

CoDrive: Improving Automobile Positioning via Collaborative Driving

Authors

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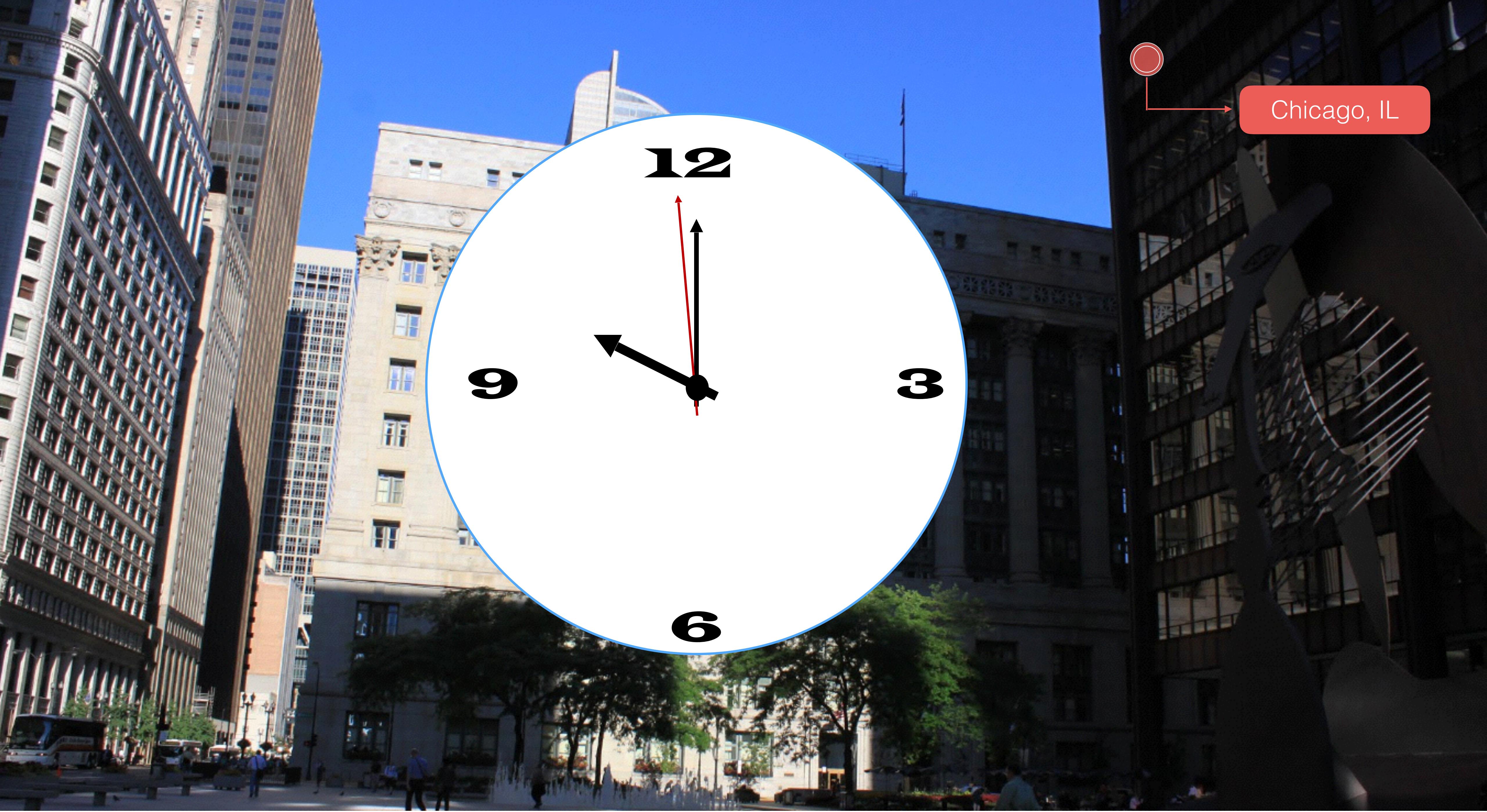
Puneet Jain (Hewlett Packard Labs)

Kyu-Han Kim (Hewlett Packard Labs)

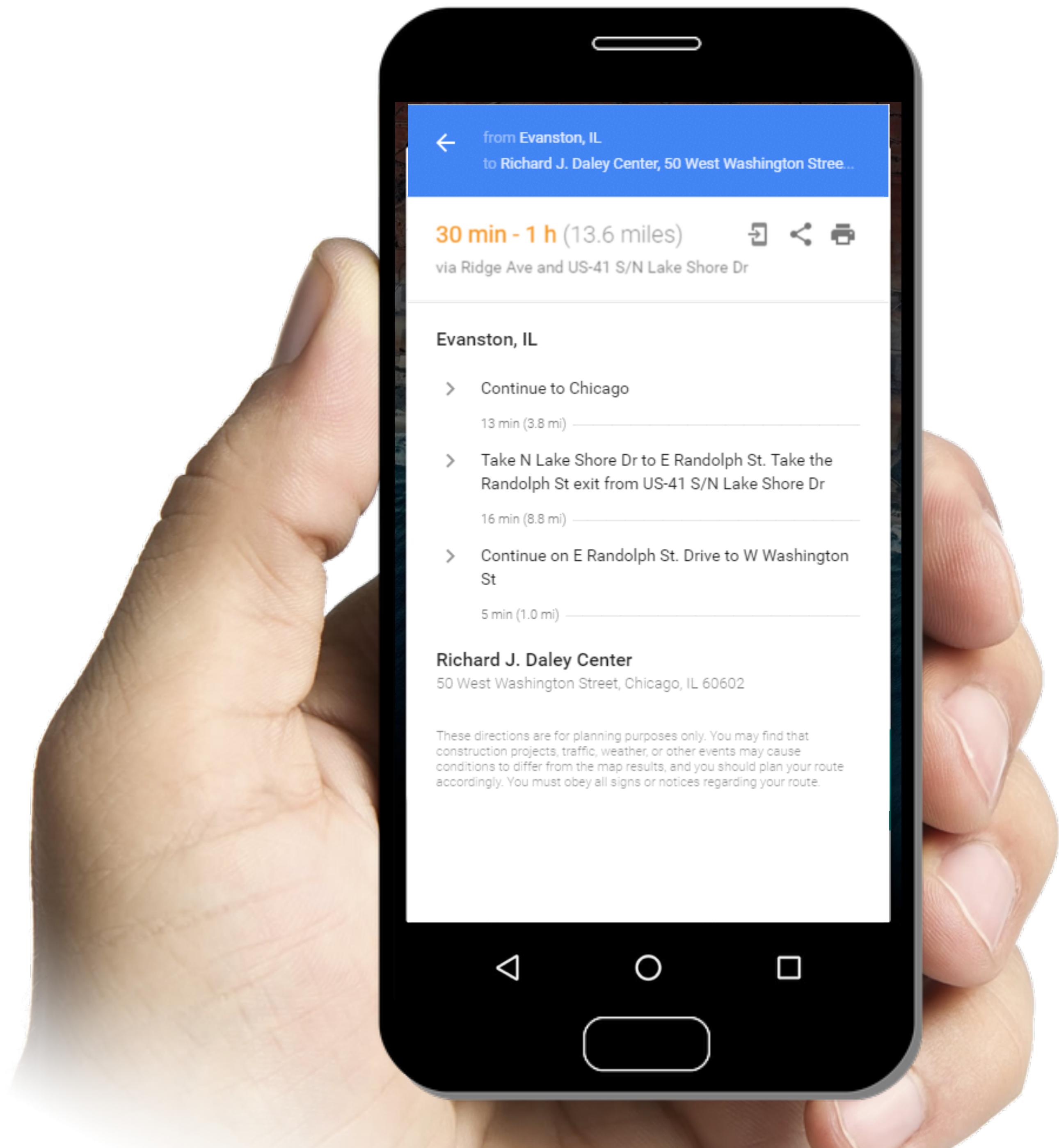


Hewlett Packard
Enterprise

Hewlett Packard
Enterprise



Chicago, IL

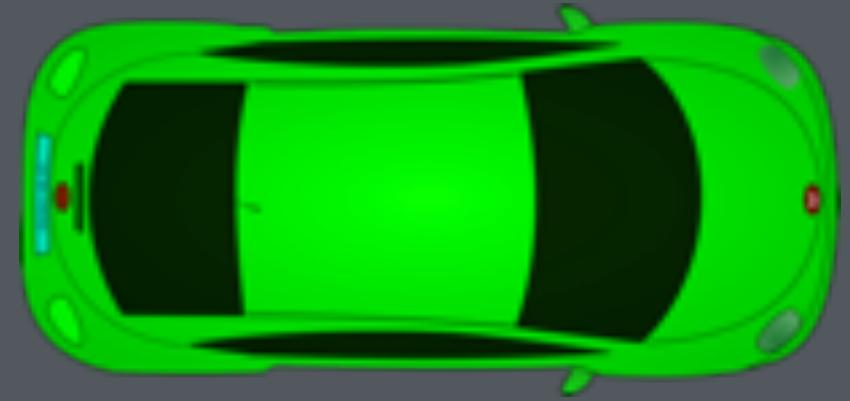
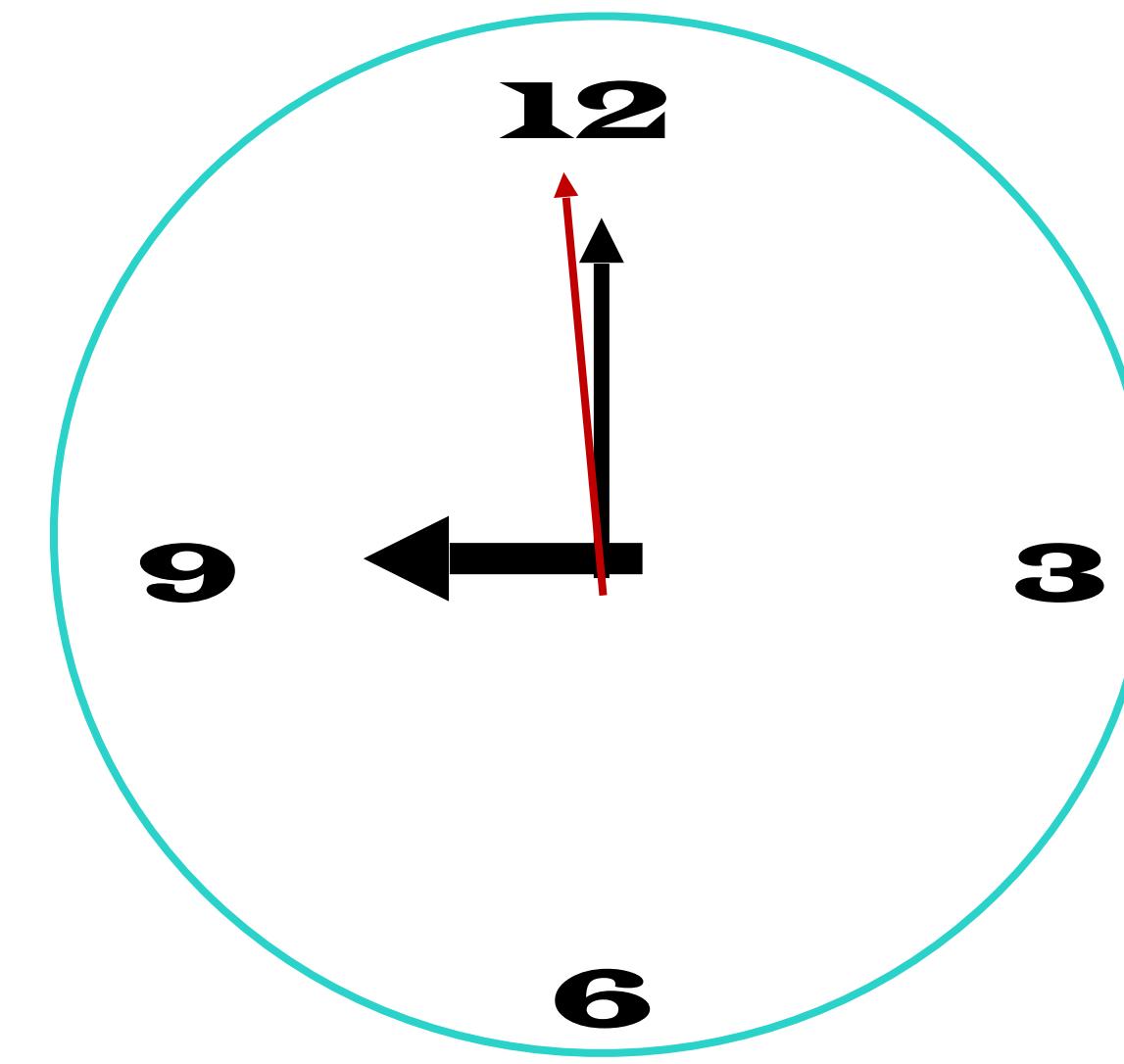


