Lab 3 Briefing: March 10, 2025

Designing a Smart + Safe Wall-Following Racecar

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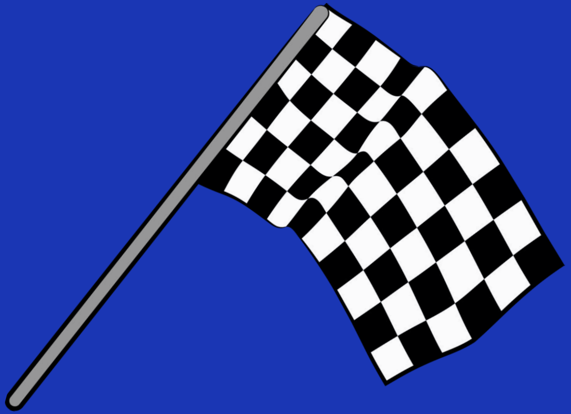

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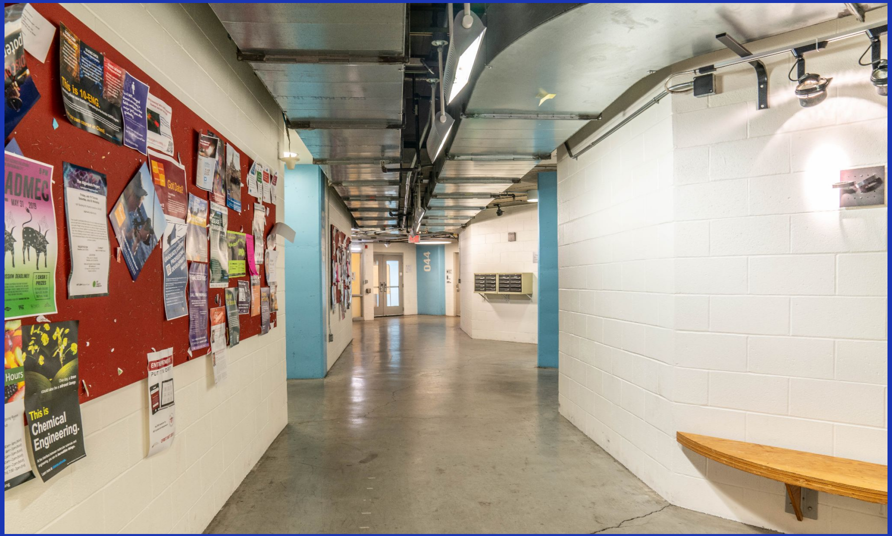
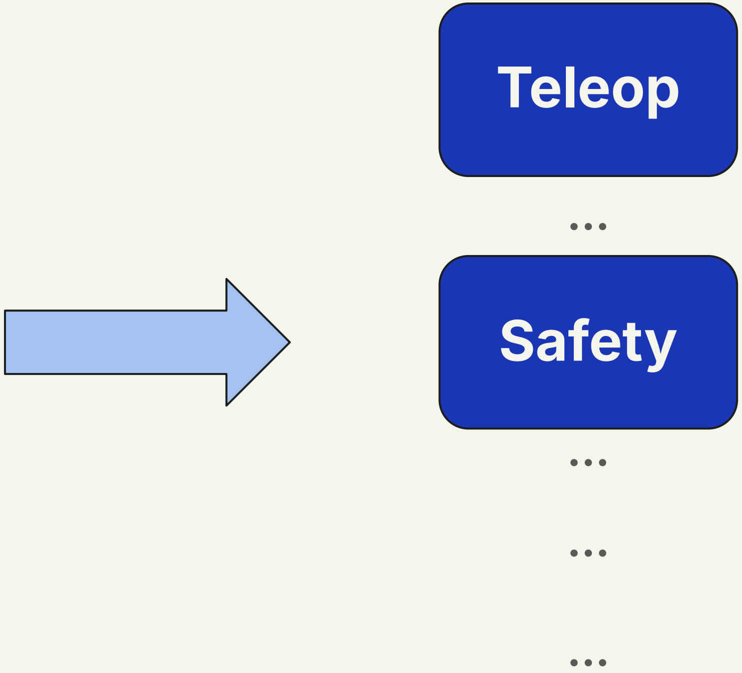
Lab Goal:

Breaking down the design constraints

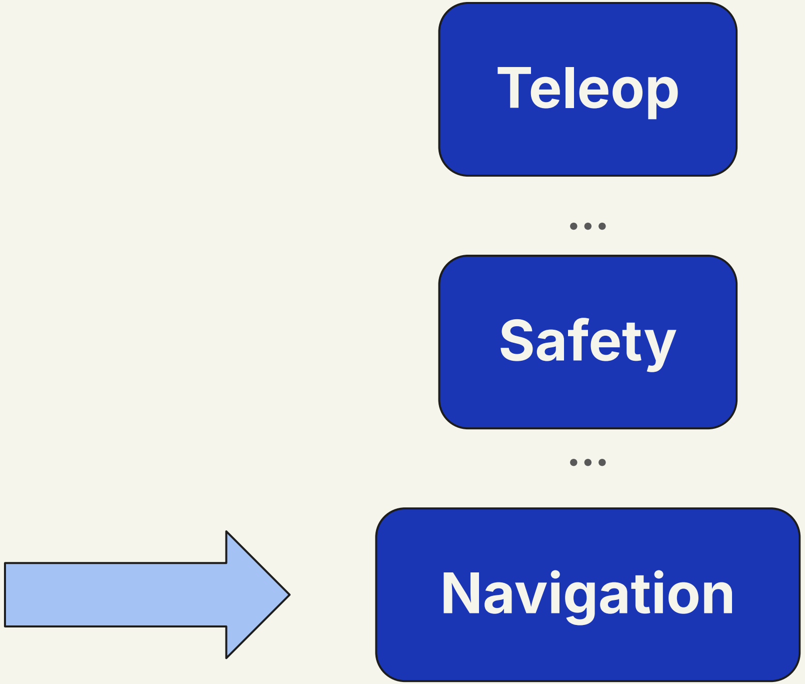


I want to follow a *real* wall!

