# Hardware Configuration Design

Module 2, Lesson 2

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

# In this lesson ...

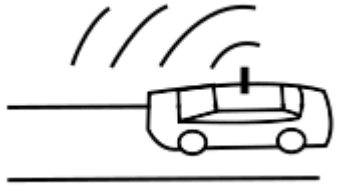
- Sensor coverage requirements for different scenarios
  - Highway driving
  - Urban driving
- Overall coverage, blind spots

# Sensors

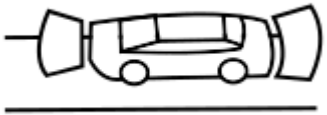
Camera

LIDAR

RADAR



Ultrasonics



GNSS/IMU

Wheel Odometry

# Assumptions

- Aggressive deceleration = $5\ ^{m}/_{s^2}$
- Comfortable deceleration = $2\ ^{m}/_{s^2}$
  - This is the norm, unless otherwise stated

- Stopping distance: $d = \frac{v^2}{2a}$

# Where to place sensors?

- Need sensors to support maneuvers within our ODD
- Broadly, we have two driving environments

| | **Highway** | **Urban / Residential** |
|---|---|---|
| Traffic Speed | High | Low - Medium |
| Traffic Volume | High | Medium - High |
| # of lanes | More | 2-4 typically |
| Other Features | Fewer, gradual curves; merges | Many turns and intersections |

# Highway Analysis

- Broadly, 3 kinds of maneuvers:
- Emergency Stop
- Maintain Speed
- Lane Change

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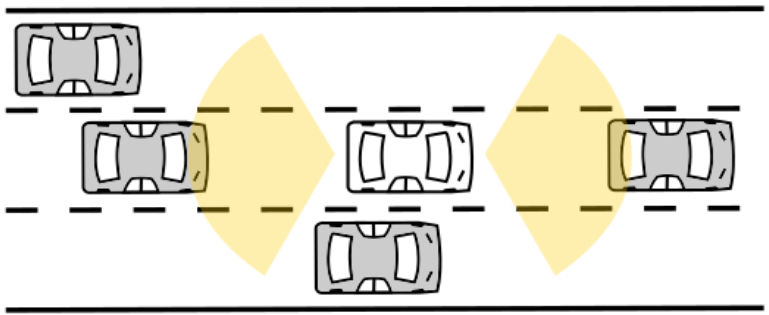
# Highway Analysis: Emergency Stop

If there is a blockage ahead, we want to stop in time.



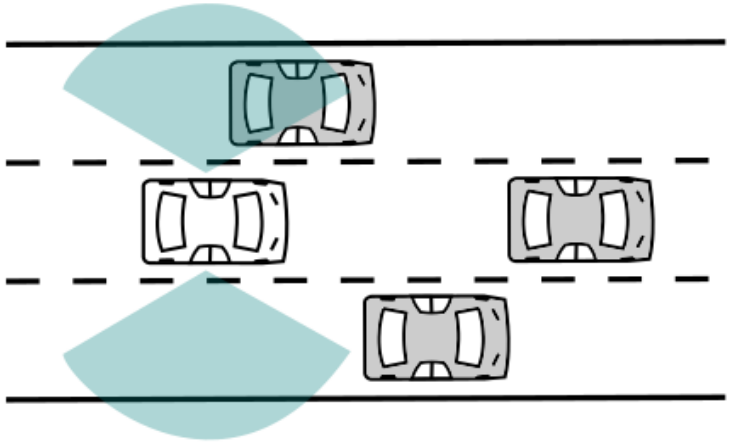
**Longitudinal Coverage**:

Assume we are speeding at 120 kmph.

Stopping distance could be ~110 metres; *aggressive deceleration*

# Highway Analysis: Emergency Stop

To avoid collision, either we stop or change lanes.

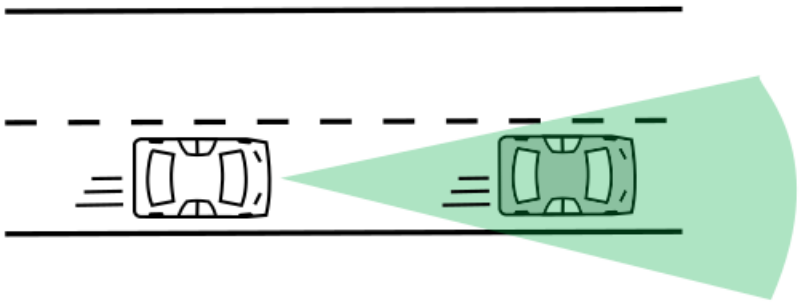


**Lateral Coverage**:

At least adjacent lanes,
since we may change lanes
to avoid a hard stop.