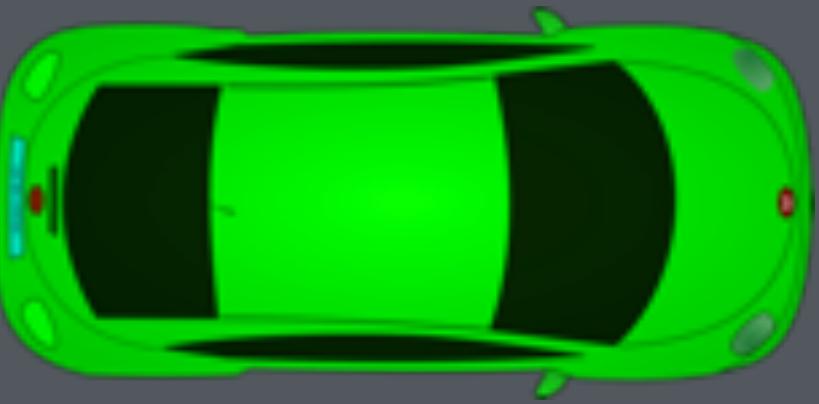
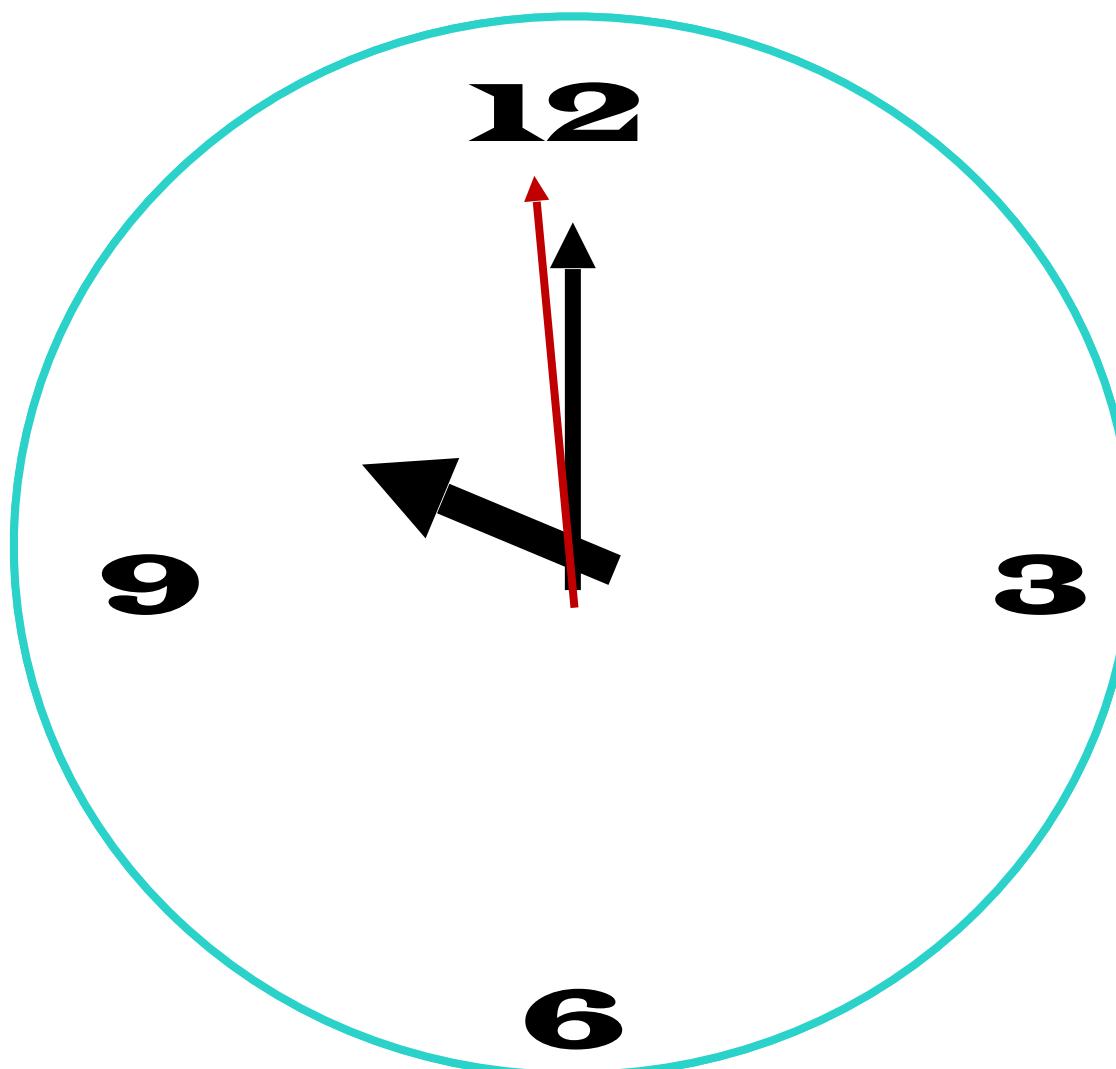


30 min - 1 h (13.6 miles)

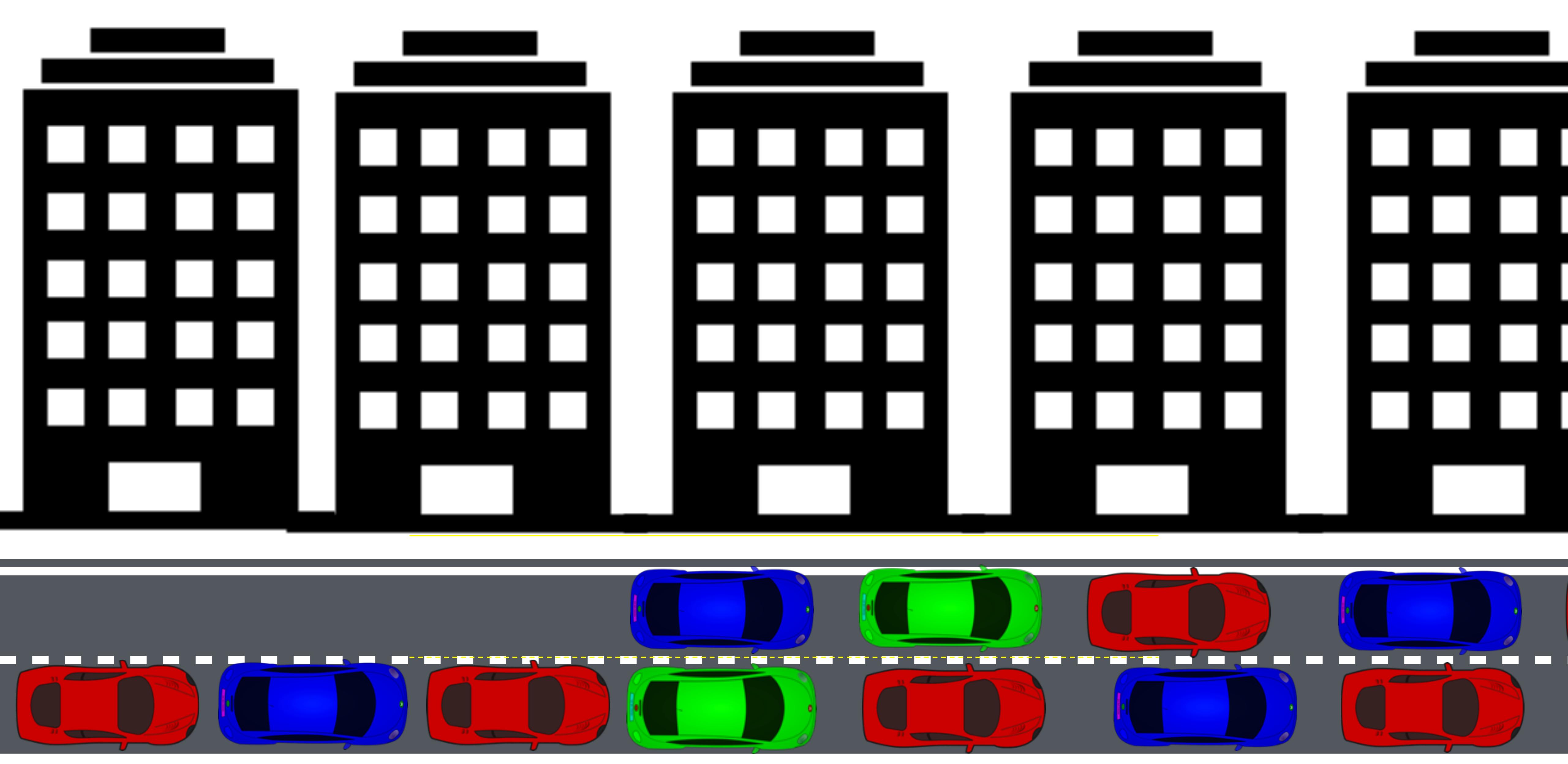
via Ridge Ave and US-41 S/N Lake Shore Dr

