Motion Planning Constraints

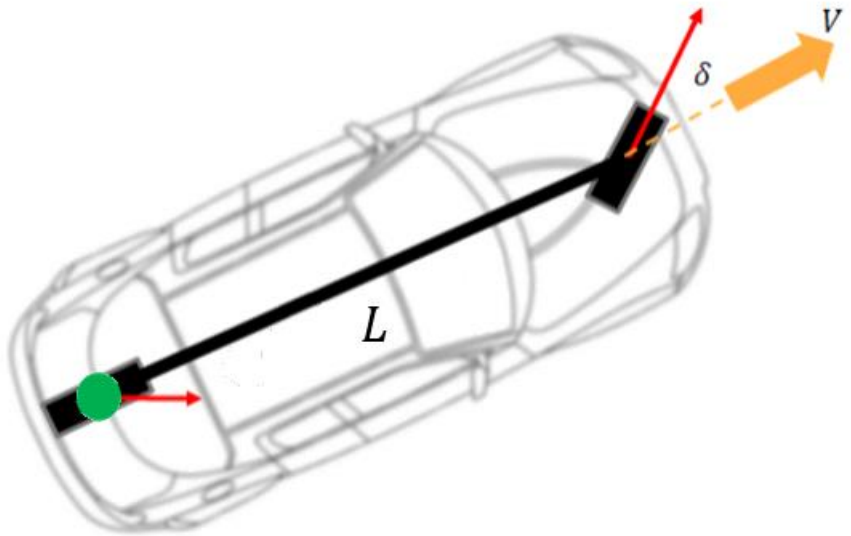
Course 4, Module 1, Lesson 2

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Bicycle Model

- Kinematics simplified to bicycle model (as discussed in Course 1)
- Bicycle model imposes curvature constraint on our path planning process

limited steering angles similar to a car

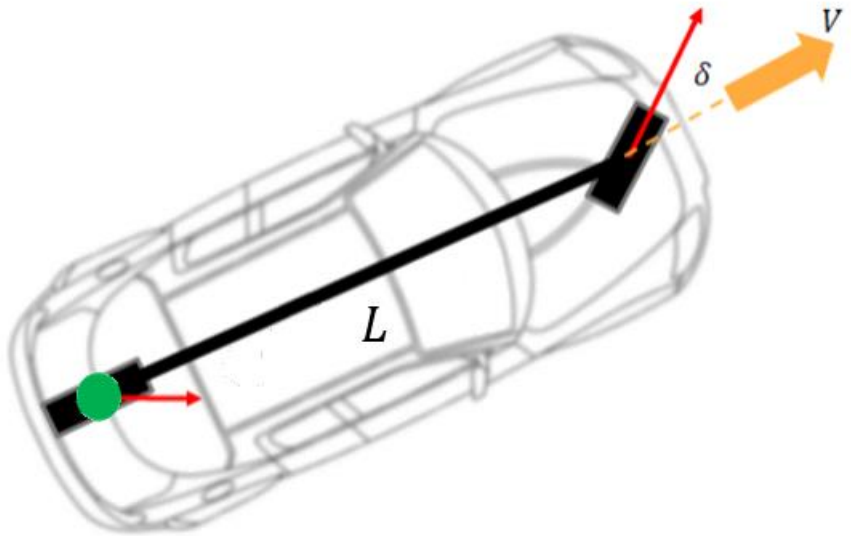


$$\dot{\theta} = \frac{V \tan(\delta)}{L}$$

$$|\kappa| \leq \kappa_{max}$$

Bicycle Model

- Kinematics simplified to bicycle model (as discussed in Course 1)
- Bicycle model imposes curvature constraint on our path planning process
- Curvature constraint is non-holonomic
  - Non-holonomic constraints reduce the directions a mobile robot can travel at any point
  - Makes motion planning challenging