1. Design a robust safety controller that prevents crashes, while still allowing car to pass close to walls.



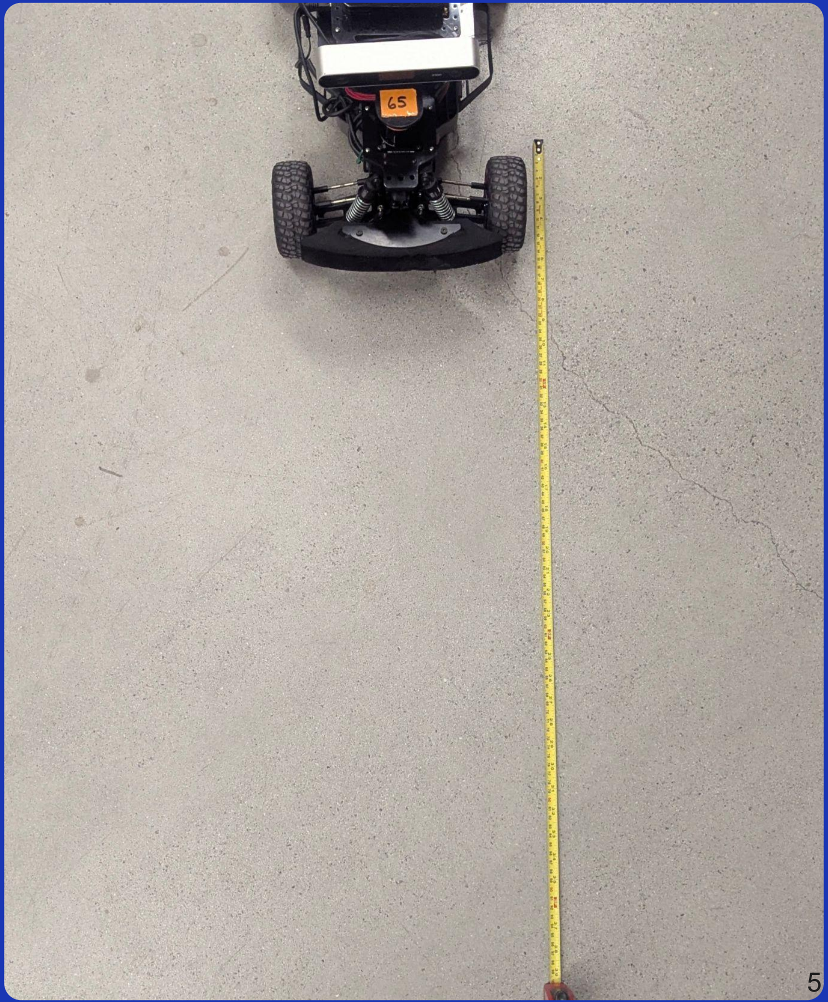
2. Adapt initial simulated wall follower controller for robust performance with real obstacles and 6.4200 hardware + integrate with safety controller.



Control Hierarchy Sketch

Technical Approach

Turning lab goals into ROS program design!