# Highway Analysis: Maintain Speed

Relative speeds are typically less than 30 kmph.

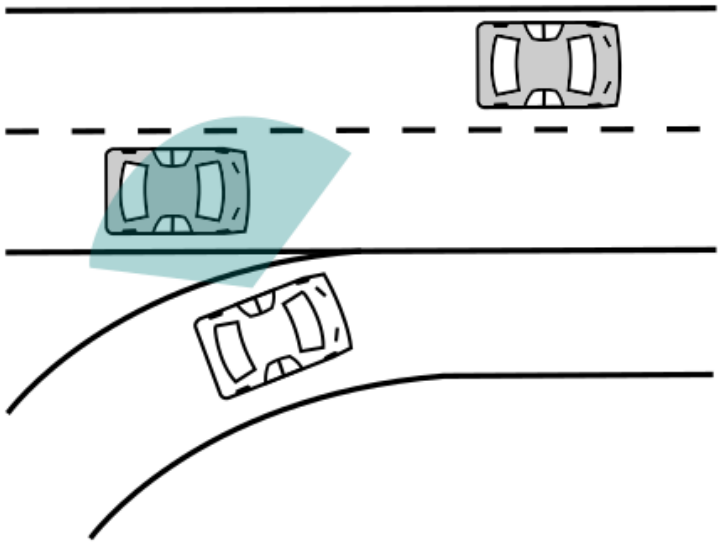


**Longitudinal coverage**:

At least ~100 metres in front.

Both vehicles are moving, so don't need to look as far as emergency-stop case.

# Highway Analysis: Maintain speed with Merge



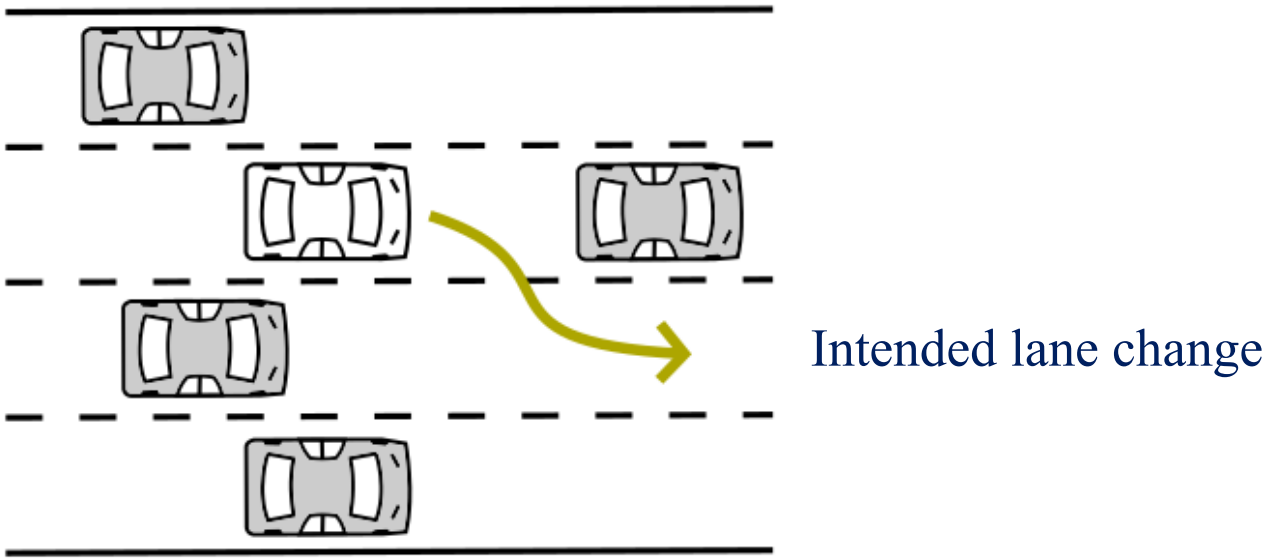
**Lateral Coverage**:

Usually current lane

Adjacent lanes would be preferred for merging vehicle detection.

