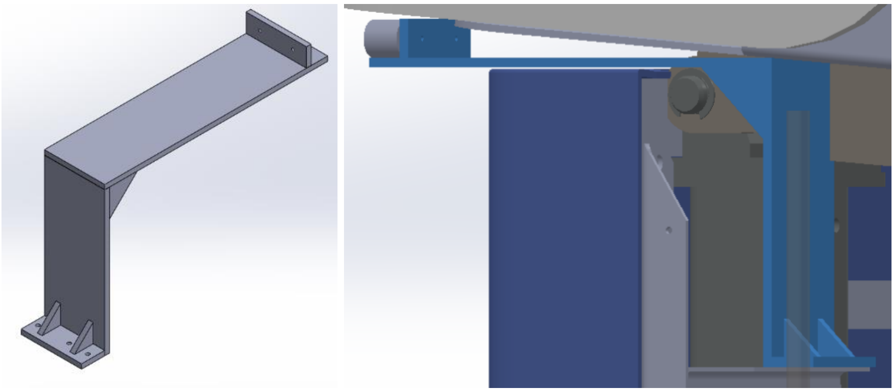

Figure 3: Camera mount for the Zamboni ice resurfacer and its location

Figure 4 below shows how the front of the Zamboni ice resurfacer will look when all 3 mounts are installed.

Figure 4: Front face of the Zamboni resurfacer with mounts installed

From a project management standpoint, I updated our work breakdown structure (WBS) to better reflect the work that the team will actually do this semester. The previous WBS was created before the drive-by-wire conversion agreement with Isuzu was made and, as a result, did not accurately represent the division of work that we now have planned. The updated WBS is shown in Figure 5 in the Appendix. It better reflects the three main verticals of work: the drive-by-wire conversion (largely handled by Isuzu), the autonomy software updates and development, and the integration of everything together on both the ATV and Zamboni ice resurfacer.

From a logistics standpoint, I assisted Rathin in getting the Zamboni machine transported to Isuzu's facilities in Michigan. This involved directing the shipping truck to the NSH B-level driveway and recording the condition of the vehicle in case any damage is done to it during transport or while at Isuzu.

2. Challenges

The main challenge I faced in designing the mounts was combining our need to mount our perception sensors on/near the front of the vehicle with Zamboni's request that any modifications we make should be temporary and non-destructive. To make the mounts non-destructive, we realized that we would need to utilize existing holes and bolts on the ice resurfacer. However, while there are plenty of usable bolts on the machine, the vast majority of them are located at the vehicle's rear (around the driver's seat and dashboard), with very few bolts and holes on the front where we needed them. Additionally, other mounting methods (like adhesive or Velcro) would likely not give the stability or positioning accuracy we desired. The solution we settled on (described above) was able to use purely pre-existing holes but comes with the cost of needing to remove the cameras anytime the snow tank is opened. In the future, if a fully autonomous system were to be developed, these camera mounts would need to be redesigned or the cameras themselves would have to be incorporated into the vehicle structure.

The other main challenge I have faced recently is familiarizing myself with the large volume of code that exists in the ATV codebase and the code in our own stack that my teammates wrote last semester. Most of the work that needs to be done this semester revolves around building out our codebase, and before I can begin to seriously contribute to that effort, I need to get up to speed on how exactly our code and the ATV code works. Through code reviews with team members who wrote different portions of our code and by reducing the ATV codebase down to just the pieces we need to interface with, I should be able to reach a workable knowledge level soon.

3. Teamwork

Rathin Shah

Rathin helped me develop concepts for the camera and lidar mounts for the Zamboni ice resurfacer and took the lead in understanding and creating the throttle object dictionary for controlling the Zamboni's speed. He also did some initial testing of the ATV's localization algorithms using rosbag files that the AirLab provided. Logistically, Rathin coordinated with Zamboni and the shipping company to get the resurfacer transported to Isuzu's office.

Yilin Cai

Yilin has done some additional literature review and researched different methods for constant-offset leader-following. Based on his research, he re-wrote the pose selection logic in the trajectory planner to implement a virtual follower that the actual follower will track. He also refactored and reorganized the code base for the autonomy stack and the simulation environment. Finally, Yilin helped Jiayi develop a PID controller for the longitudinal velocity.

Jiayi Qiu

Jiayi wrote a PID controller for better controlling the follower's longitudinal velocity and maintaining the desired 6m distance between vehicles. She also wrote a script that will allow us to publish steering and velocity commands to the ATV. Jiayi worked alongside Rathin in running various tests on the AirLab's rosbag files to gain a better understanding of how the ATV's stack works. She has remained the main point of contact between our team and Isuzu.

