Module C: Reactive Methods for Obstacle Avoidance

Part 1. Gap Following Methods

Part 2. Other Reactive Methods for Obstacle Avoidance

References:

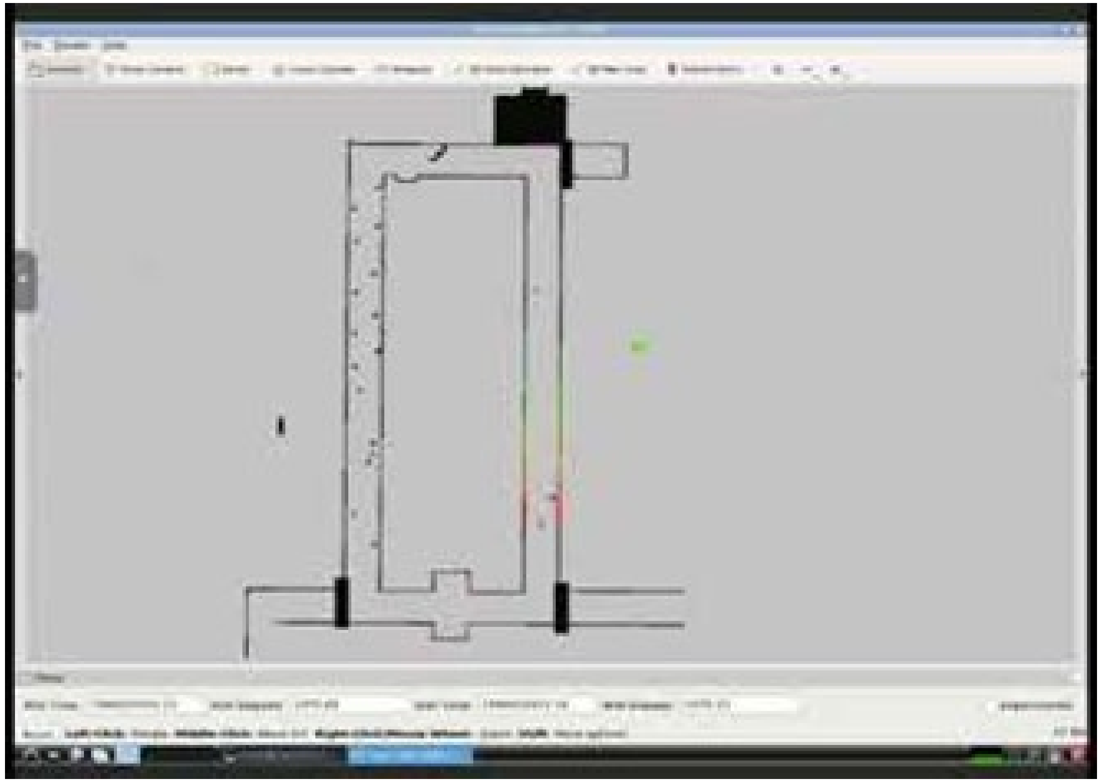
https://f1tenth.org and UPenn ESE 680 Slides

http://www.cs.cmu.edu/~choset/

References for Gap Based Methods

- First proposed as GND method: J. Minguez, L. Montano, T. Simeon, and R. Alami, "Global nearness diagram navigation (GND),"IEEE ICRA 2001.
- Later renamed as Follow the Gap Method (FGM): V. Sezer and M. Gokasan, "A novel obstacle avoidance algorithm: follow the gap method," Robotics and Autonomous Systems, Elsevier, vol. 60, no. 9, pp. 1123–1134, 2012.
- Variants: CGF and TGF: M. Mujahed, D. Fischer, B. Mertsching, and H. Jaddu, "Closest gap based (CG) reactive obstacle avoidance navigation for highly cluttered environments," in IROS, pp. 1805 – 1812, 2010. -- "Tangential gap flow (tgf) navigation: A new reactive obstacle avoidance approach for highly cluttered environments," ACM Rob. Auto. Sys., vol. 84, pp. 15–30, 2016.
- A detailed review of reactive methods including FGM: J.A. Tobaruela and A.O. Rodriguez, "Reactive navigation in extremely dense and highly intricate environments," PLOS One, https://doi.org/10.1371/journal.pone.0189008, pp1-51, Feb. 2017.