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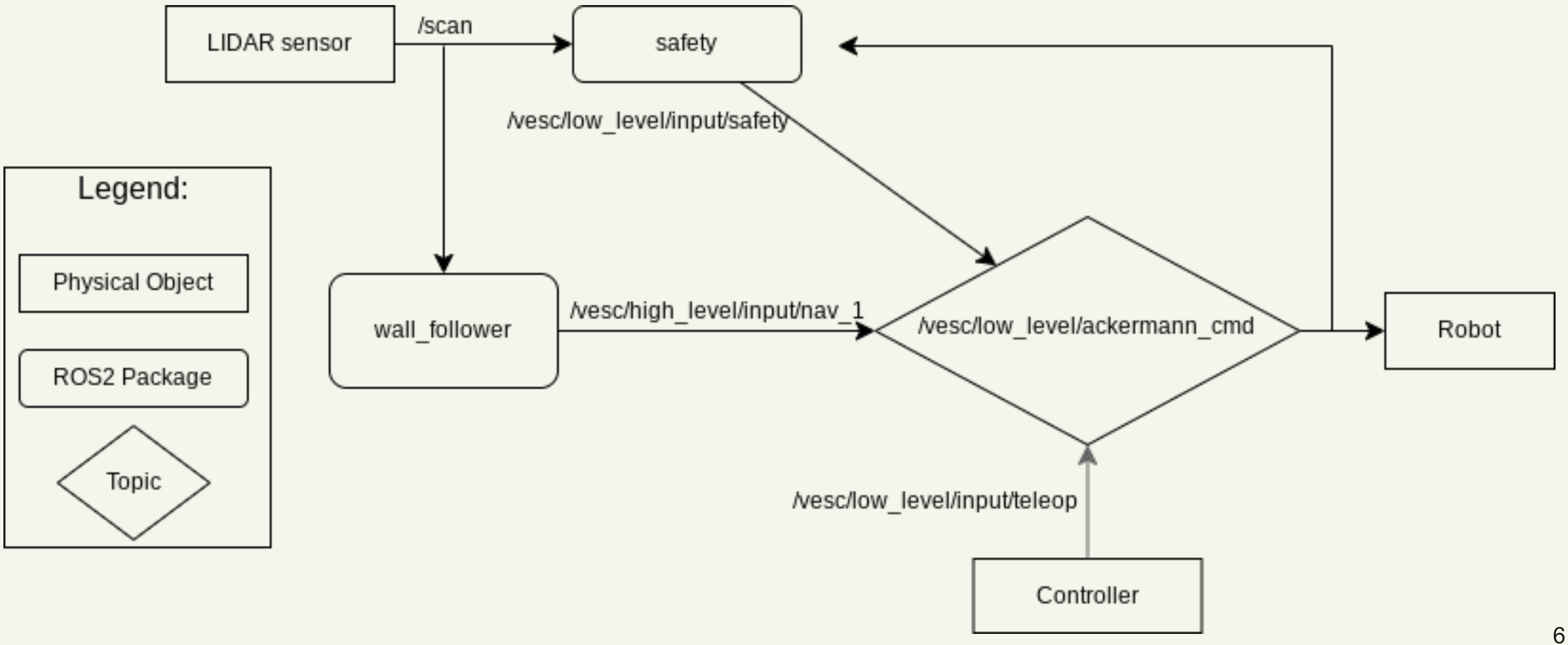
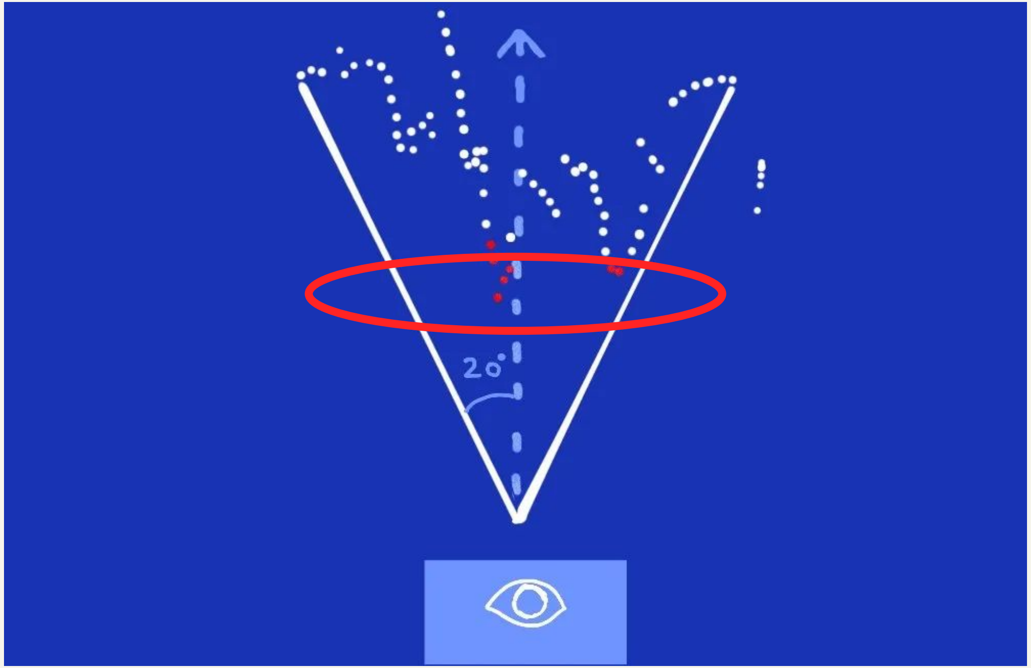
Use mux hierarchy of publishing topics to actualize lab goal priorities in ROS.