Kelvin Shen

Kelvin performed some initial testing to get an understanding of how well the RealSense camera detects the ArUco markers at the required 6m distance. During this testing, he observed the markers getting lost whenever the camera itself was rotated. As an initial step in finding a solution for this, he tested the performance of the RealSense under different camera settings (RGB vs IR data stream and different frame rates). He also experimented with some lidar-camera calibration techniques using data that was available online. Finally, Kelvin was instrumental in coordinating with the AirLab to get us access to the ATV.

4. Plans

In the coming weeks, I plan on having a meeting with Tim Angert from the RI shop, who has years of experience designing and manufacturing robots for RI, to get his feedback on the sensor mounts for the Zamboni ice resurfacer. Once I get his feedback, I will make any necessary changes before working with Tim to get the mounts manufactured. This way, we will be able to mount our cameras and lidar onto the Zamboni as soon as it comes back from Isuzu. I will also 3D print the camera mount for the ATV so that drive testing can begin as soon as possible. Now that we have access to the ATV, I plan on working with my teammates to do the initial testing of our autonomy stack on the ATV and help develop or improve algorithms as needed.

5. Appendix

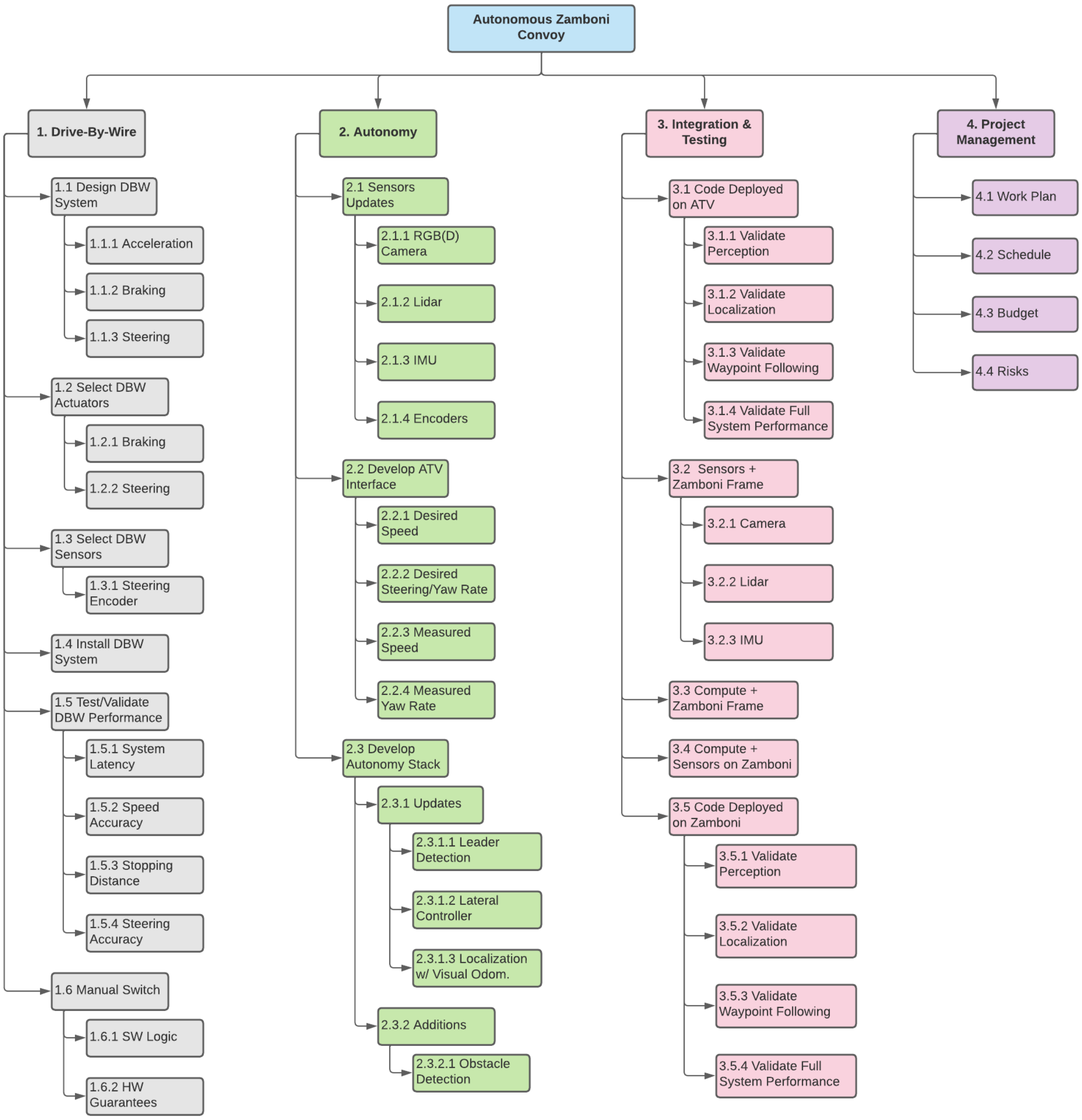

Figure 5: Updated WBS for the Fall semester