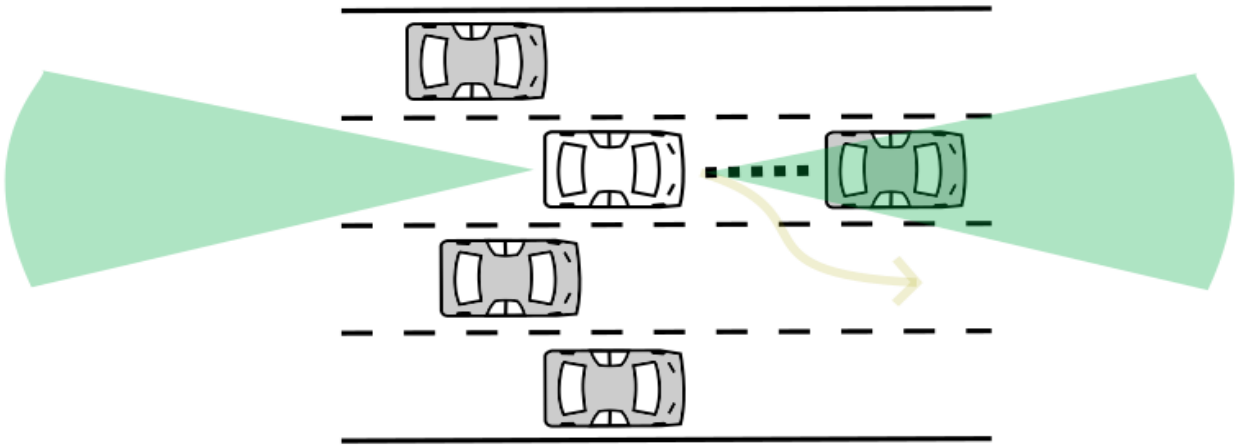
# Highway Analysis: Lane Change

Consider this possible lane change scenario:



# Highway Analysis: Lane Change

Longitudinal coverage: Need to look forward to maintain a safe distance.

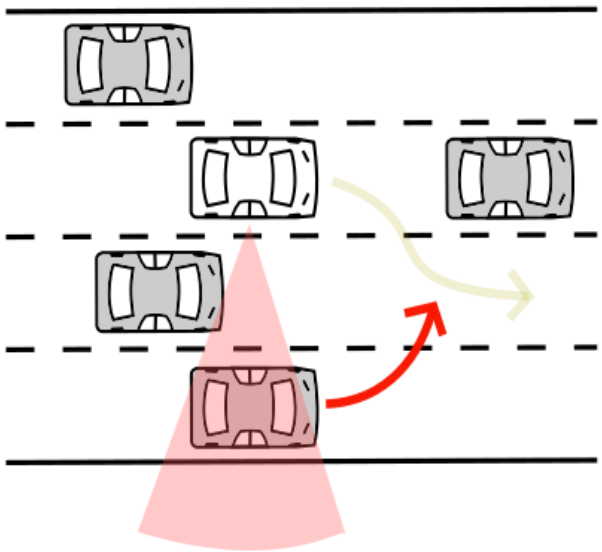


Need to look behind to see what rear vehicles are doing.

# Highway Analysis: Lane Change

Laterally, we need to look not just in the adjacent lanes, but probably further.