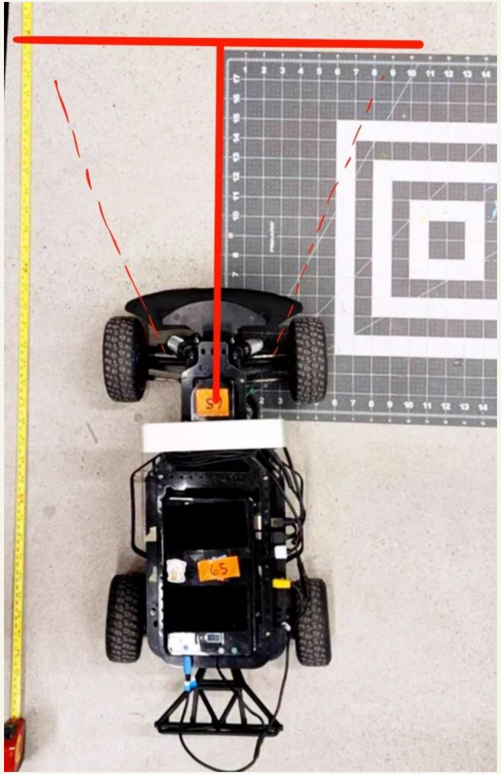


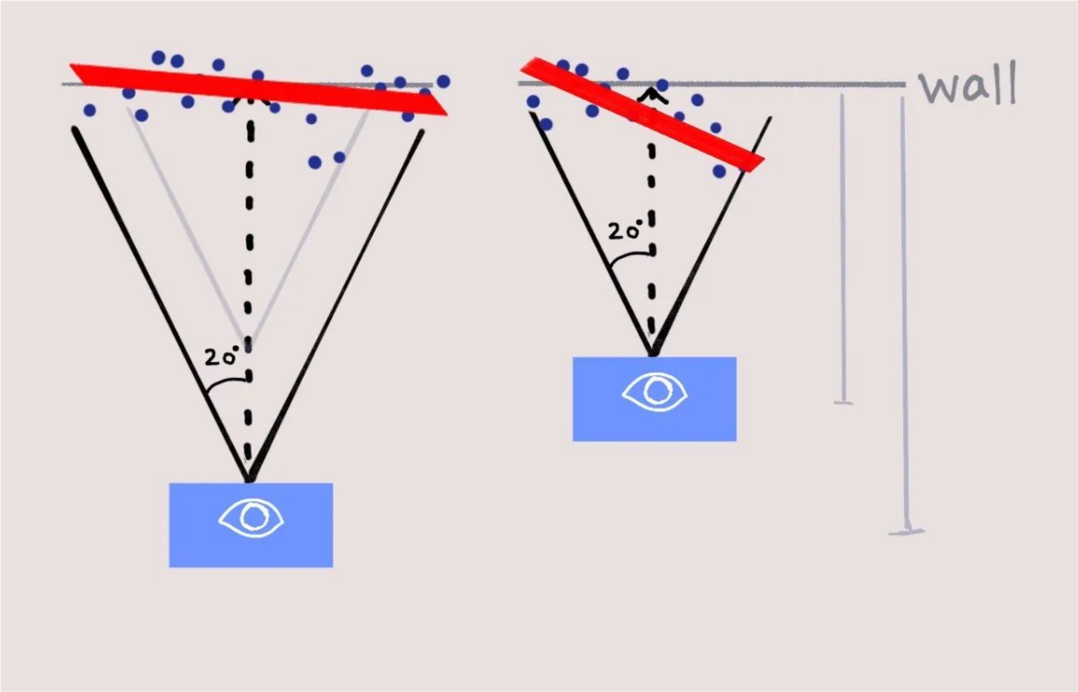
Use 10th-percentile of all laser scans within a 20° FOV centered in front of the camera to determine the likelihood of an obstacle.



Goal 1: Design Safety Controller

Identify target "safe" distance from wall, balancing low clearance with sufficient data points for stable linear regression