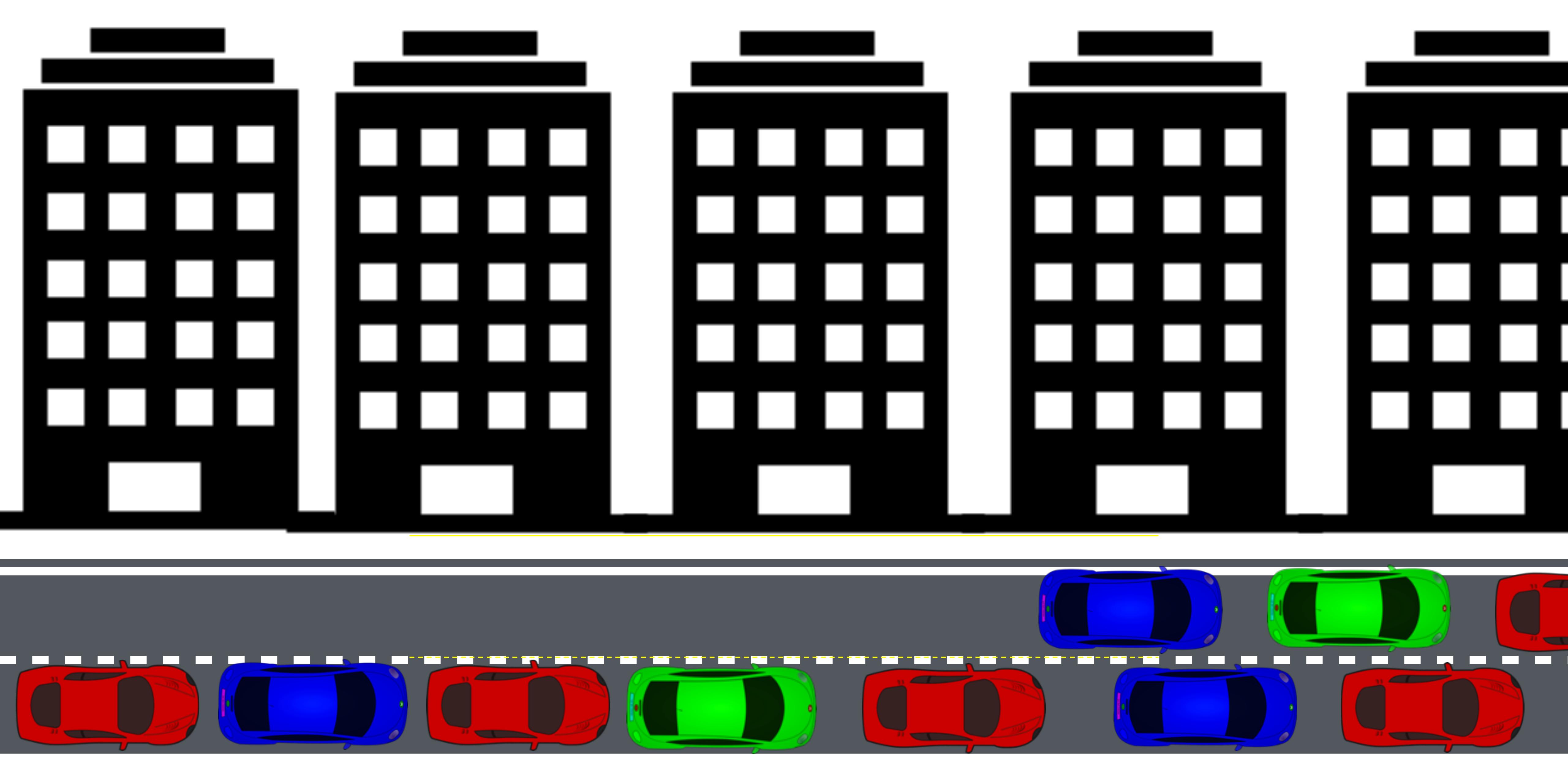


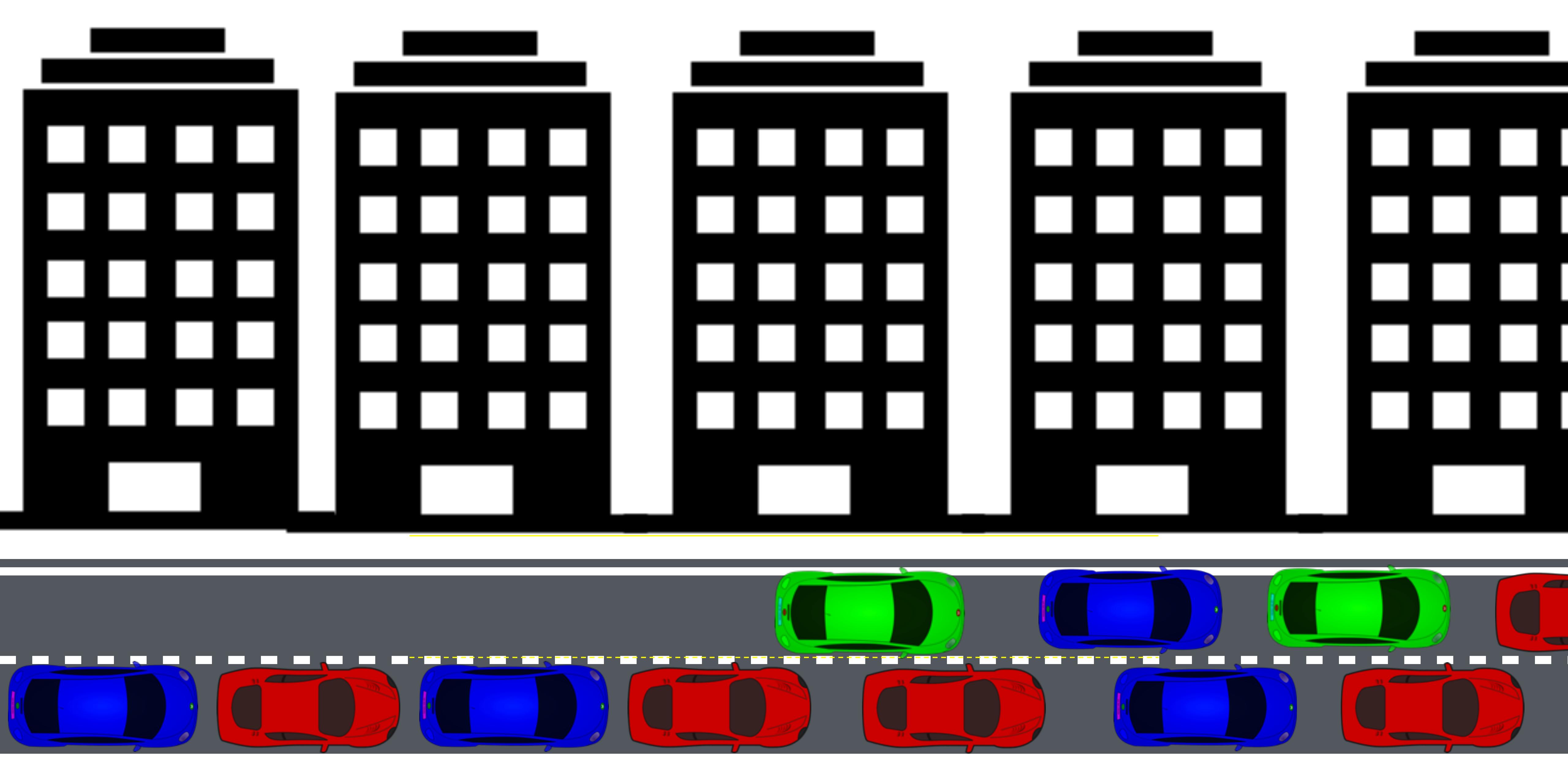


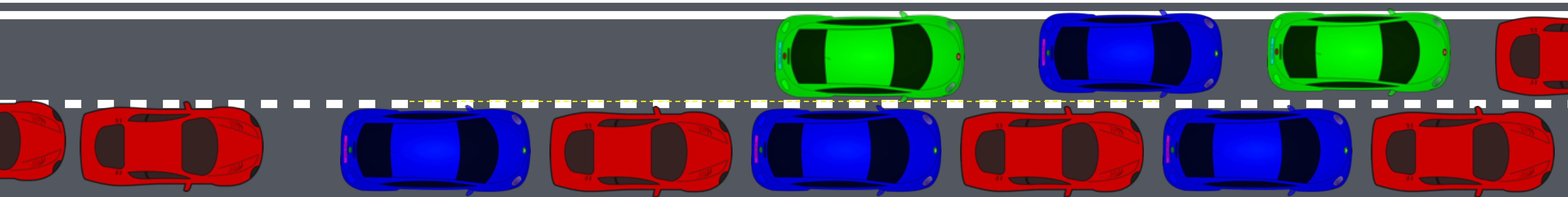




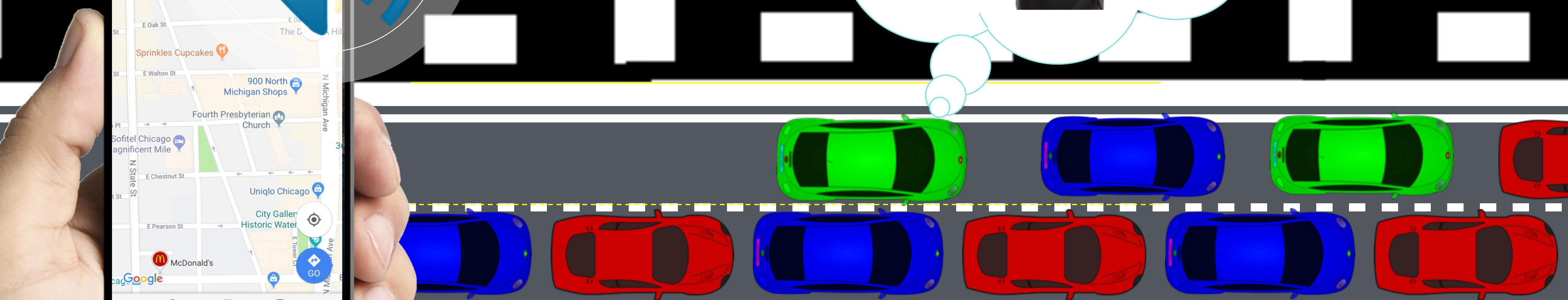






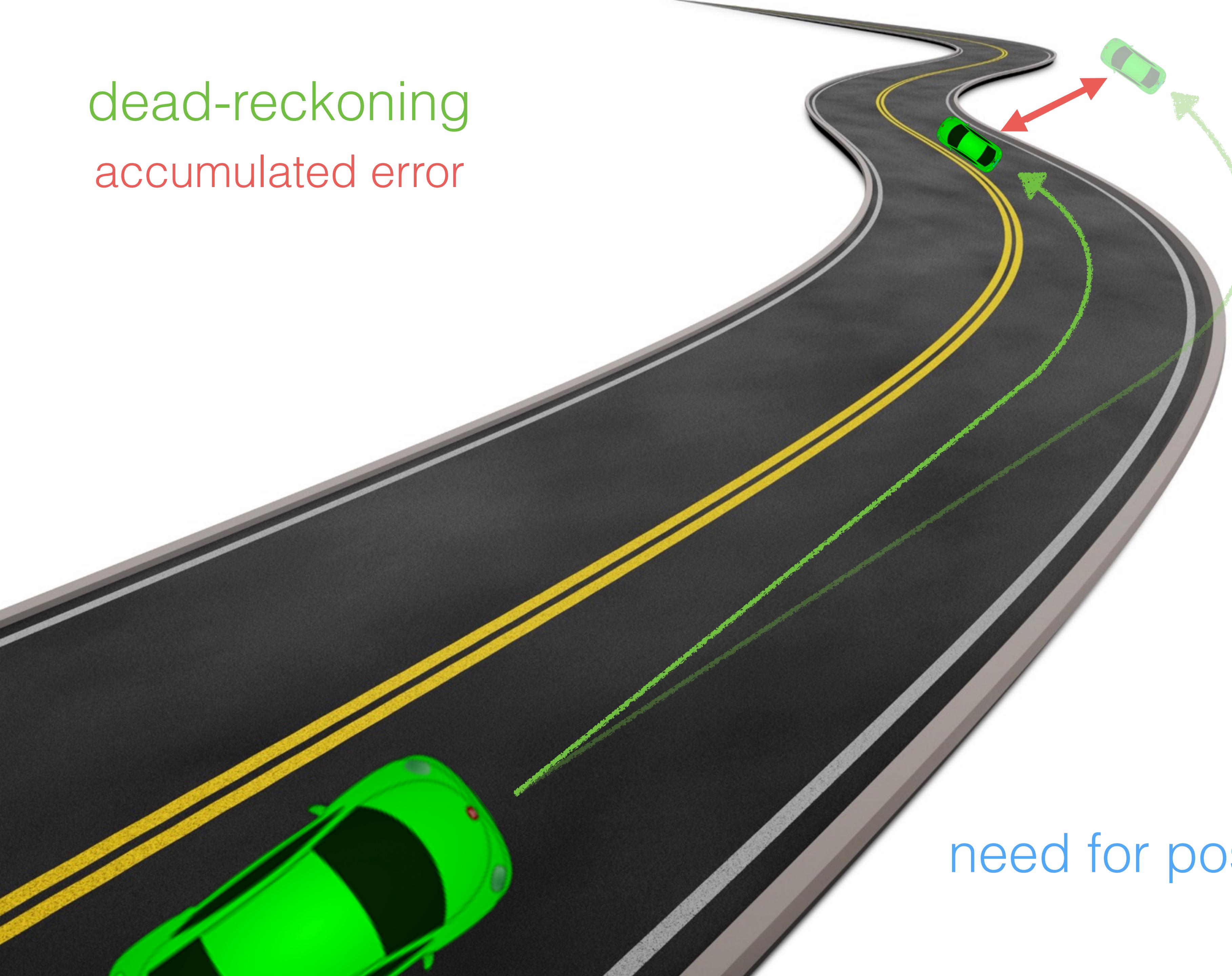