Module C1: Gap Following Method

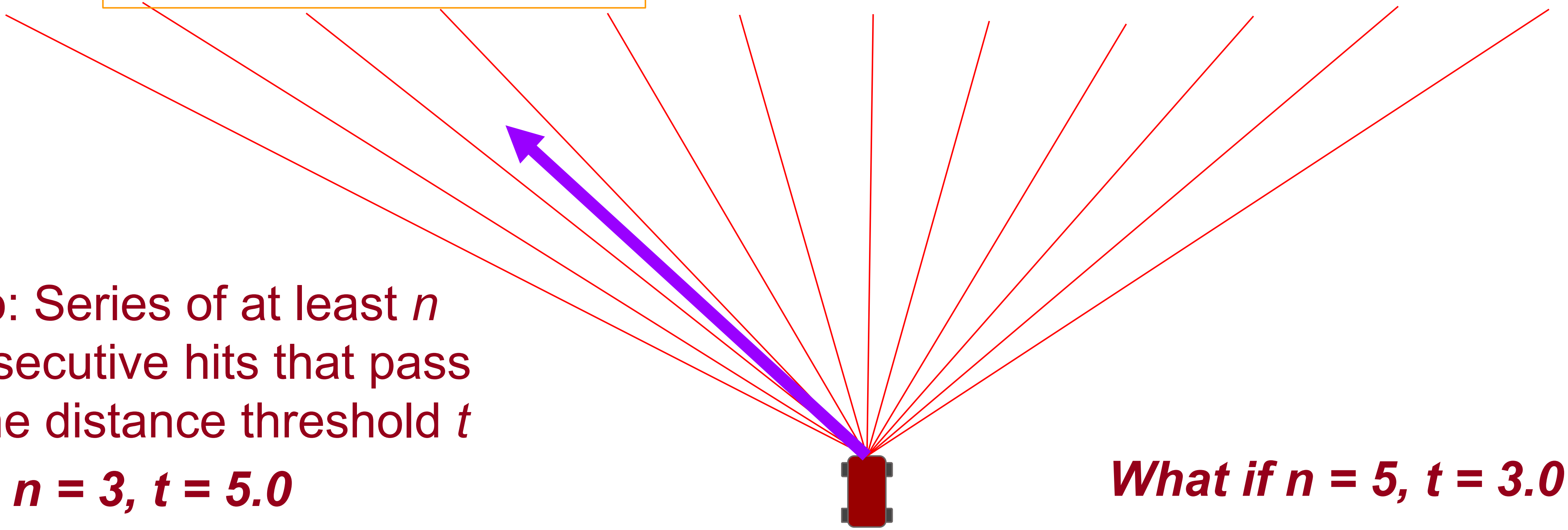


https://www.youtube.com/watch?v=byqFPKjF78s

https://www.youtube.com/watch?v=3erOYWFrTcI

Module C1: How to Follow the Gap

$$[0.5, \underbrace{5.1, 6.0, 7.0, inf}_{\text{Gap 1}}, 3.0, inf, 3.0, \underbrace{inf, 8.0, 5.0}_{\text{Gap 2}}, 3.0]$$