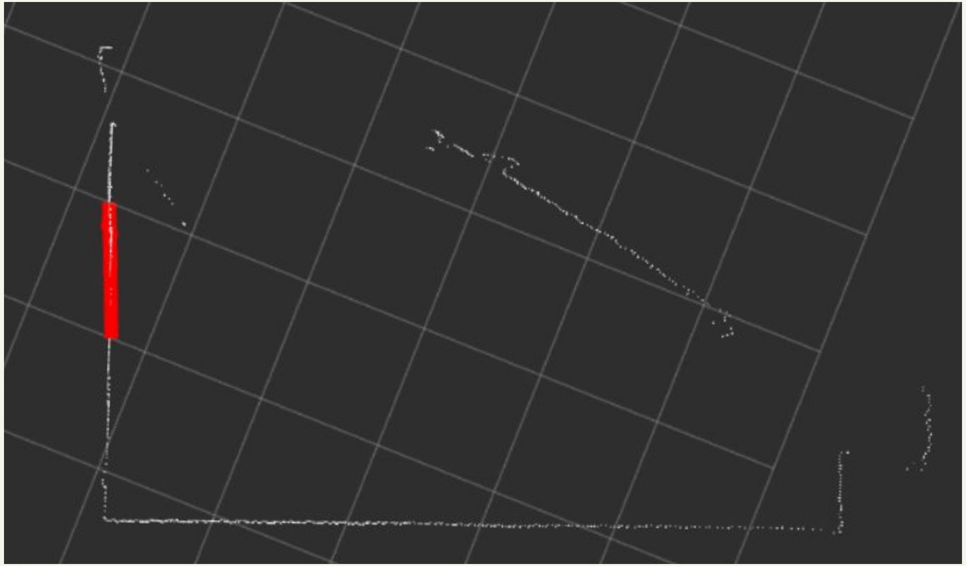




Goal 1: Design Safety Controller

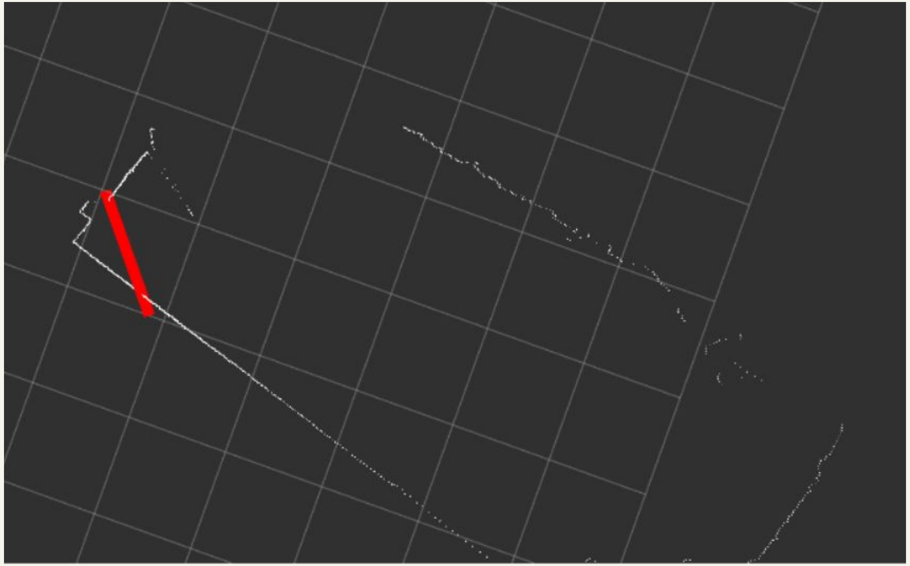
Goal 1: Design Safety Controller

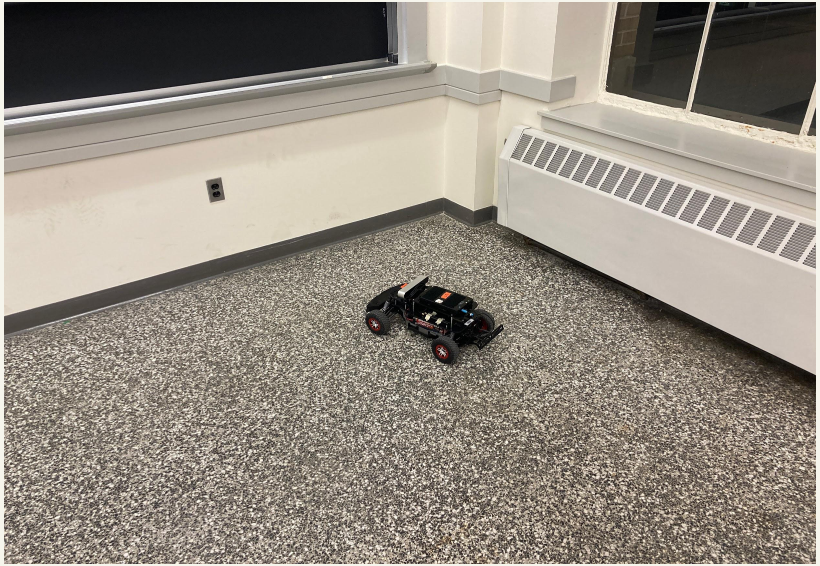
Estimate orthogonal distance between car and wall using linear regression approximation of wall position and orientation.



Goal 2: Adapt Navigation Program

Estimate orthogonal distance between car and wall using linear regression approximation of wall position and orientation.





Goal 2: Adapt Navigation Program

Optimize PD parameters for the wall follower controller by adjusting parameters according to results of continuous trials.

Goal 2: Adapt Navigation Program

Experimental Evaluation

Informal mini-task metrics for debugging, qualitative performance metrics on common obstacles, & quantitative evaluation of resulting system

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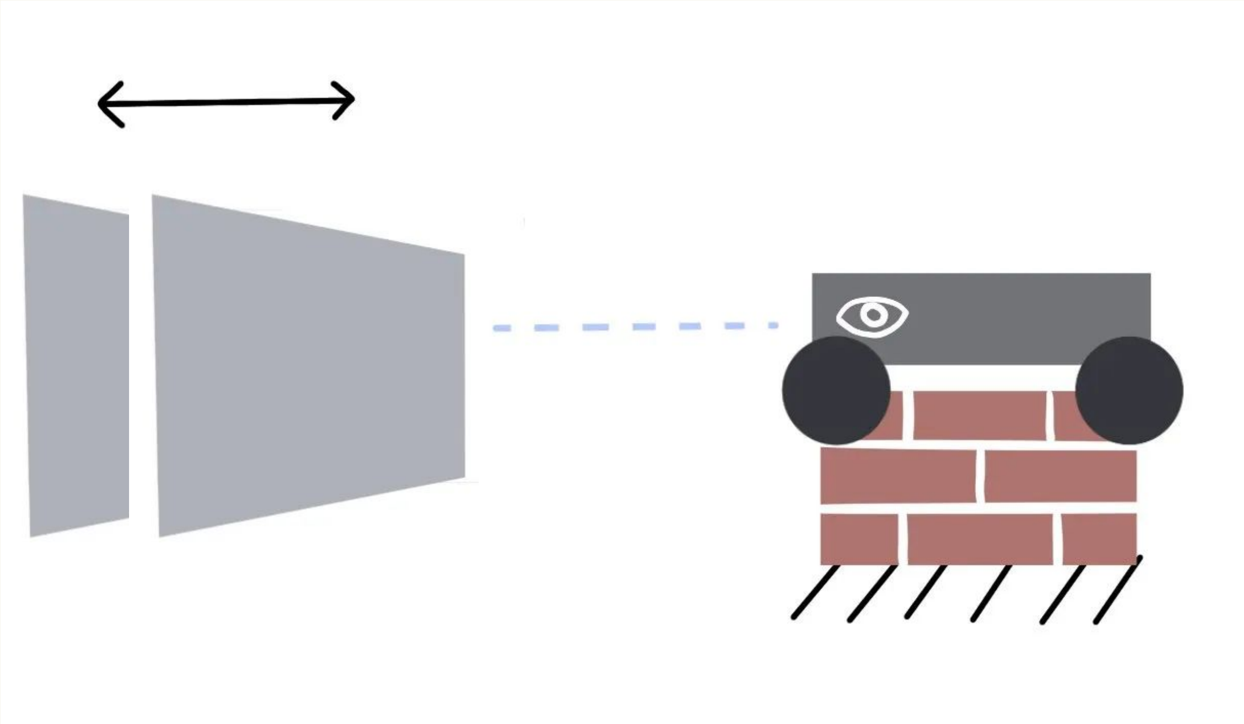
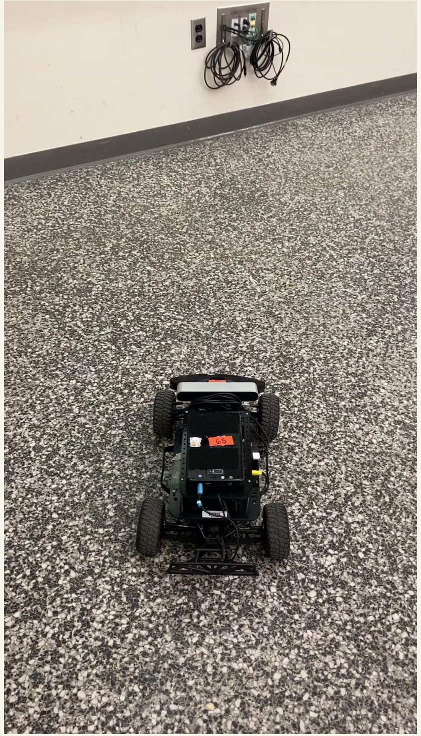
Test if the safety controller is activated when a “wall” (dummy obstacle) is presented at varying distances and angles.