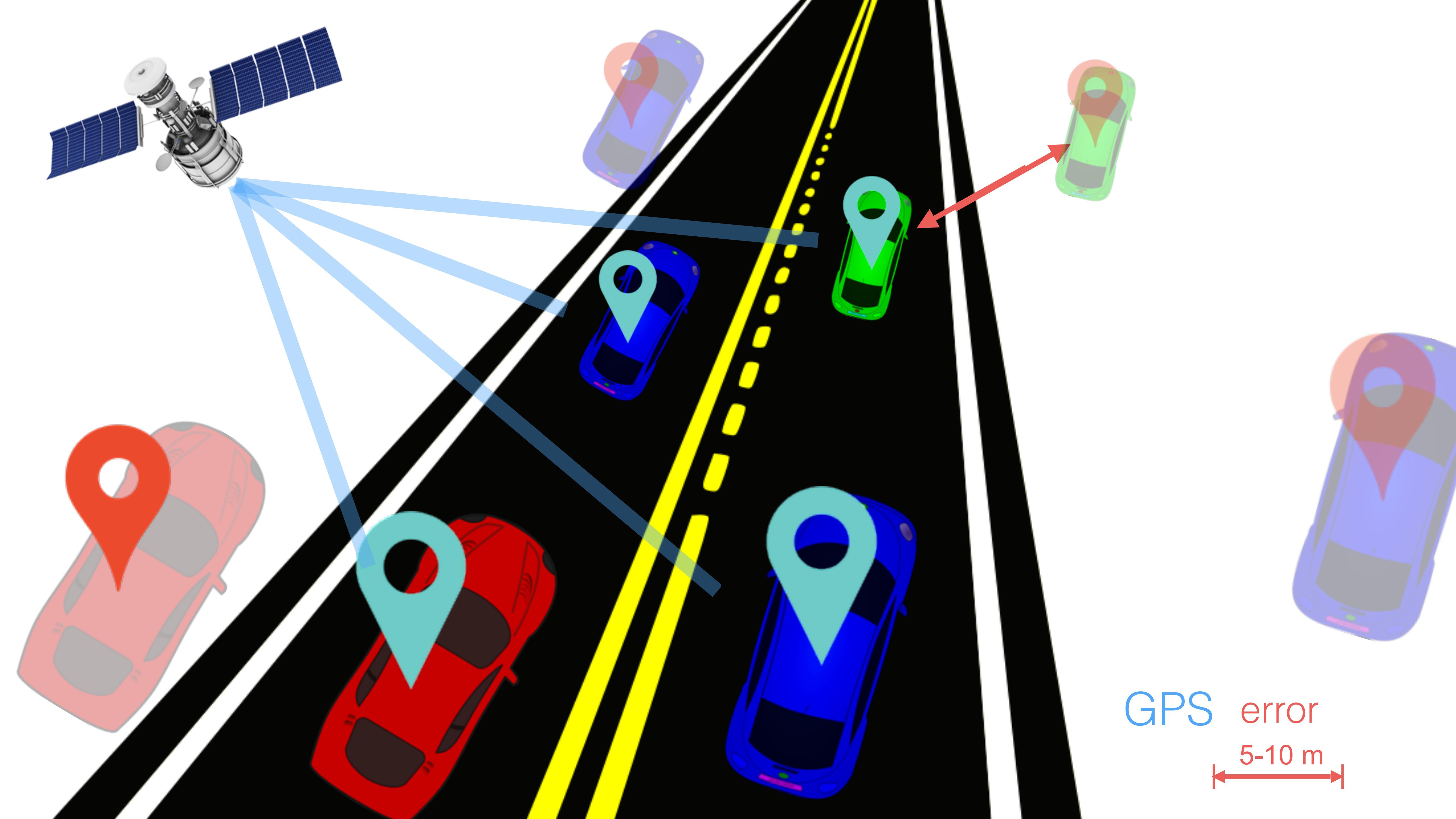


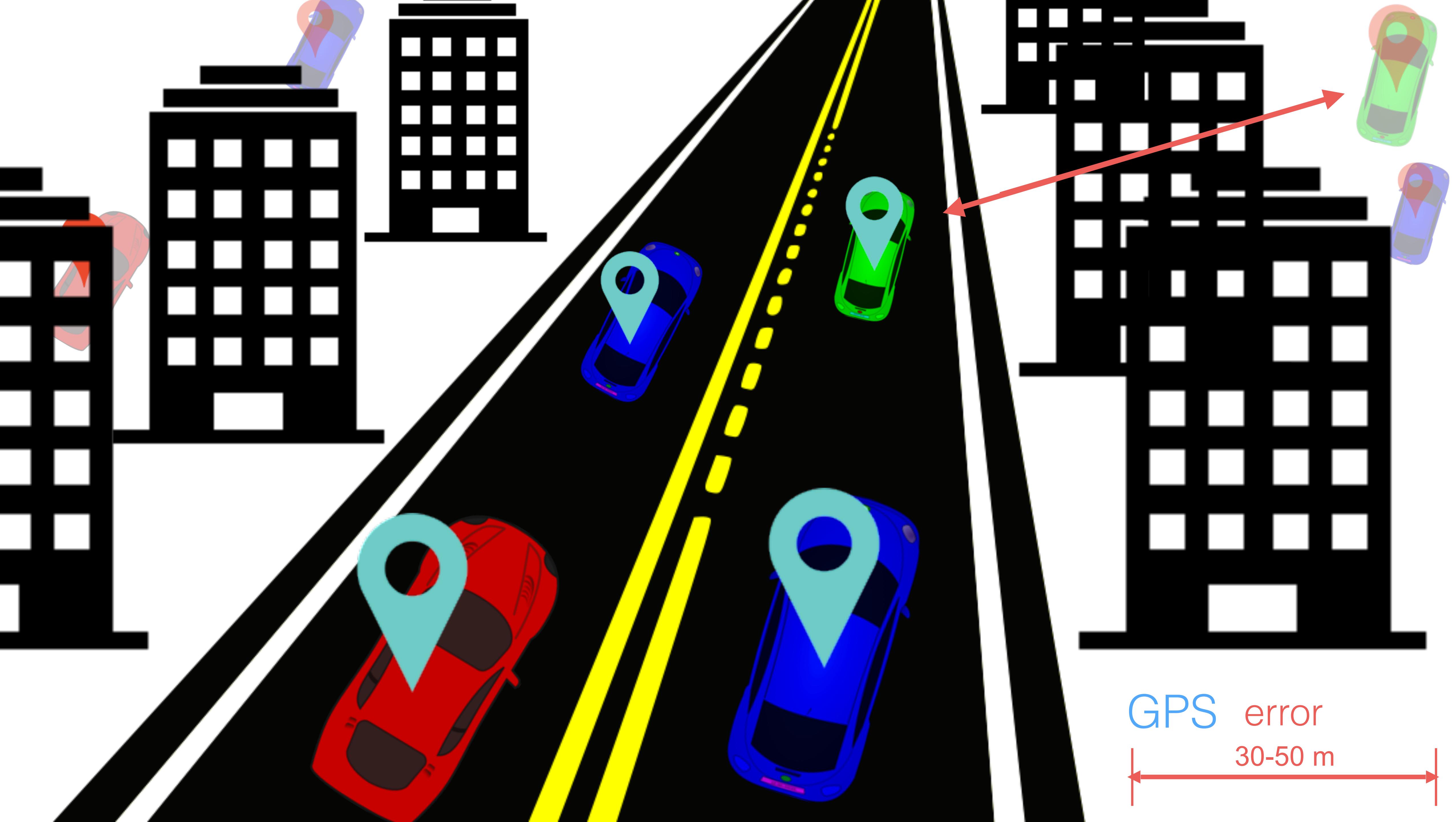
Why is this happening?

dead-reckoning
accumulated error



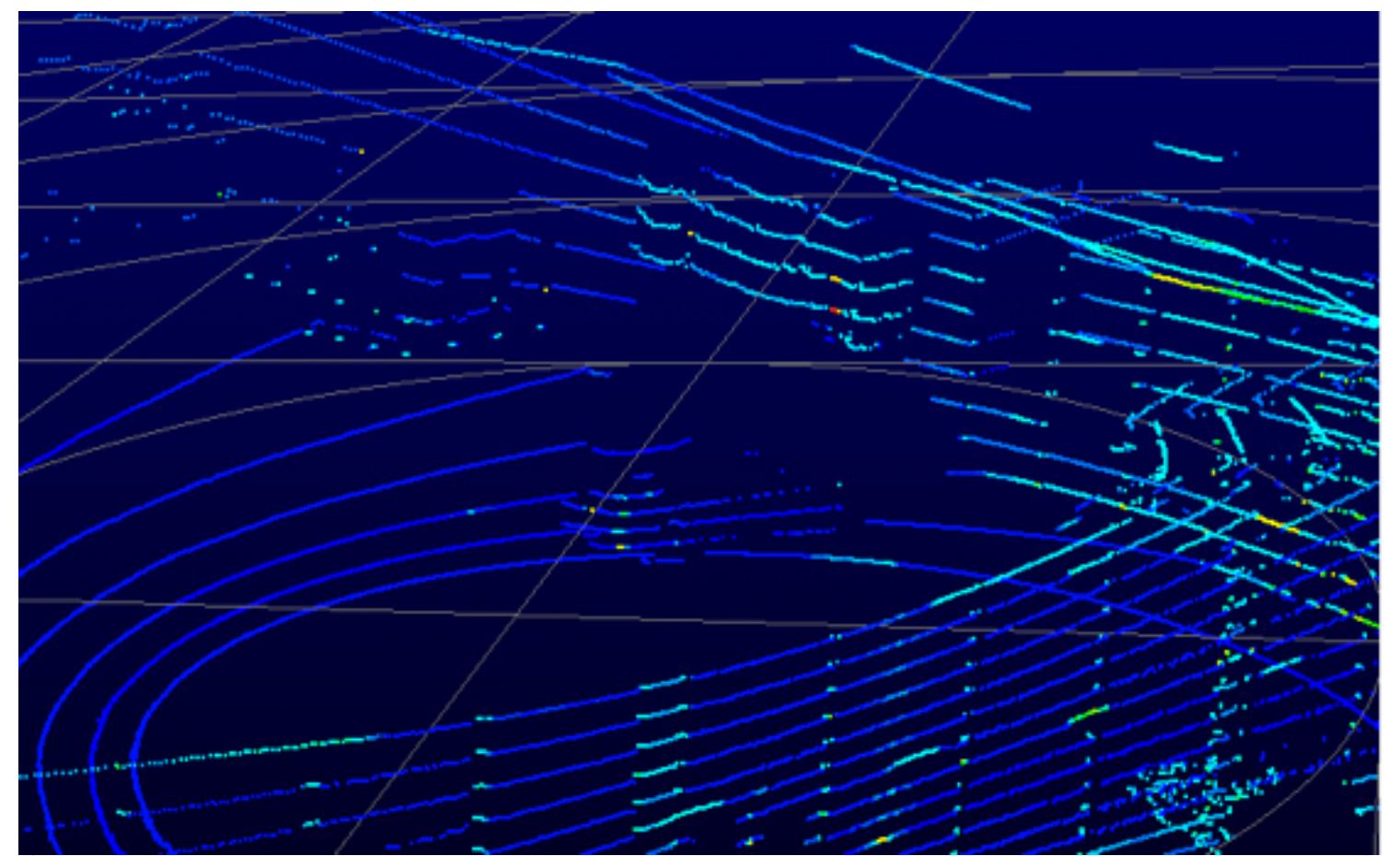
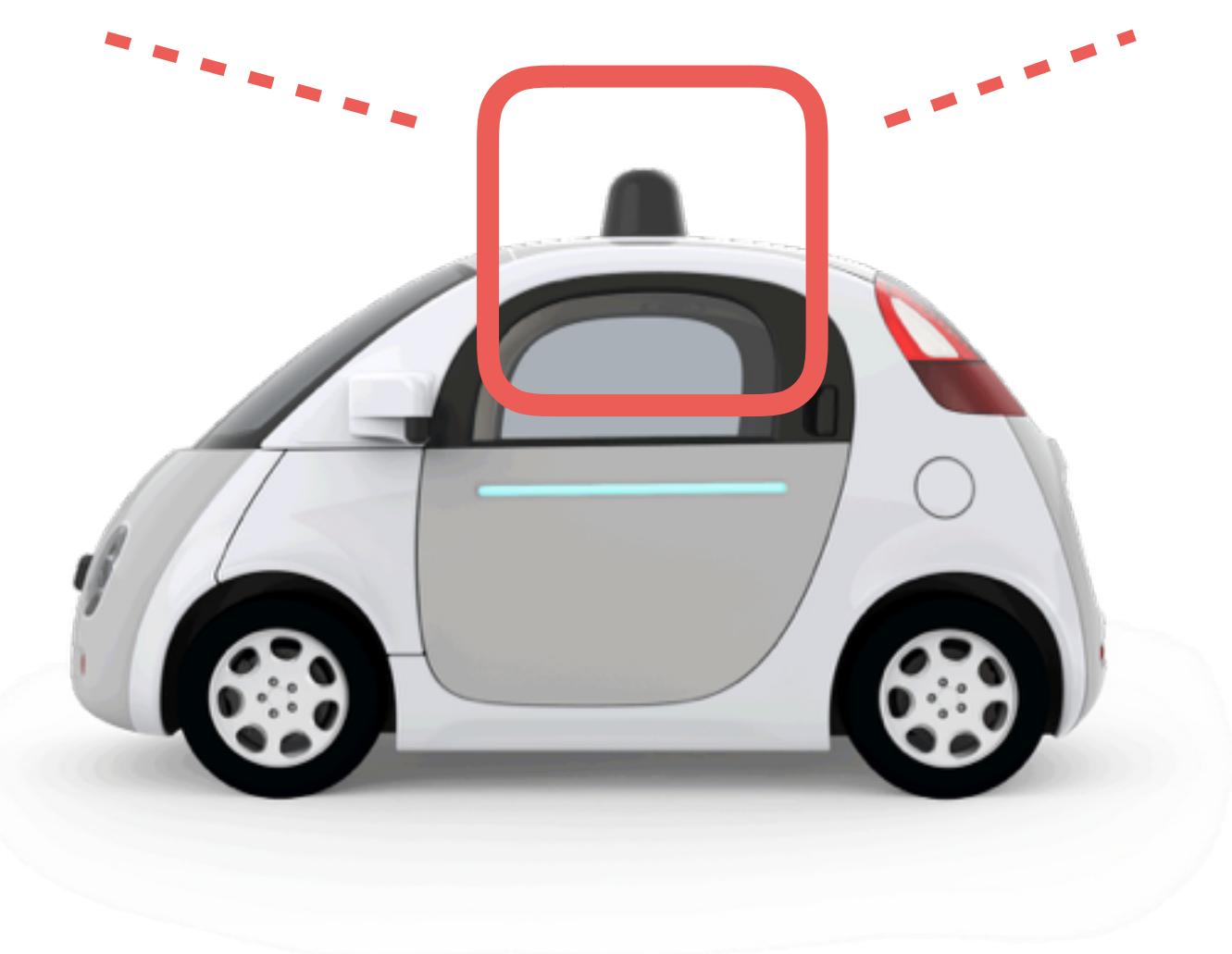
need for positioning correction