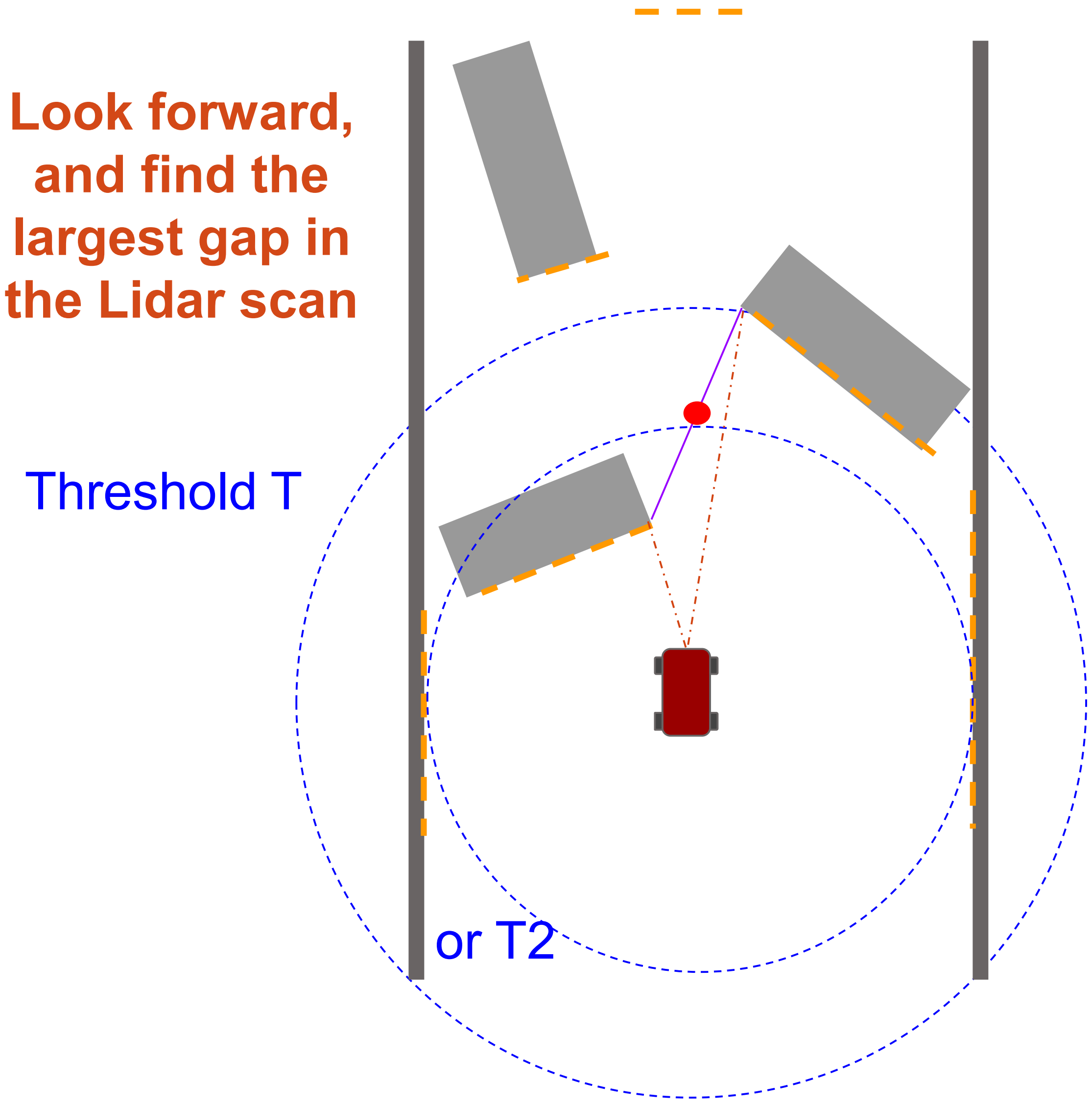
Gap: Series of at least *n* consecutive hits that pass some distance threshold *t*

***n* = 3, *t* = 5.0**

What if n = 5, t = 3.0?