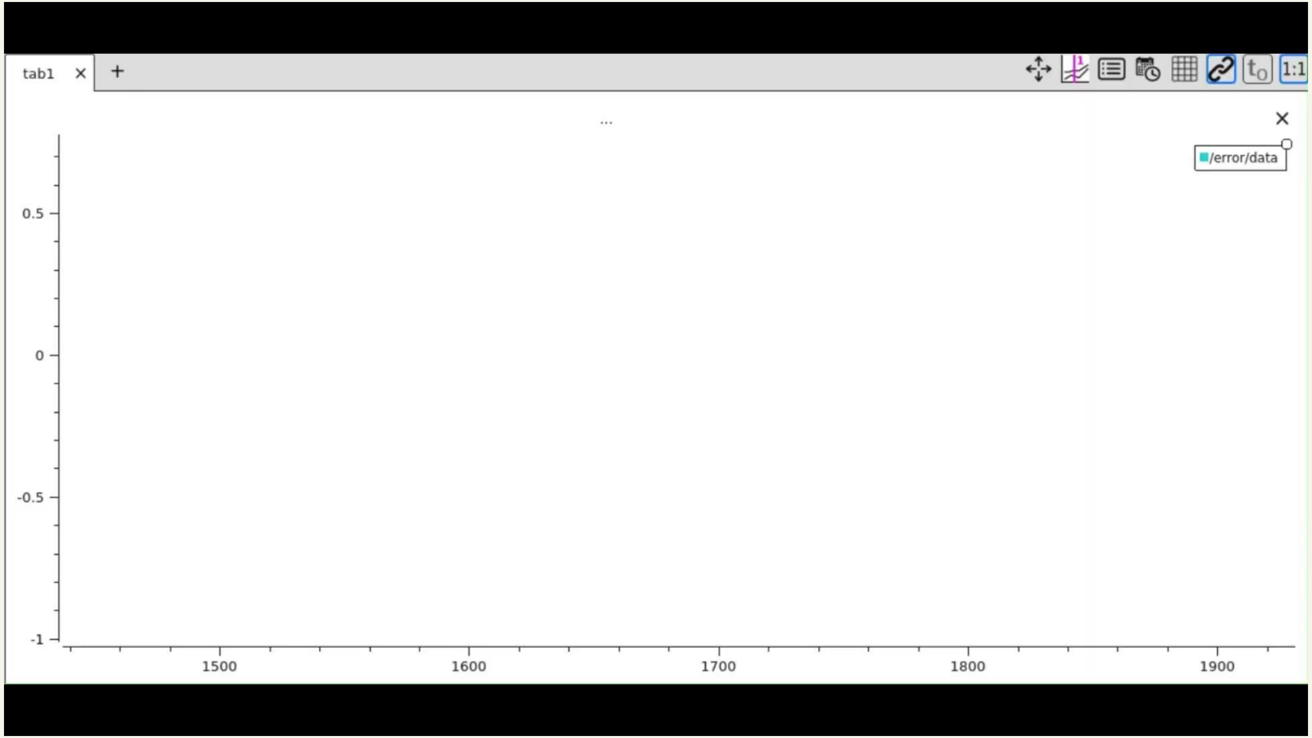
Evaluate each safety cutoff method for the safety controller, comparing performance on differently angled obstacles.



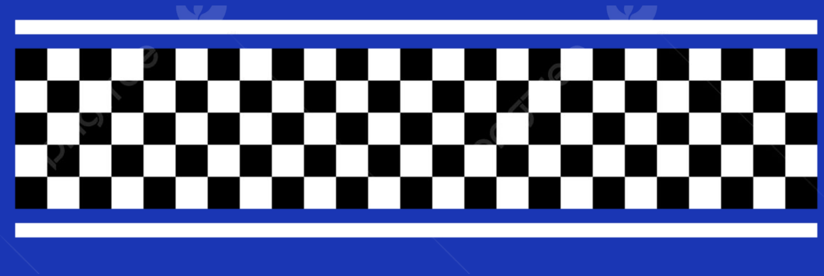
Test wall follower around 90 degree corners, ensuring success is reliable/repeatable.