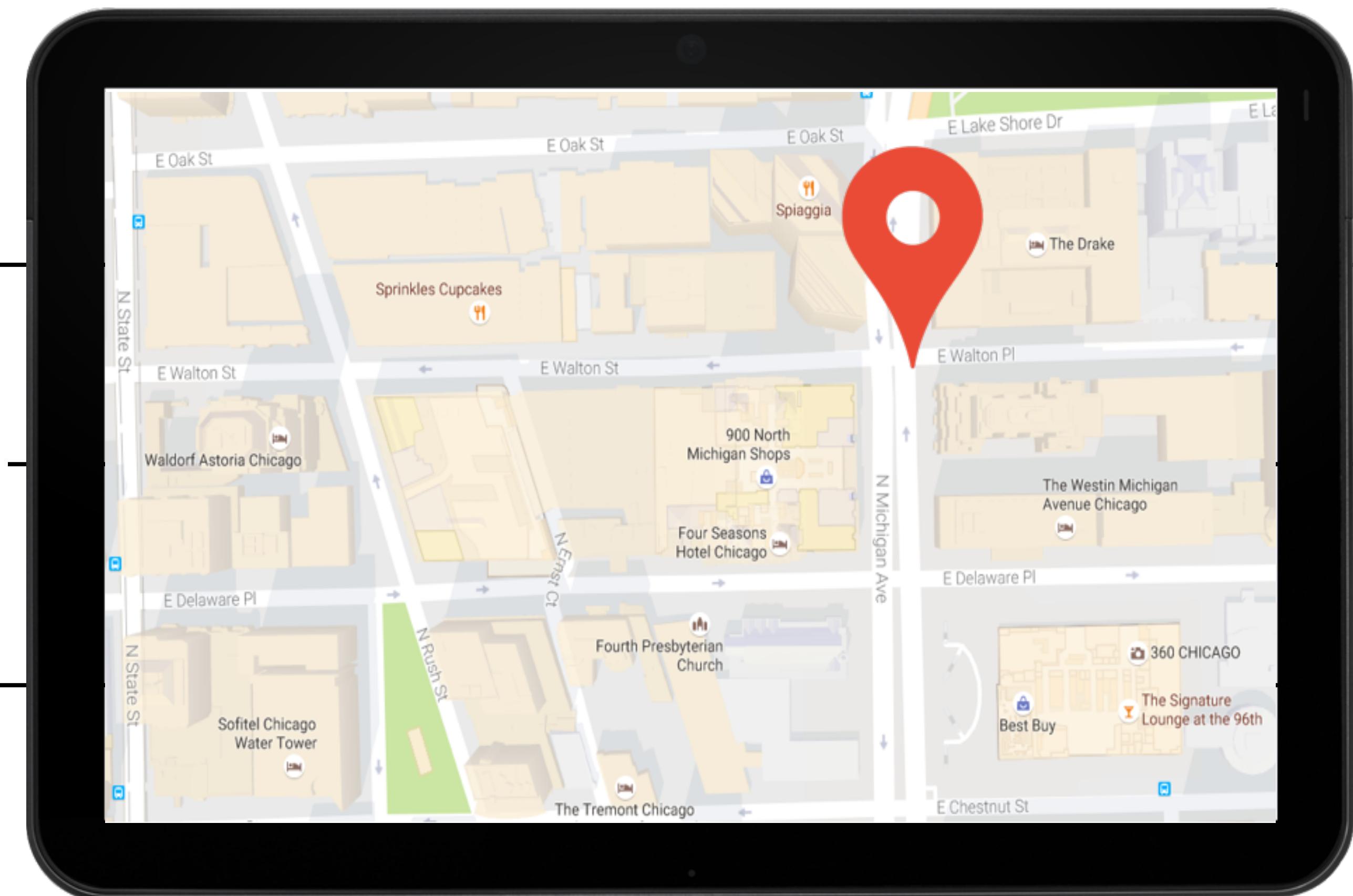


Stationary Landmarks



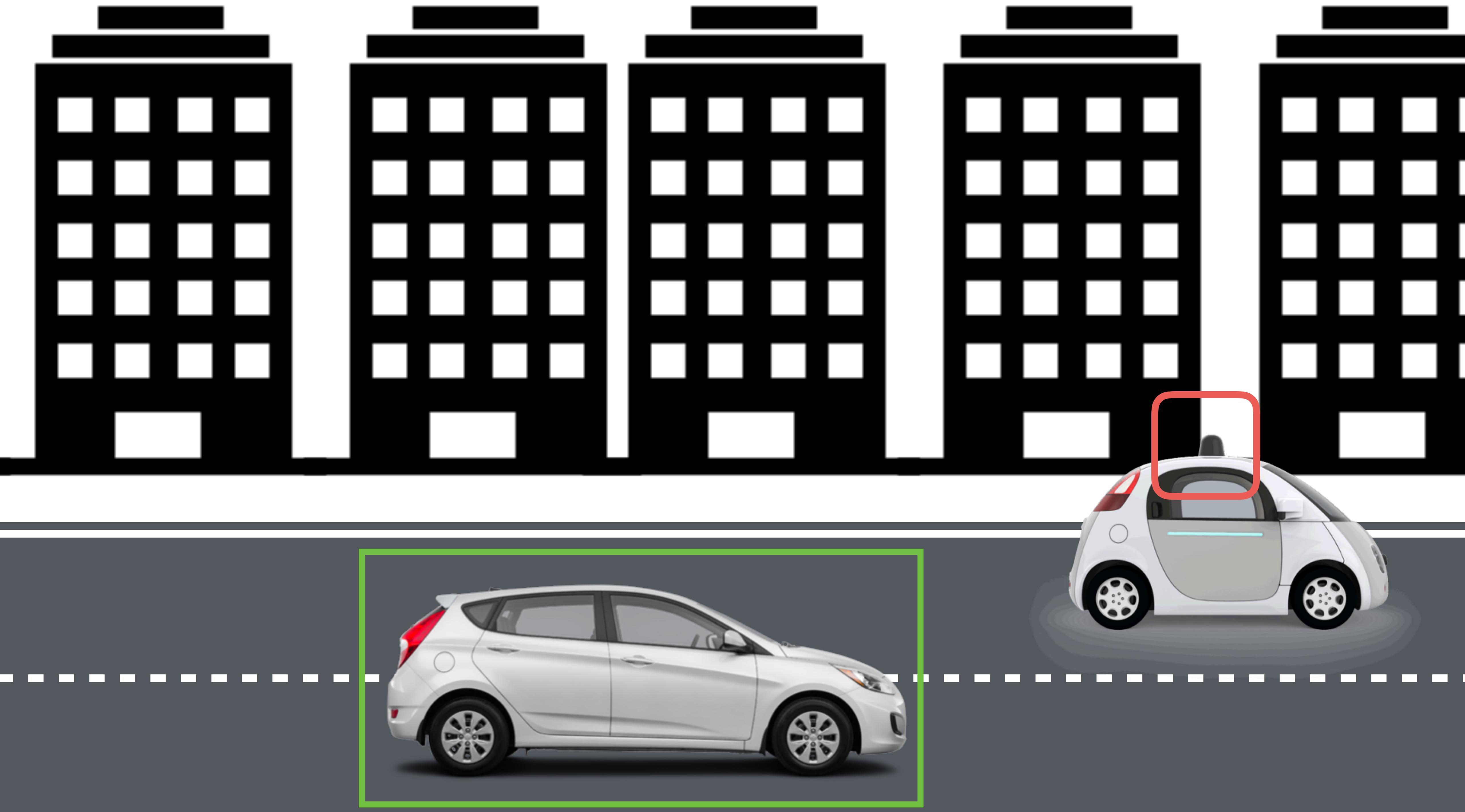


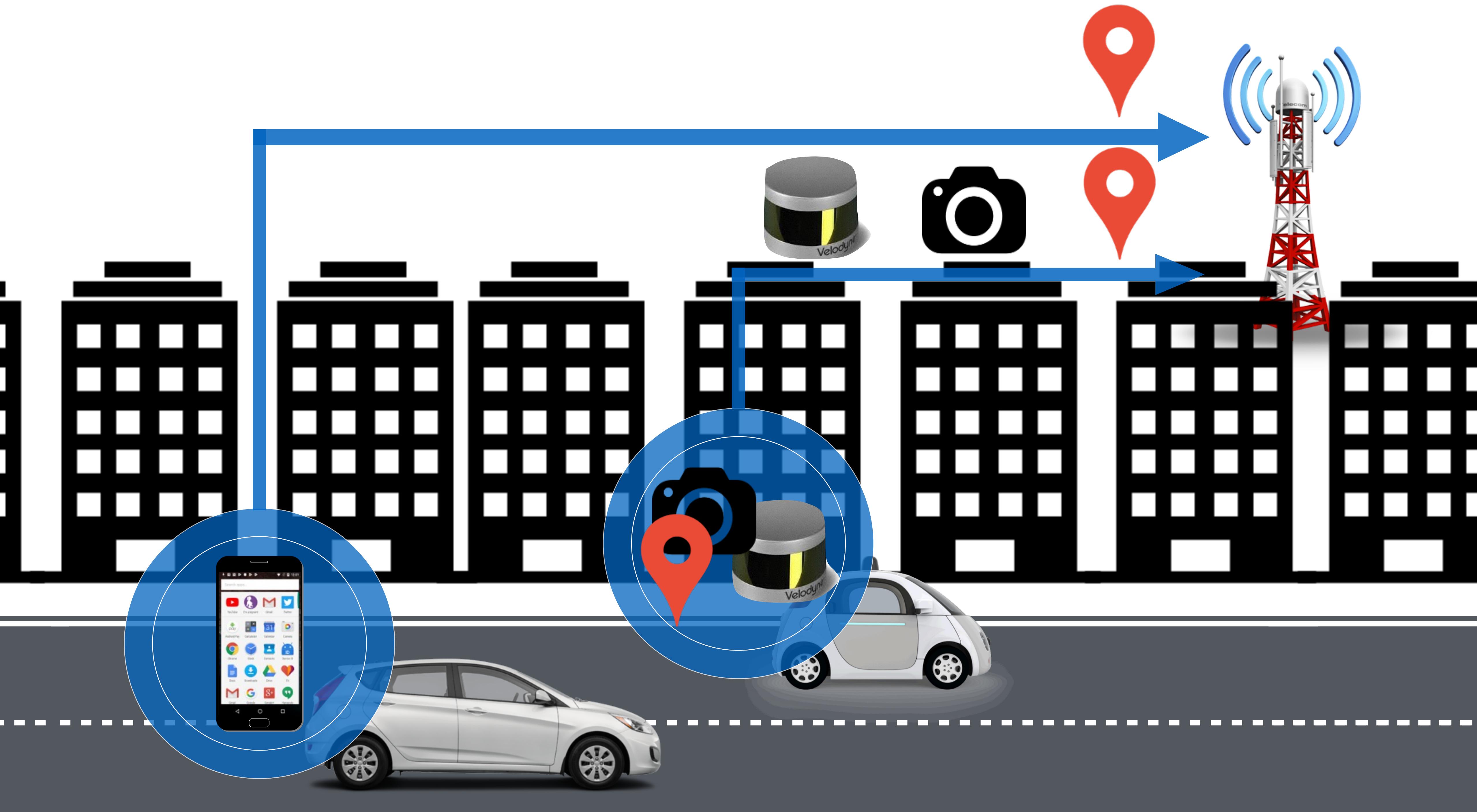
Co-Existence between legacy and next generation vehicles