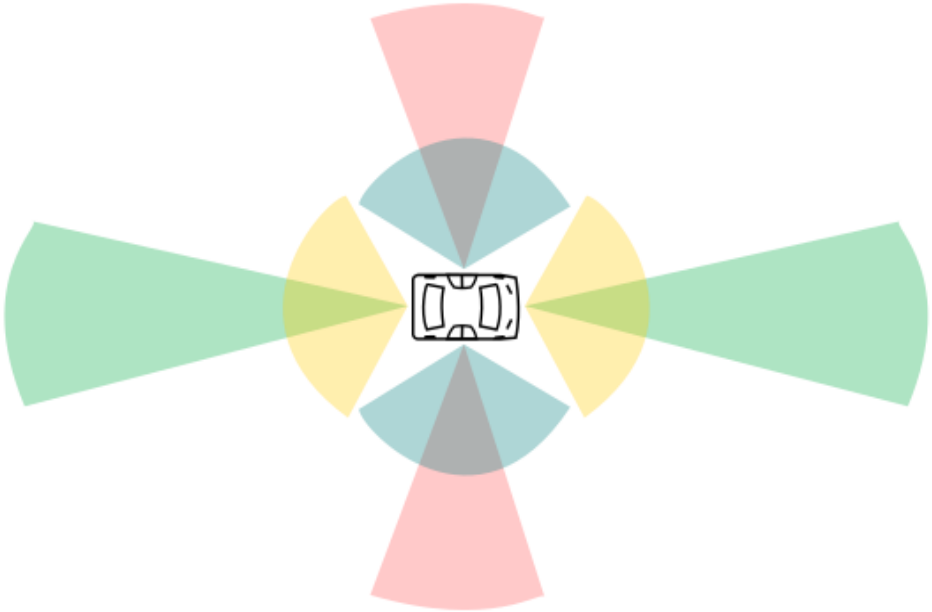
Lateral coverage:
Need wider sensing



*what if?*

# Highway Analysis: Overall Coverage

- Emergency Stop
- Emergency Stop, Maintain Speed
- Maintain Speed, Lane Change
- Lane Change



# Urban Analysis

Broadly, 6 kinds of maneuvers:

- Emergency Stop
- Maintain Speed
- Lane Change

- Overtaking
- Turning, crossing at intersections
- Passing roundabouts

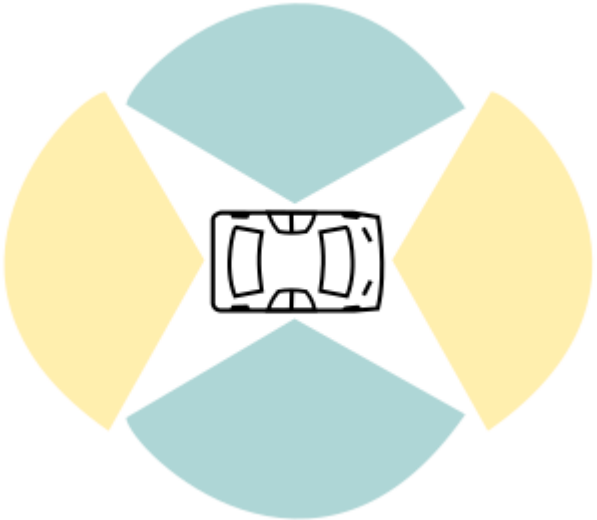
# Urban Analysis

Broadly, 6 kinds of maneuvers:

- Emergency Stop
- Maintain Speed
- Lane Change

**Similar to highway analysis!**

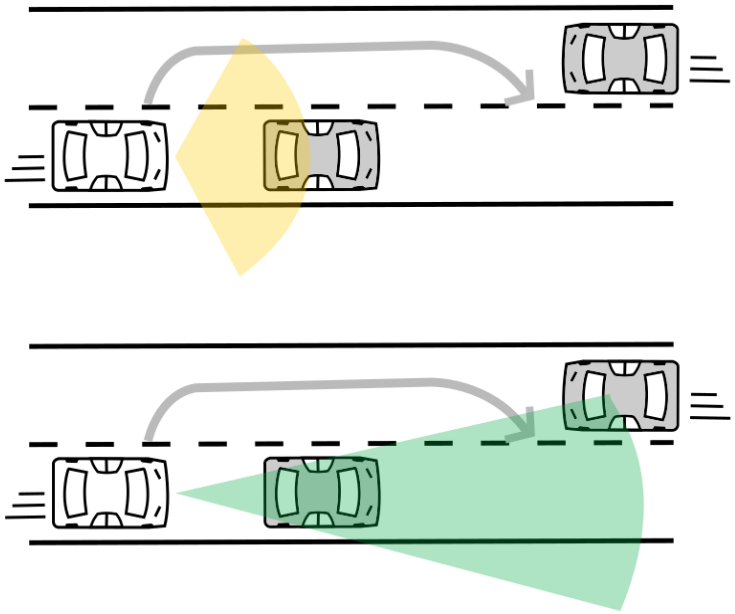
- Overtaking
- Turning, crossing at intersections
- Passing roundabouts



# Urban Analysis: Overtaking

**Longitudinal coverage:**

If overtaking a parked or moving vehicle, need to detec oncoming traffic beyond point of return to own lane.