Test ability to navigate around slimmer obstacles, without halting, colliding, or losing recognition of wall

Quantitative analysis: evaluate error for the corners scenario



Conclusion



Results: To what extent was the lab goal achieved?
What are the next steps forwards in light of our current progress?

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Results in summary...

Successfully follows wall without collisions!

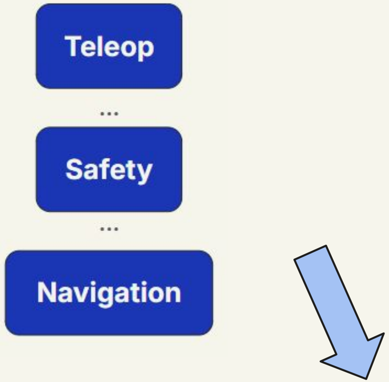
- Able to handle slim obstacles, corners of varying angles
- Maintains relatively stable distance to wall
    - (mean ~0.2m absolute error in corner scenario, 0.6m peak)

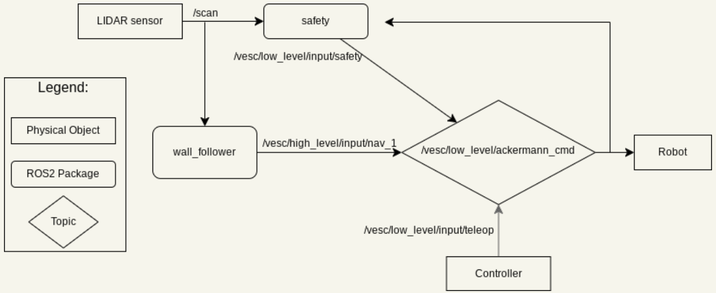
Areas for design improvement:

- Car path not optimally smooth/efficient

Lessons Learnt

- How to create a ROS control hierarchy meeting specified design requirements
- How to increase robustness against “spiky” and noisy scan data
- How to debug a system through a collection of mini tasks



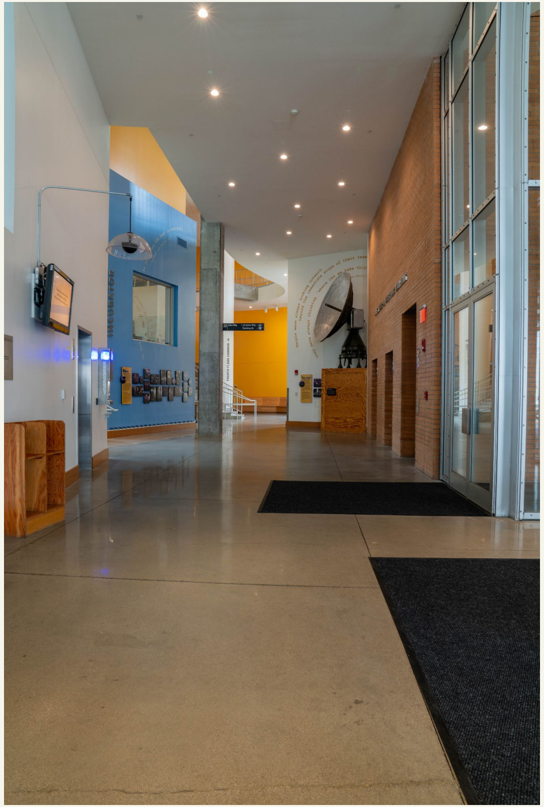


Our Next Steps

Implementation done → comprehensive performance testing

- Complex environments (oddly shaped obstacles, longer courses)
- Collect rosbags + quantitative data

- Is error data collected from the car itself reliable?
- How will we need to adapt our car's program design to perform well at higher speeds?



Thank you!

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Yuewei Liu (Mechanical Engineering & Math)
Miguel Padilla (Electrical Engineering & Computer Science)

Introduction

- Task: Design an autonomous robot to follow a wall and avoid collisions
- Technical Problem:
  - Design a controller that keeps robot a desired distance away from the wall
  - Implement a safety controller that prevents robot from crashing if trajectory is deemed dangerous
- Approach:
  - Design a Proportional-Derivative (PD) or Proportional-Integral-Derivative Controller (PID) that tracks the error between the robot’s desired distance from the wall and the measured distance
  - Use the updated data to adjust some value of the controller
  - For safety controller, determine if the predicted turn time is less than the time it will take for the robot to reach the wall; if it’s not, then stop the robot
- Measuring Success:
  - Qualitatively: Does the robot follow the wall?
  - Quantitatively:
    - Plot convergence time of system controller (Does the robot adjust quickly?)
    - Place the robot in situations where the safety controller should stop it and check if it does indeed stop

Experimental Evaluation

- Evaluate error based on difference between desired distance to the wall and actual distance
- Create a plot based on the position of the car over time to visualize the cars response
- Using the above metrics to tune controller gains in order to produce a good response
    - Specifically, a “good” response would reach a steady state quickly and accurately without much oscillation, or overshoot, and respond well to changes in wall direction
- Include videos of the wall follower and safety controller in practice