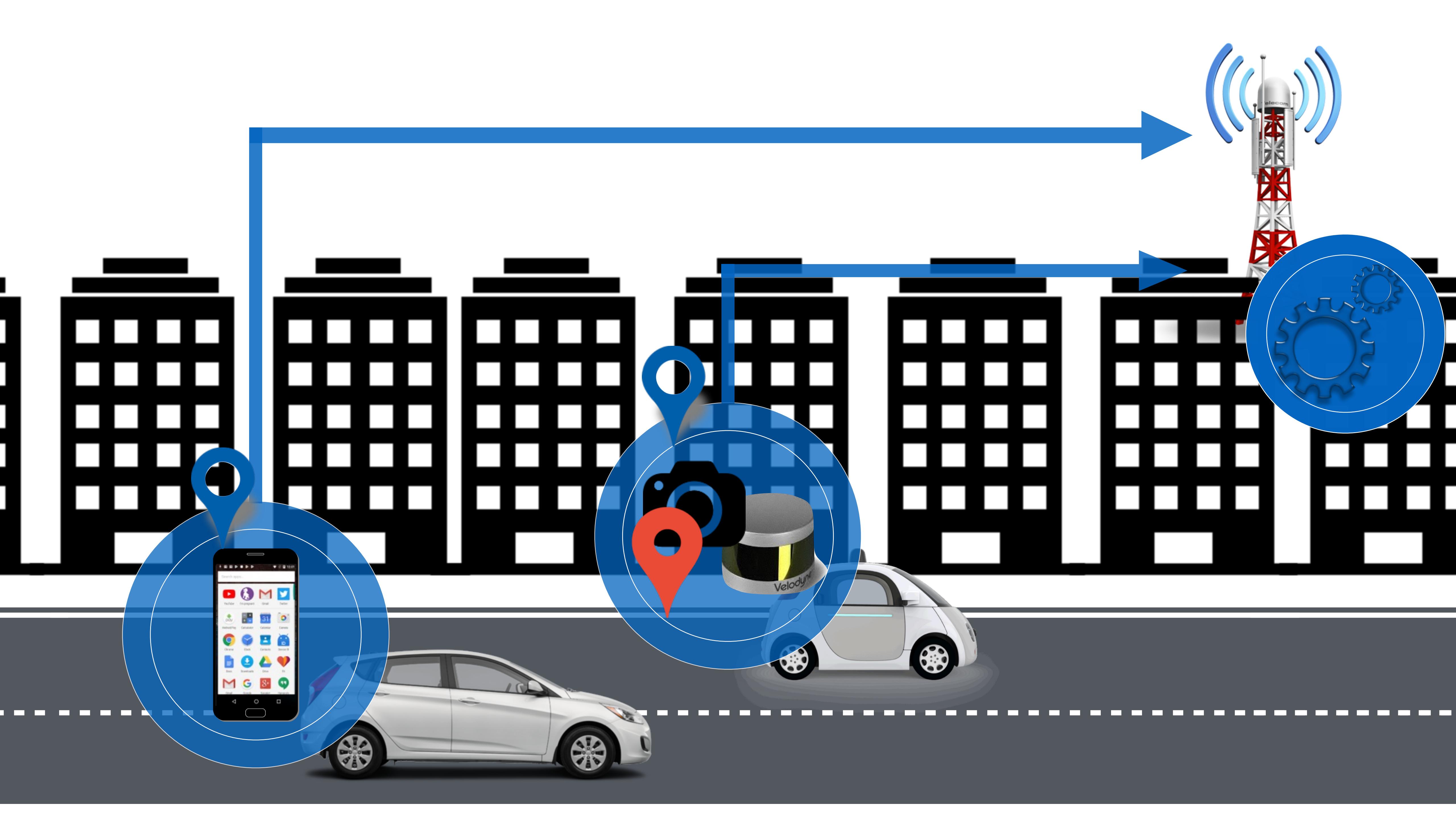


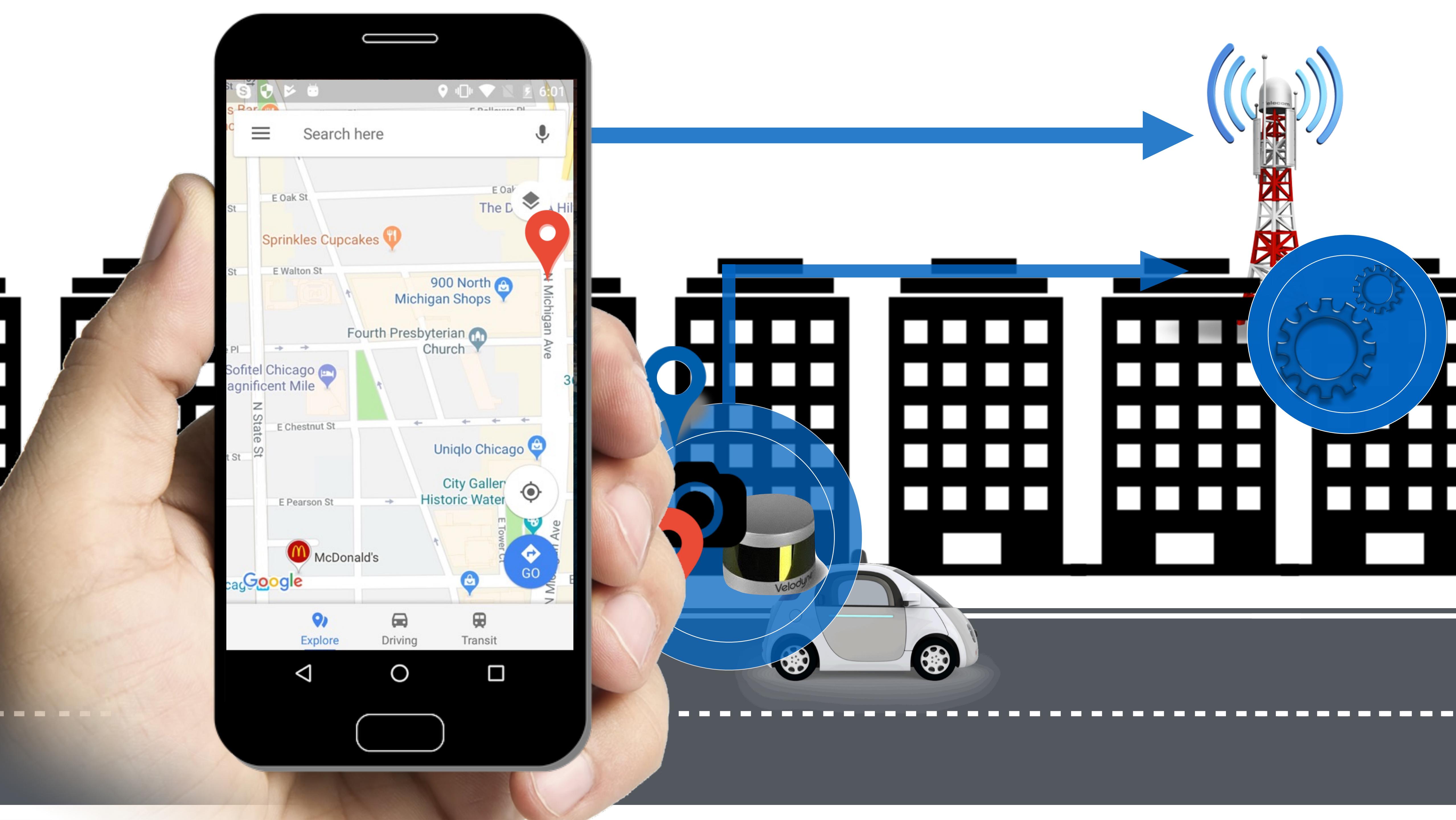


CoDrive: collaborative driving





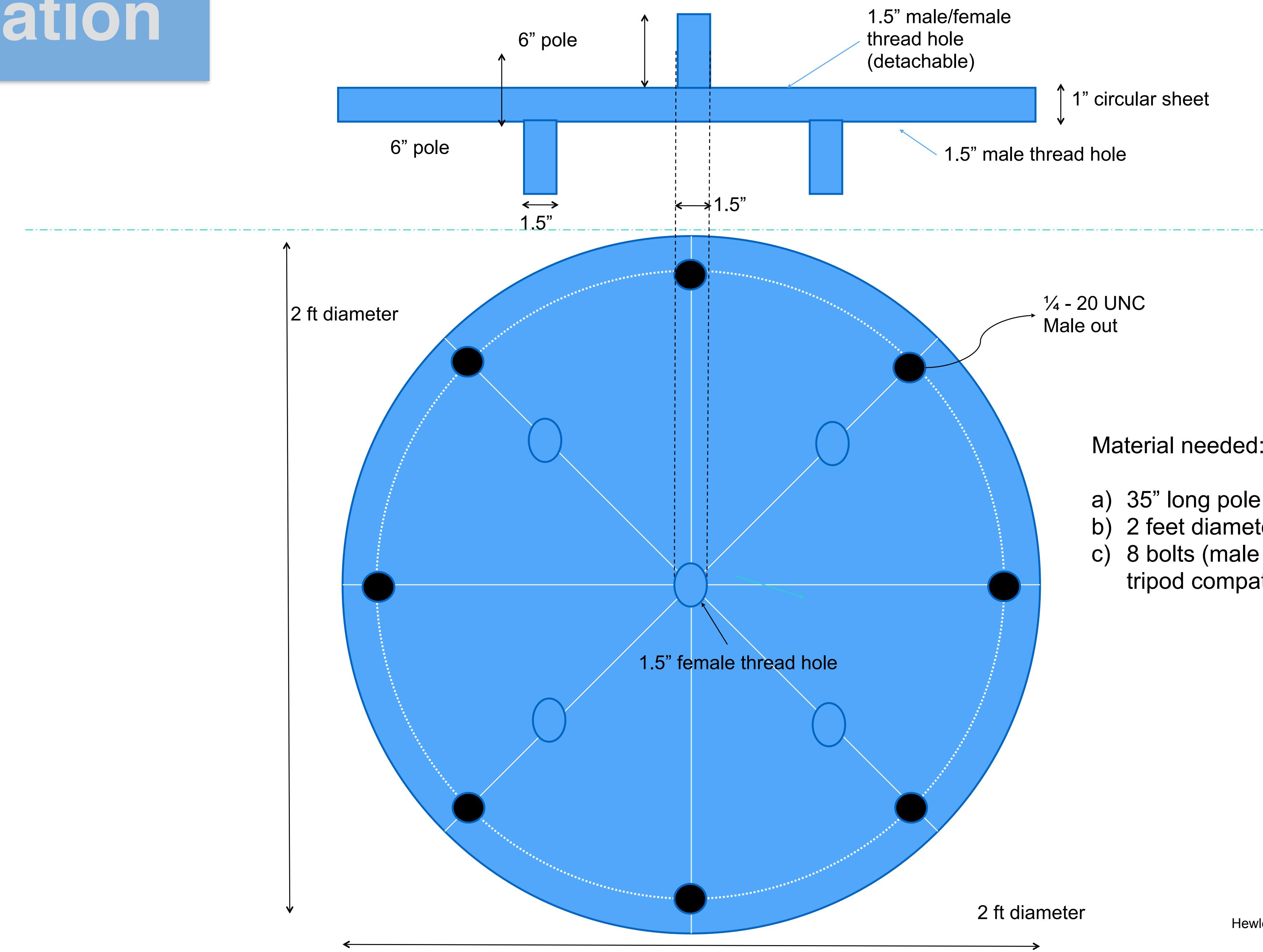




problem: we do not have a sensor-rich car....

let's build one!