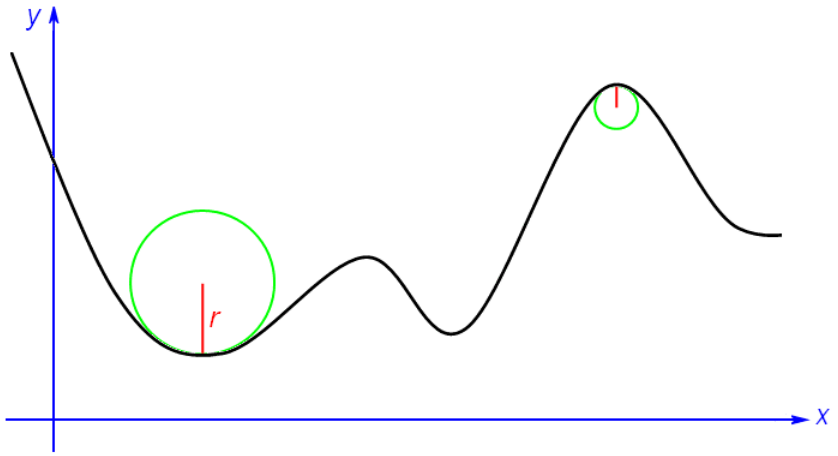


$$\dot{\theta} = \frac{V \tan(\delta)}{L}$$

$$|\kappa| \leq \kappa_{max}$$

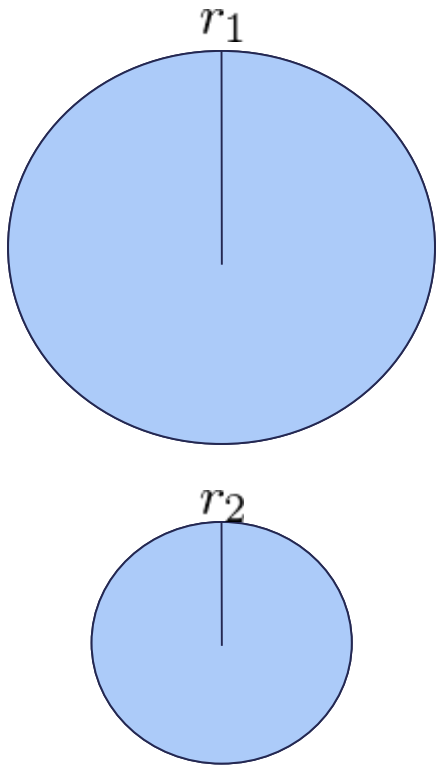
Curvature

$$\kappa = \frac{1}{r}$$



derivative

$$\kappa = \frac{x'y'' - y'x''}{(x'^2 + y'^2)^{3/2}}$$