Follow the Gap: the Naïve Algorithm

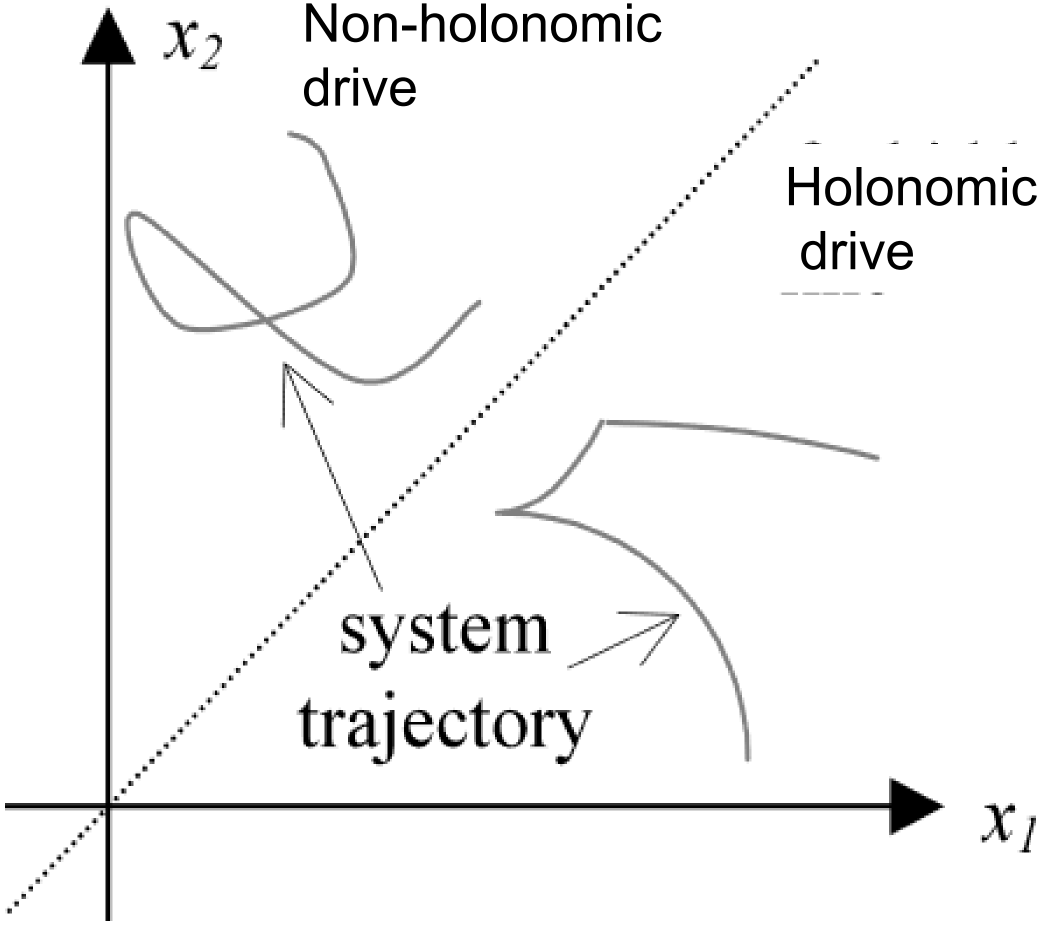
Look forward, and find the largest gap in the Lidar scan



- ❑ Naïve Algorithms: Find the Largest Gap:
  - Set a range threshold T;
  - Find the largest gap w/ ranges exceeding T;
  - Move towards the middle of the gap
- ❑ Works fine with:
  - Holonomic robots (eg. Turtlebots)
  - Non-holonomic robots in tracks with sparse obstacles;
- ❑ Disadvantages:
  - Safety concerns when running fast;
  - Static obstacle vs. moving obstacles;
  - How to factor in car dimension?
  - How to determine threshold T dynamically?

Holonomic vs. non-holonomic

- Holonomic robots:
  - spherical wheel or omni-wheels which can roll in any direction,
  - vehicle can take sharp turns, and
  - vehicle trajectory has no constraints
- Non-holonomic drive:
  - Wheels w/o slipping cannot roll in any direction;
  - Vehicle cannot take sharp turns, and
  - Vehicle trajectory has to be continuous or smooth → G0 continuity;
  - G1 continuity means the derivative of the trajectory (or the speed) is smooth;
  - G2 continuity means 2nd derivatives of the trajectory (or the acceleration) is smooth



https://alliance.seas.upenn.edu/~meam535/cgi-bin/pmwiki/uploads/Main/Constraints10.pdf