Emulation



Emulation

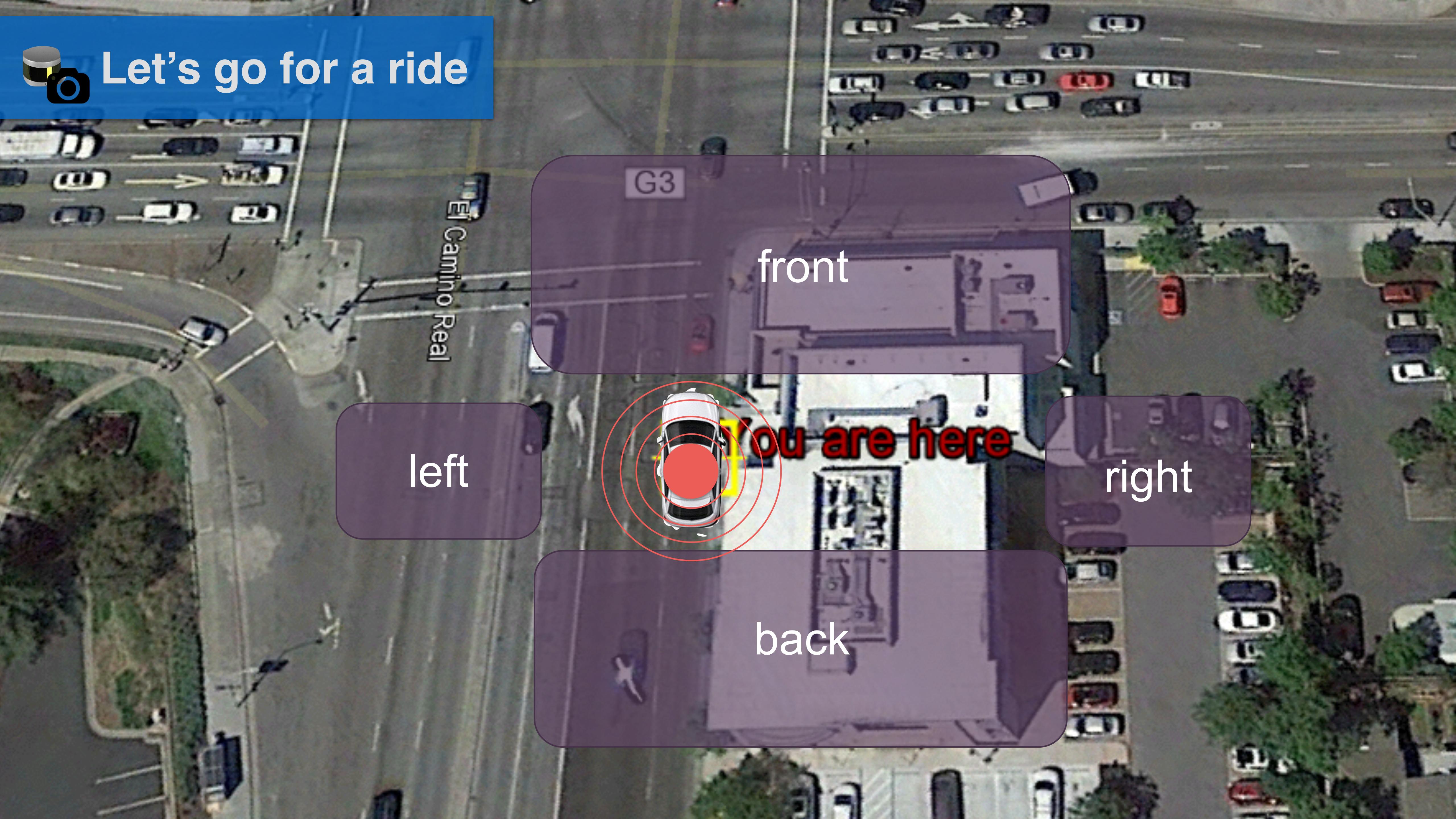
Velodyne VLP-16 Lidar

Samsung Galaxy
S6 edge phone

Garmin GPS

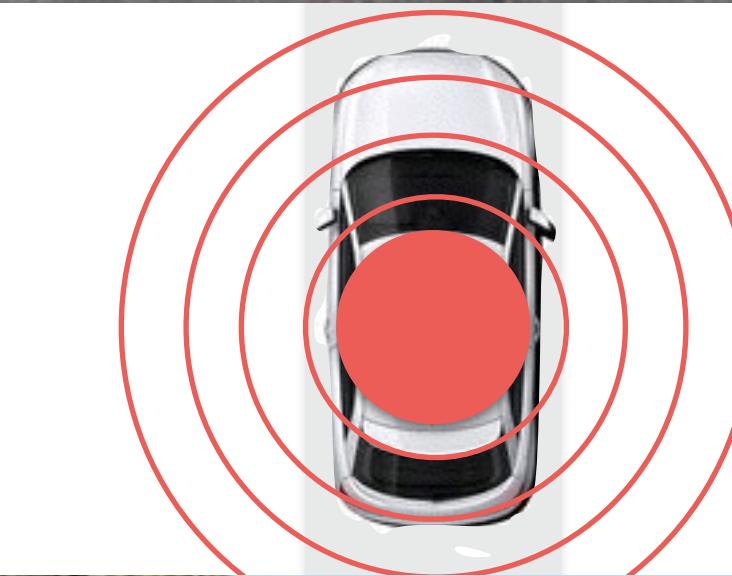
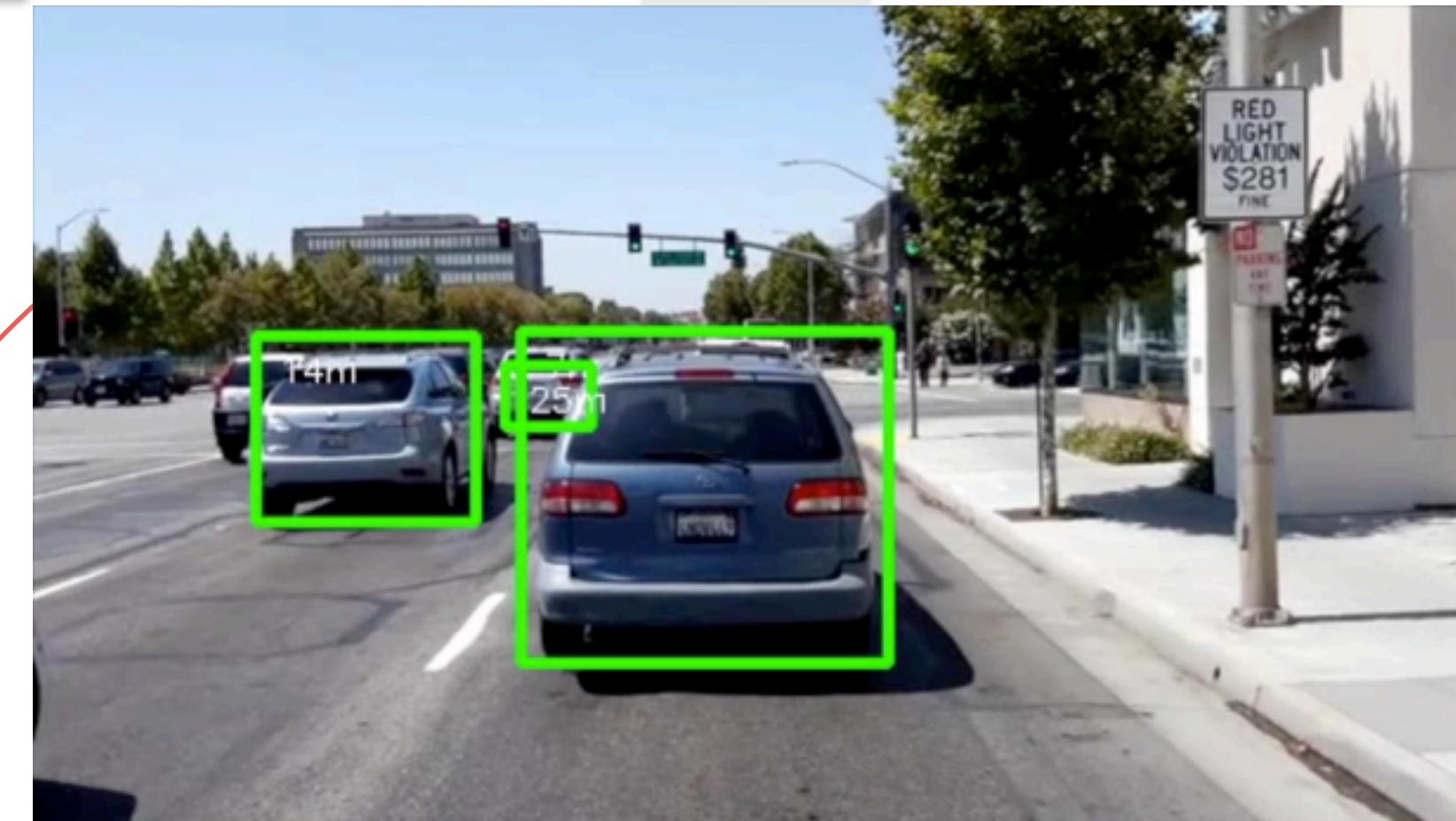
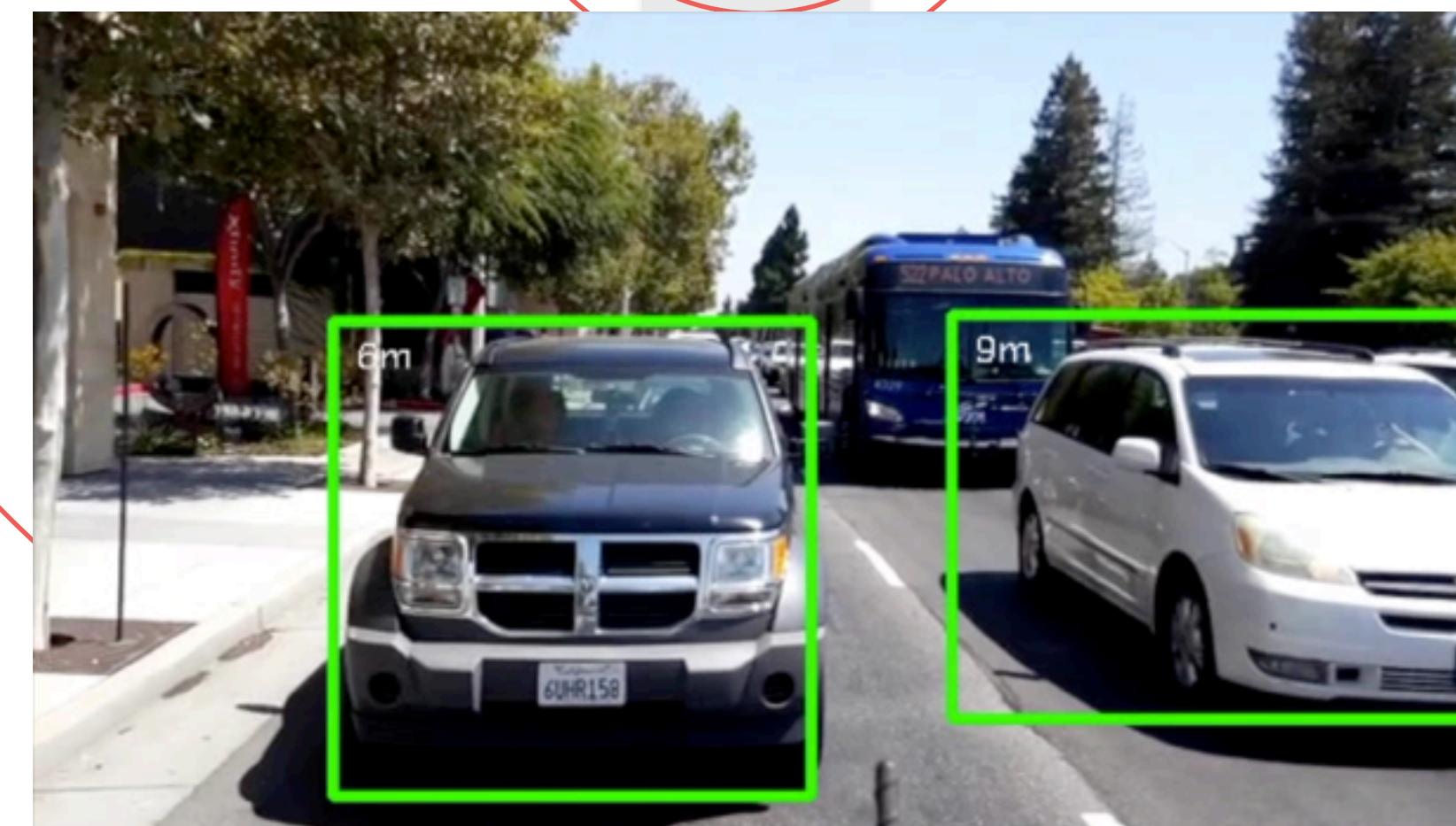