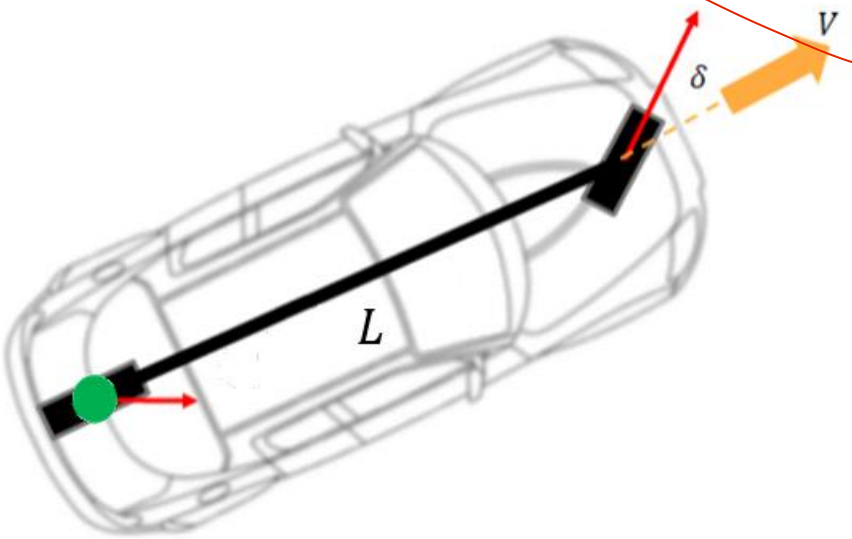


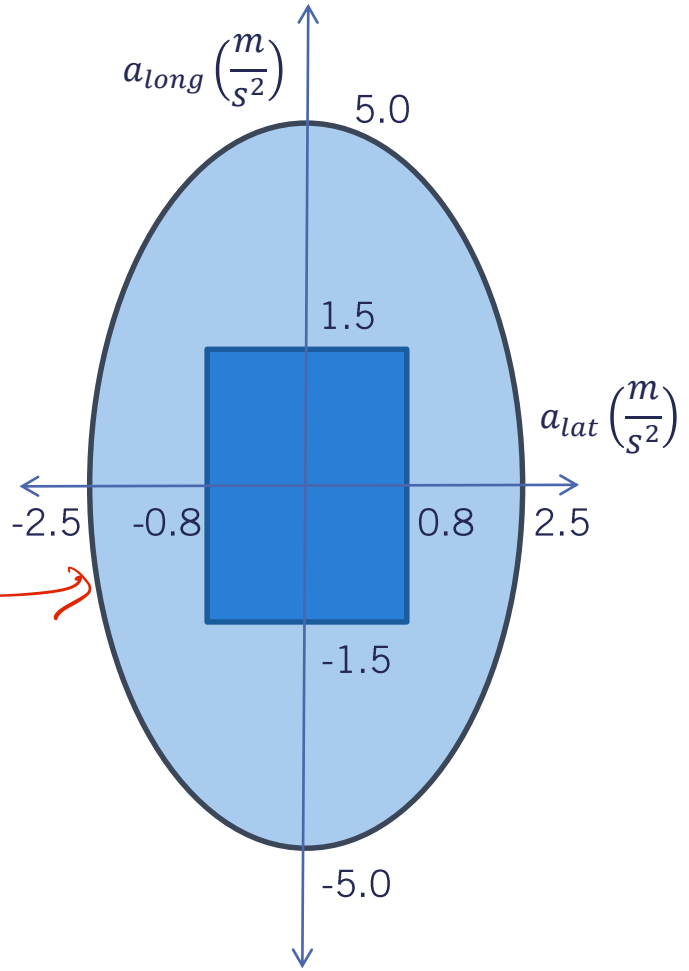
$r_2 < r_1$

$\kappa_2 > \kappa_1$

Vehicle Dynamics

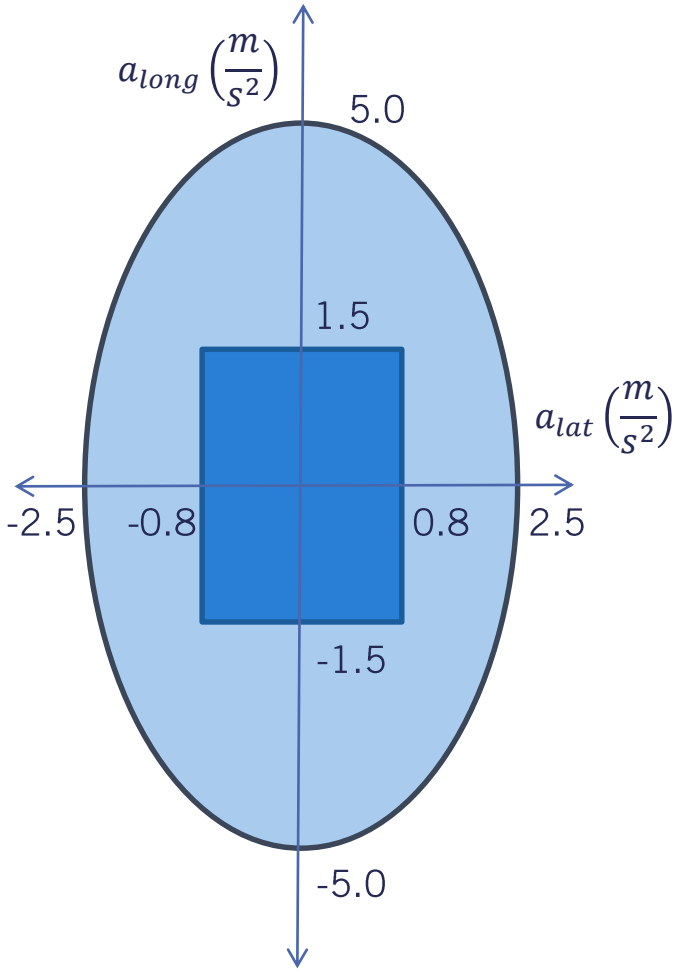
- Recall: friction ellipse denotes maximum magnitude of tire forces before stability loss