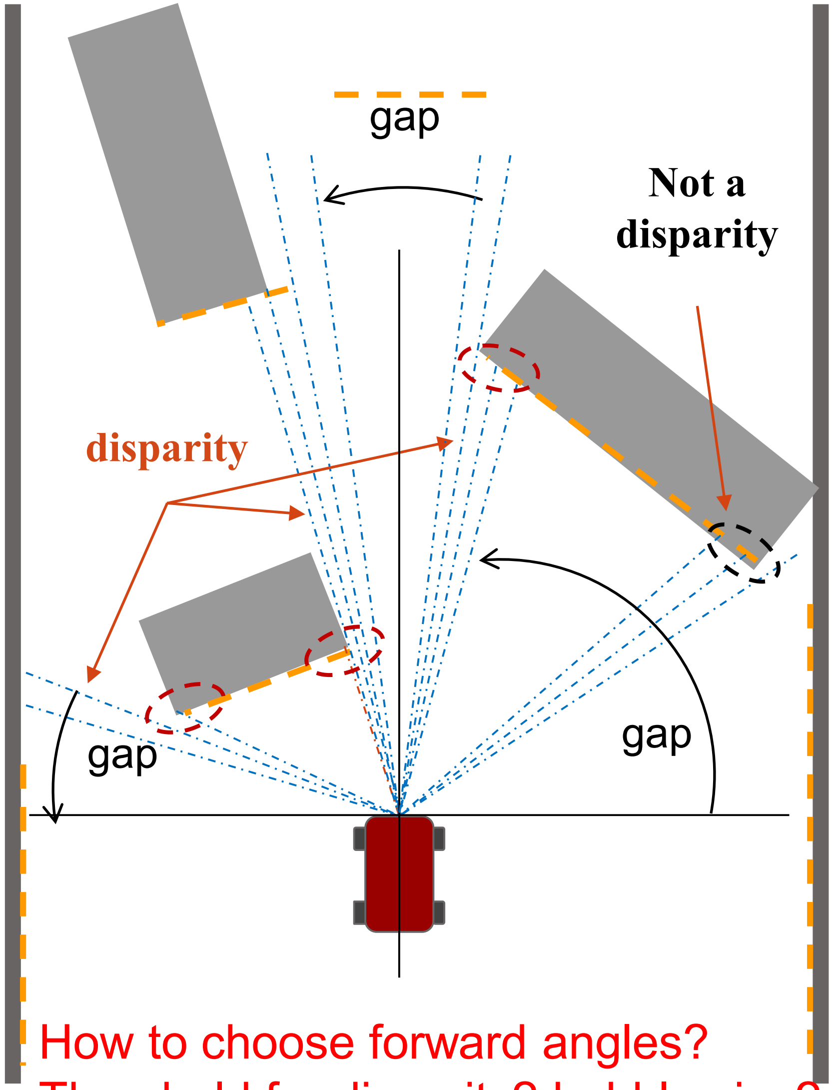
What if you have to run fast?

The UNC method: ***cleverly* avoid the nearest obstacle.**

Won the F1/10 Grand Prix @ Montreal

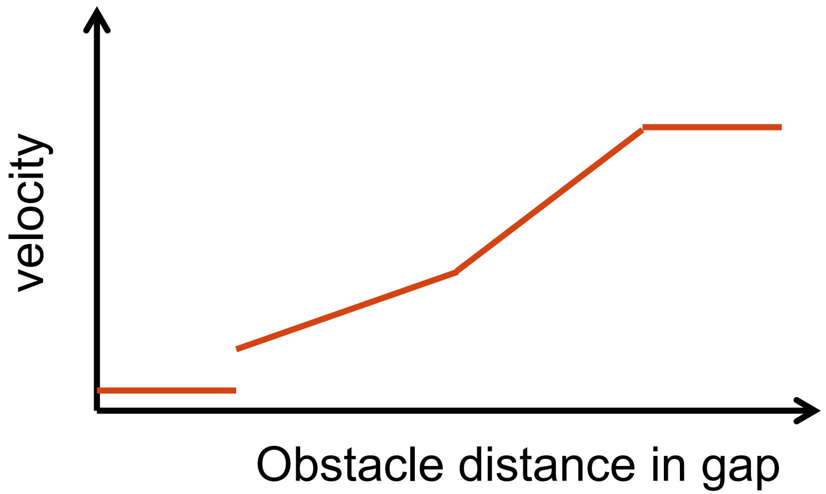
https://www.youtube.com/watch?v=ctTJHueaTcY

The UNC Algorithm



How to choose forward angles?
Threshold for disparity? bubble size?

- Set a threshold to detect disparities in Lidar scan ranges
- Set a bubble at each disparity and all points in the bubble are set to zero. All non-zero points are considered as gaps;
- Decide which gap to follow and at what speed
- Piece-wise linear speed settings, as shown in figure. Pick your parameters and strategies.