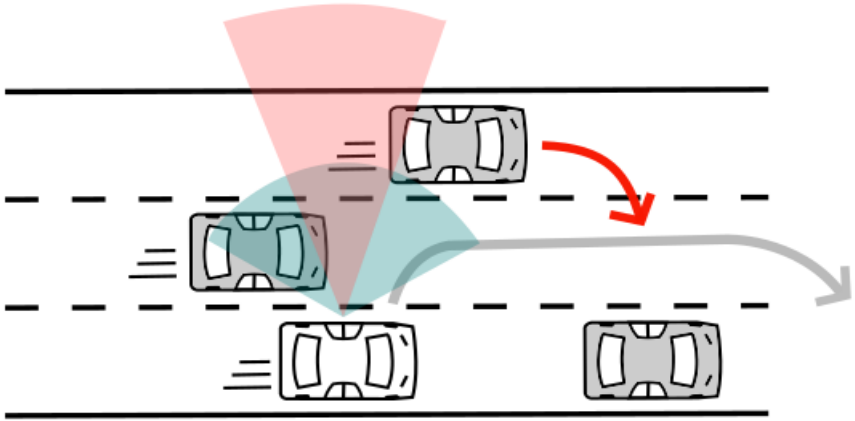


# Urban Analysis: Overtaking

**Lateral coverage**:

Always need to observe adjacent lanes.

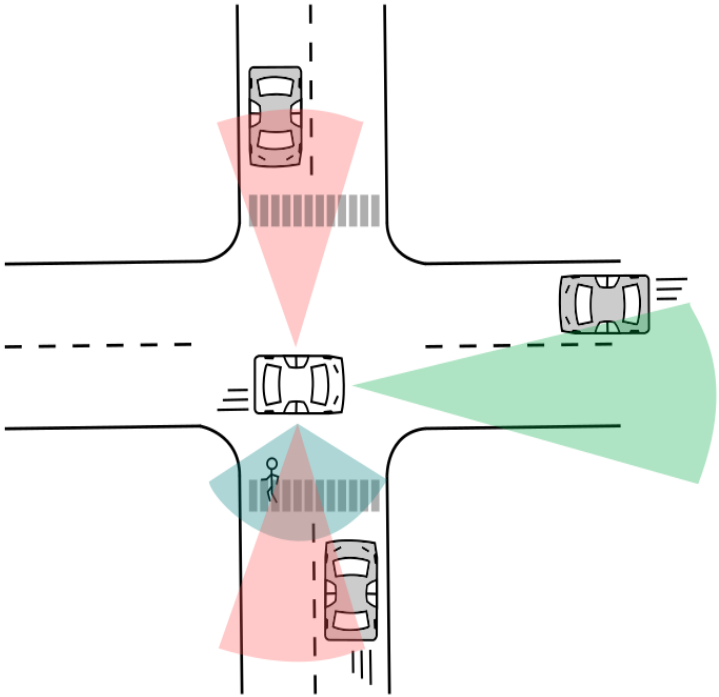
Need to observe additional lanes if other vehicles can move into adjacent lanes.



# Urban Analysis: Intersections

Observe beyond intersection for approaching vehicles, pedestrian crossings, clear exit lanes.

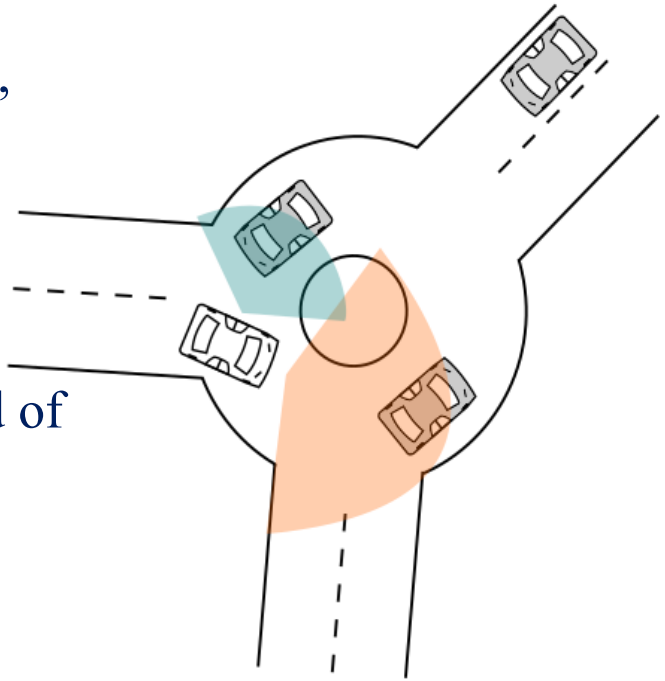
Requires near omni-directional sensing for arbitrary intersection angles