Vehicle Dynamics

- Recall: friction ellipse denotes maximum magnitude of tire forces before stability loss
- Friction forces are extreme limit; more useful constraint is accelerations tolerable by passengers
  - Given by “comfort rectangle” range of lateral and longitudinal accelerations



Dynamics and Curvature

- Friction limits and comfort restrict lateral acceleration
  - Lateral acceleration is a function of instantaneous turning radius of path and velocity
- Recall: instantaneous curvature is inverse of instantaneous turning radius
- Substituting, velocity is constrained by path curvature and lateral acceleration

$$a_{lat} = \frac{v^2}{r}, \qquad a_{lat} \leq a_{lat_{max}}$$

+

$$\kappa = \frac{1}{r}$$

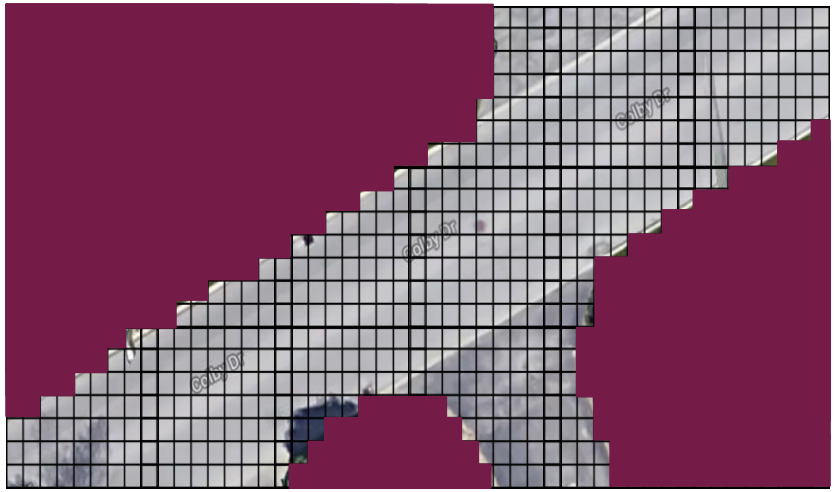
⇓

$$v^2 \leq \frac{a_{lat_{max}}}{\kappa}$$

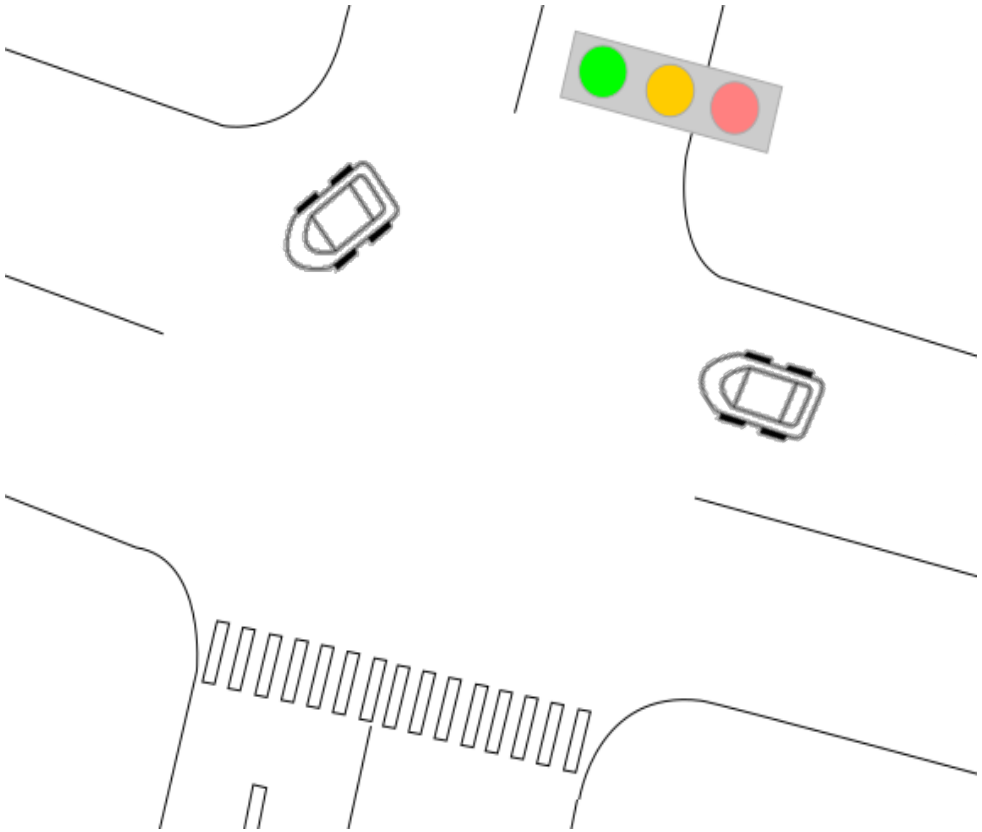
← curvature of the path

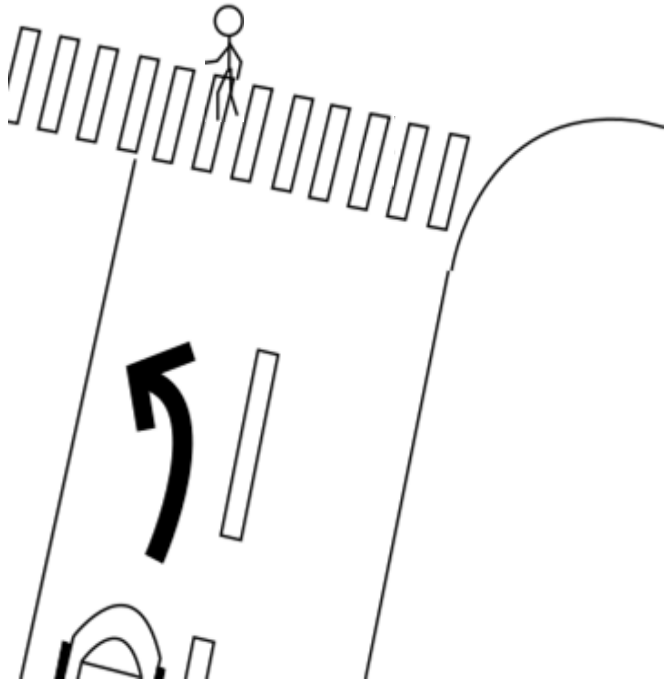
Static Obstacles

- Static obstacles block portions of workspace
  - Occupancy grid encoding stores obstacle locations
- Static obstacle constraints satisfied by performing collision checking
  - Can check for collisions using the swath of the vehicle's path union of ego vehicle positions
  - Can also check for closest obstacle along ego vehicle's path