The Upenn Gap Follow Algorithm

Step 1

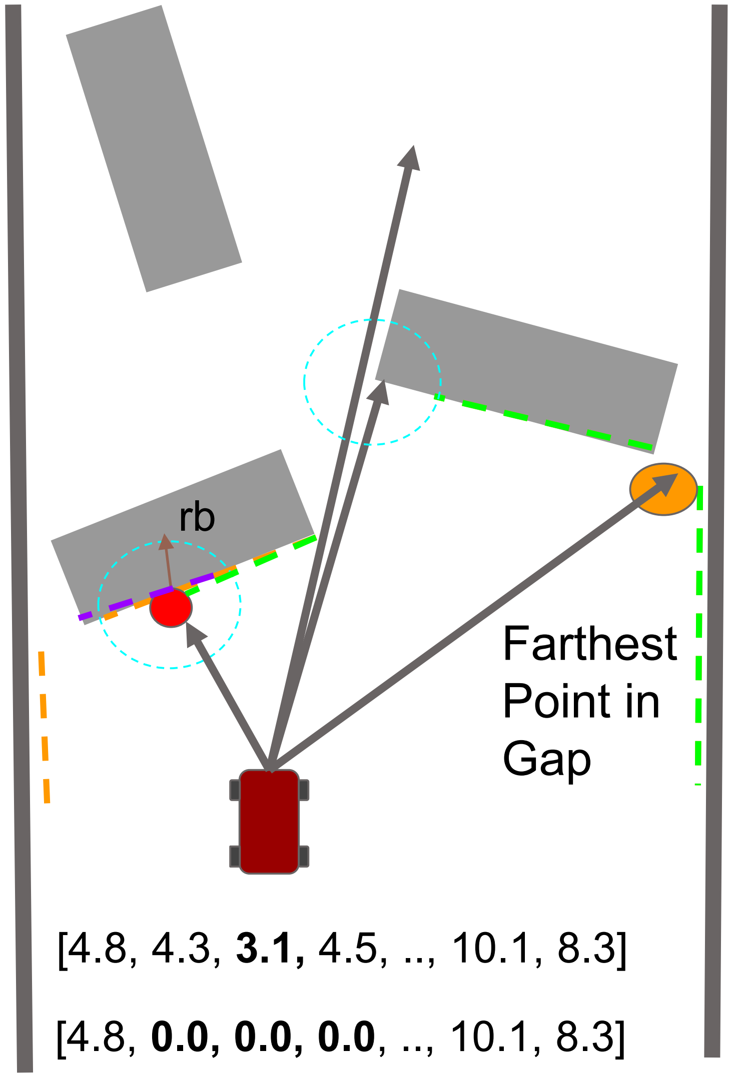
Find nearest LIDAR point and put a "safety bubble" of radius *rb* around the bubble

Step 2

Set all points inside safety bubble to 0. All nonzero points are considered 'free space'

Step 3

Find maximum length sequence of consecutive non-zeros among the 'free space' points - The **max-gap**



Step 4

Find the 'best' point among this maximum length sequence

Naive: Choose the furthest point in free space, and set your steering angle towards it

Changing speed results in you losing velocity

Better Idea Intuition

If you're 3-4m away from your closest obstacle, should you immediately make a sharp turn to avoid it?

Slide modified from UPenn course ESE680

Lab 3 and Race 2 are combined

- **Implement a reactive algorithm to avoid collision and win the race**
  - Race track similar to Race 1 track, but with static obstacles. No dynamic obstacles.
  - Obstacles may be dense or sparse on the track;
  - Two test tracks are provided for you to test your algorithm;
  - The race 2 track is similar to the test tracks but may be different.
- Grading Scheme for Race 2 and Lab 3 combined:
  - Simulator runs successfully with race track map → 20 points
  - Finish 3 laps in 120 seconds without collision → 50 points
  - Finish additional laps in 120 seconds without collision → each additional lap adds 2.5 points
  - Ranking in the race (if a team does not finish race, then it earns 0 points)
    - Shortest time to finish 3 laps: race winner, earn 10 points
    - Longest time to finish 3 laps: ranks #10 and earns 1 point.
  - Quality of report: 60 points (see lab instructions for requirements)