# Urban Analysis: Roundabouts

**Lateral coverage:**
Vehicles are slower than usual, limited range requirement.

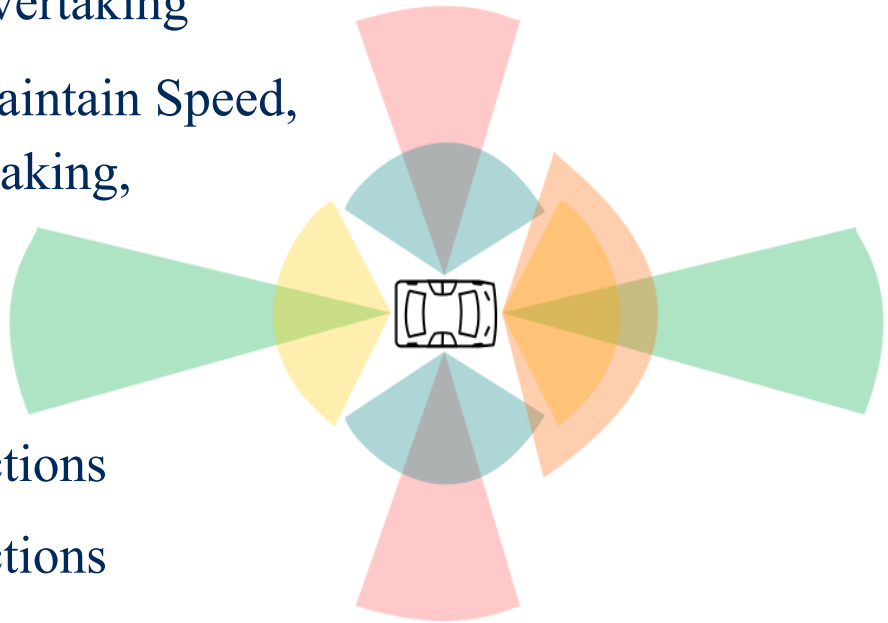
**Longitudinal coverage:**
Due to the shape of the roundabout, need a wider field of view.



# Urban Analysis: Overall Coverage

Emergency Stop, Overtaking

Emergency Stop, Maintain Speed, Lane Change, Overtaking, Intersections, Roundabouts



Overtaking, Intersections

Overtaking, Intersections

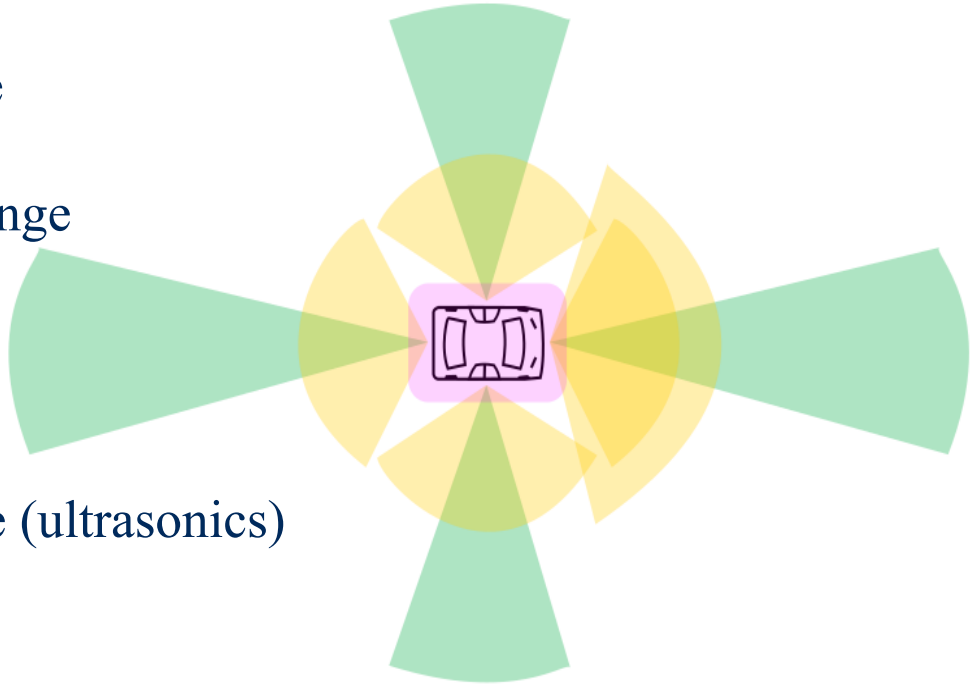
Roundabouts

# Overall Coverage & Sensors Analysis

Long range

Medium range

Short range (ultrasonics)



# Summary

- Sensor coverage analysis - longitudinal and lateral coverage
  - highway driving
  - urban driving
- costs, blind spots