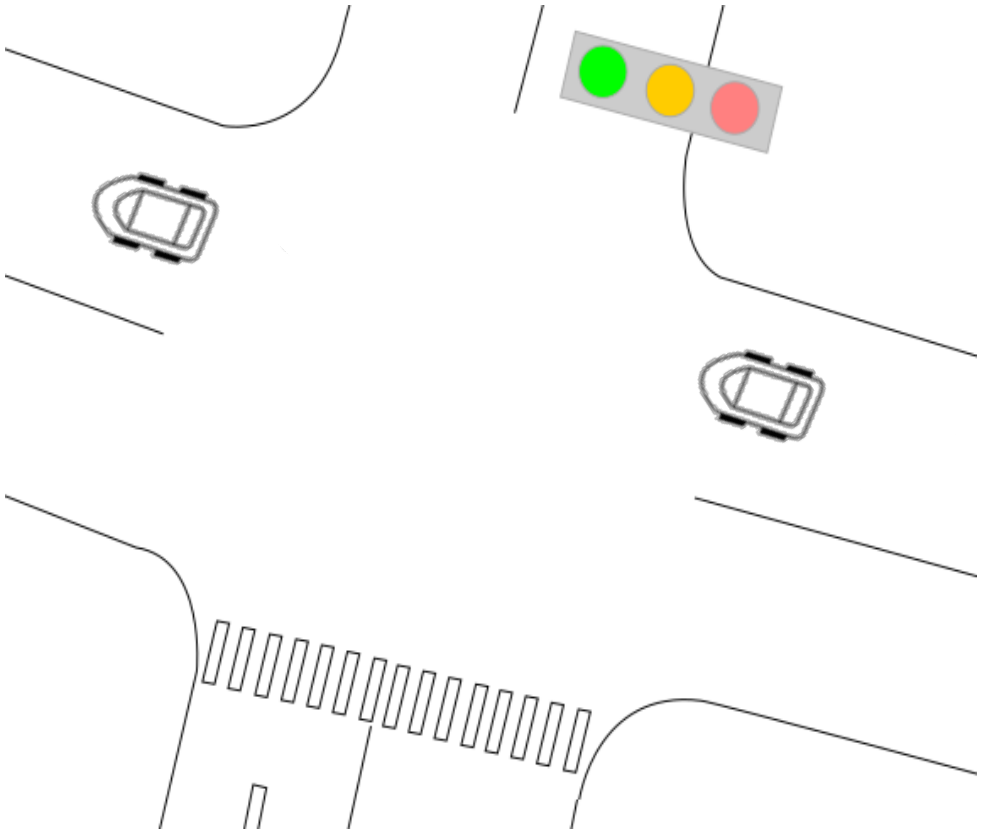


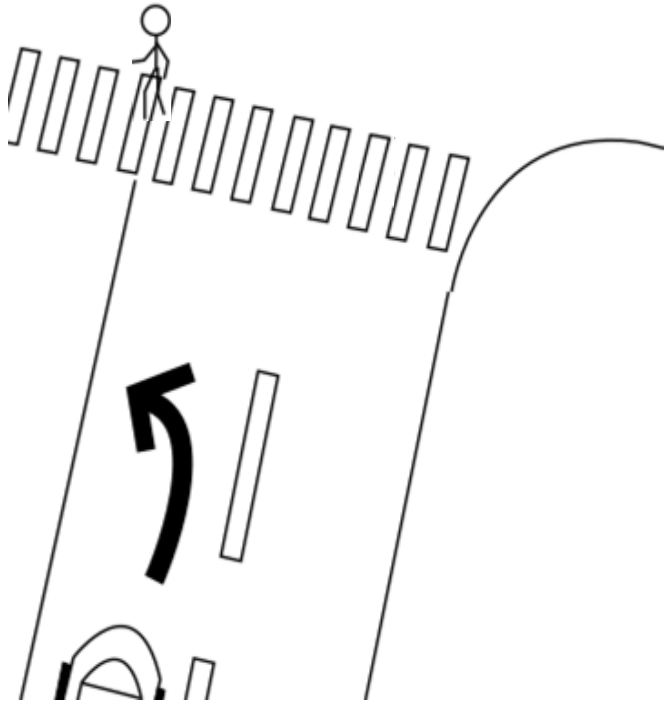
Dynamic Obstacles





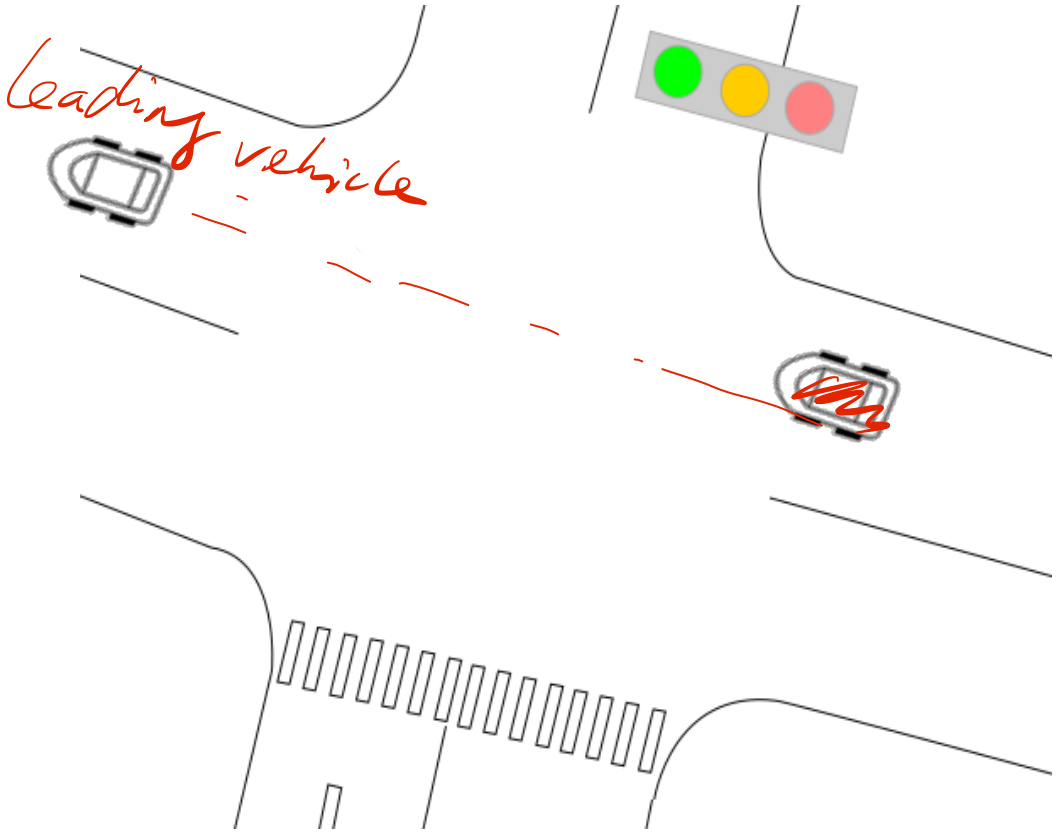
Dynamic Obstacles

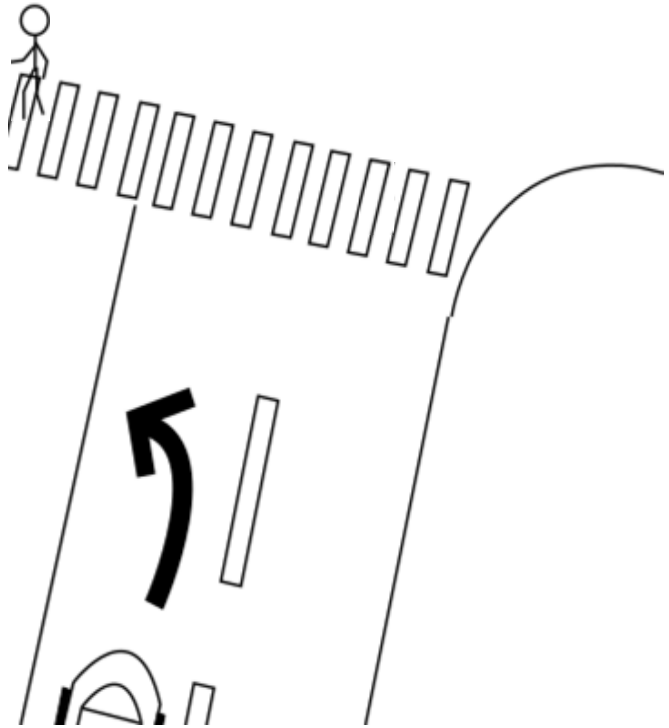




Dynamic Obstacles

{ behavior planning (maneuver decisions)
{ local planning





Rules of the Road and Regulatory Elements

- Lane constraints restrict path locations
- Signs, traffic lights influence vehicle behaviour