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Lab goal → ROS Implementation

- In general, the car should move according to a wall following program maintaining a specified distance from the walls
- Safety controller must be robust at preventing crashes, while still allowing car to pass close to walls
- Teleop human intervention should override everything as a fail safe

Translation to technical approach in ROS:

- Taking advantage of ROS's hierarchical structure:
  - Teleop > safety controller > wall following program

*Tuning: To ensure the desired clearance is achieved, test if the safety controller is activated when a "wall" (dummy obstacle) is presented at varying distances and angles

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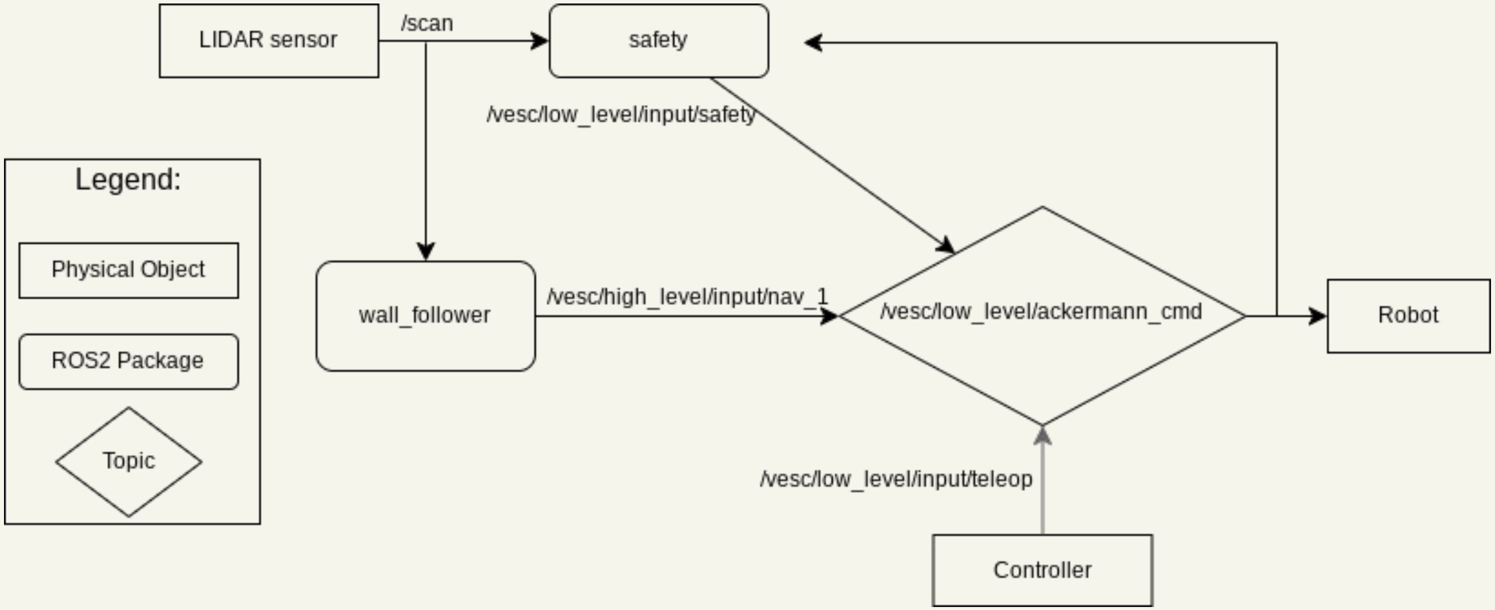
Technical Approach



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Conclusion

- Reiterate the task (to avoid collisions and follow the wall at a set distance)
- Comment on how well our car performed, drawing on ideas from experimental evaluation
- Reflection on performance / possible next steps

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Segment 2 Subtitle

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Briefing - Technical Grade

Criteria	Ratings		Pts
INTRODUCTION Goals and motivations behind the lab / challenge are clearly presented and contextualized (accessible to a technical audience outside RSS).	1.5 pts Full Marks	0 pts No Marks	1.5 pts
TECHNICAL APPROACH • Problem/challenge stated and described. • Solution/approach clear and technically sound. • Key mathematical relations are presented.	2 pts Full Marks	0 pts No Marks	2 pts
EXPERIMENTAL EVALUATION • Performance metrics meaningful & clear. • Analysis of the results is detailed, persuasive.	2.5 pts Full Marks	0 pts No Marks	2.5 pts
CONCLUSION Conclusions are complete and compelling.	0.5 pts Full Marks	0 pts No Marks	0.5 pts
Q&A • Questions are handled honestly and skillfully. • Notes taken for follow-up, as appropriate.	0.5 pts Full Marks	0 pts No Marks	0.5 pts
SLIDES • Slides making assertions have full-sentence titles stating the point. • Visuals are readable, focused, and uncluttered. • Content, detail, tone, and style are appropriate to a professional technical audience unfamiliar with RSS. • Minimal text, animated bullet points.	2.5 pts Full Marks	0 pts No Marks	2.5 pts
DELIVERY • Speakers are engaged with audience. • Speakers are loud enough. • Demeanor and speech are professional. • Team is attentive, handoffs are smooth.	0.5 pts Full Marks	0 pts No Marks	0.5 pts
Team Members' Assessment	0.5 pts Full Marks	0 pts No Marks	0.5 pts
			Total Points: 10.5