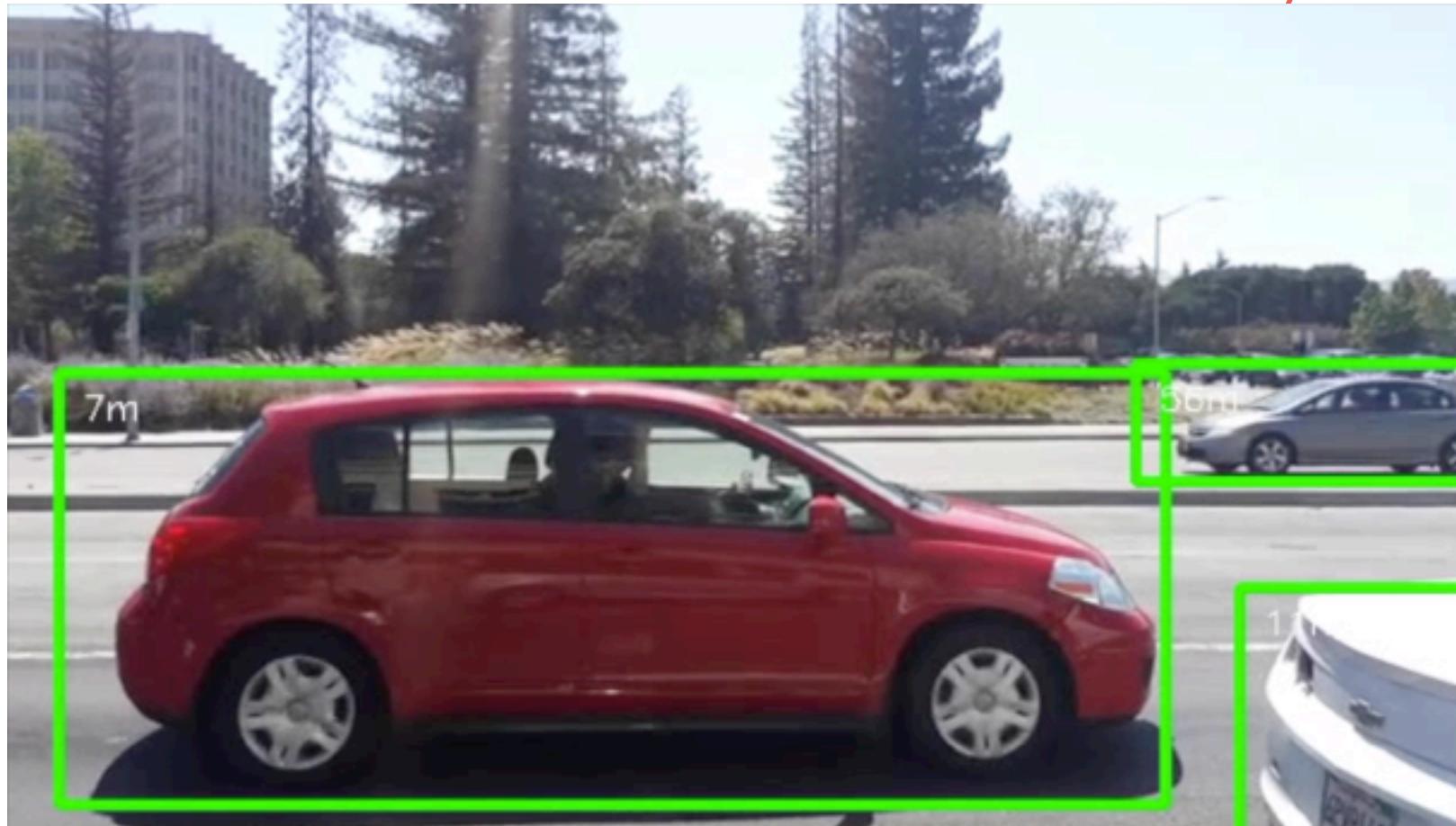


Let's go for a ride





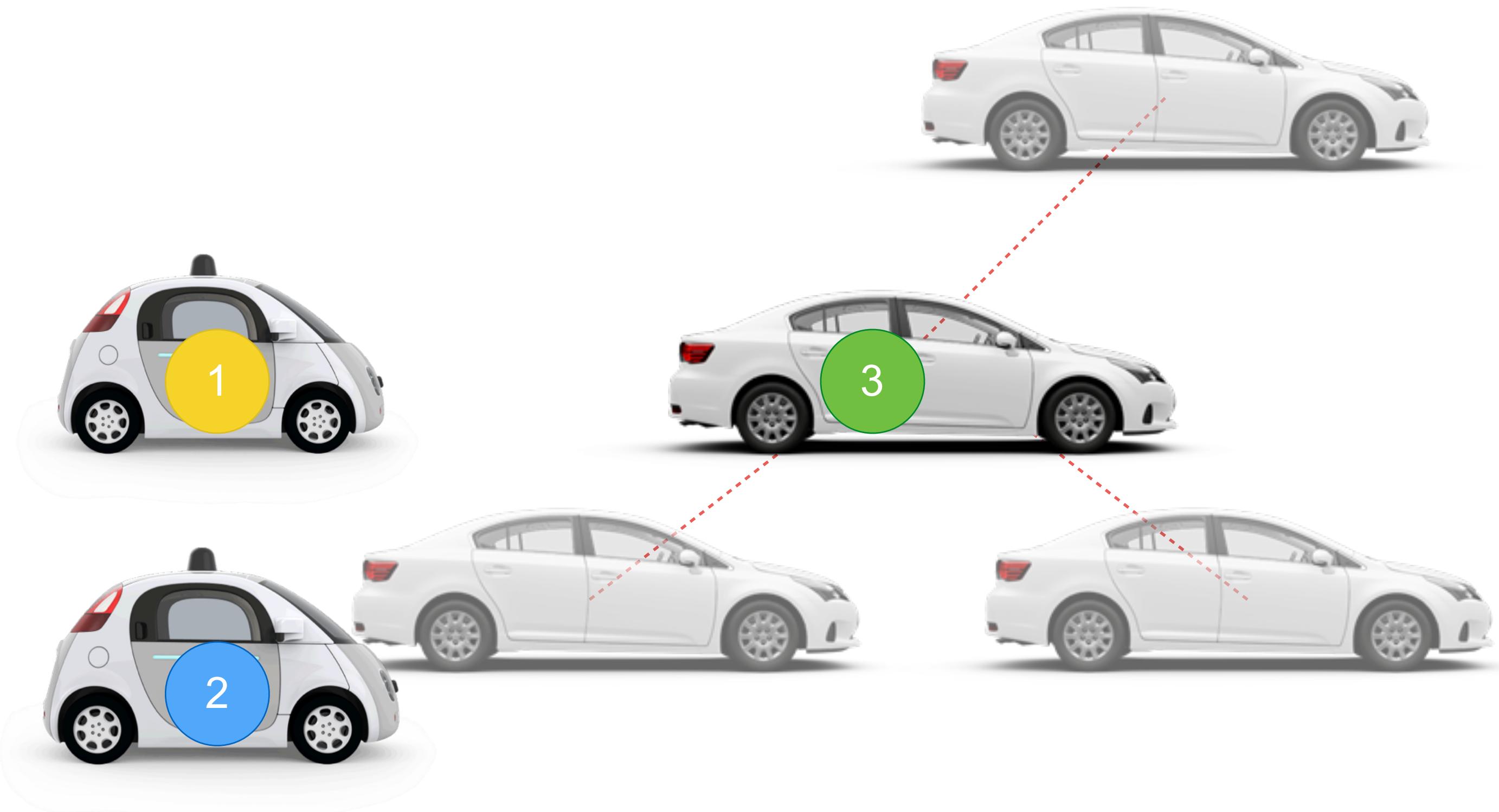
Combined data



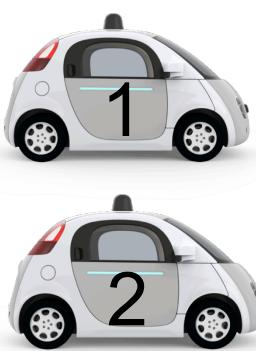
How do we use such data to refine cars' locations?

we approach it as an optimization problem

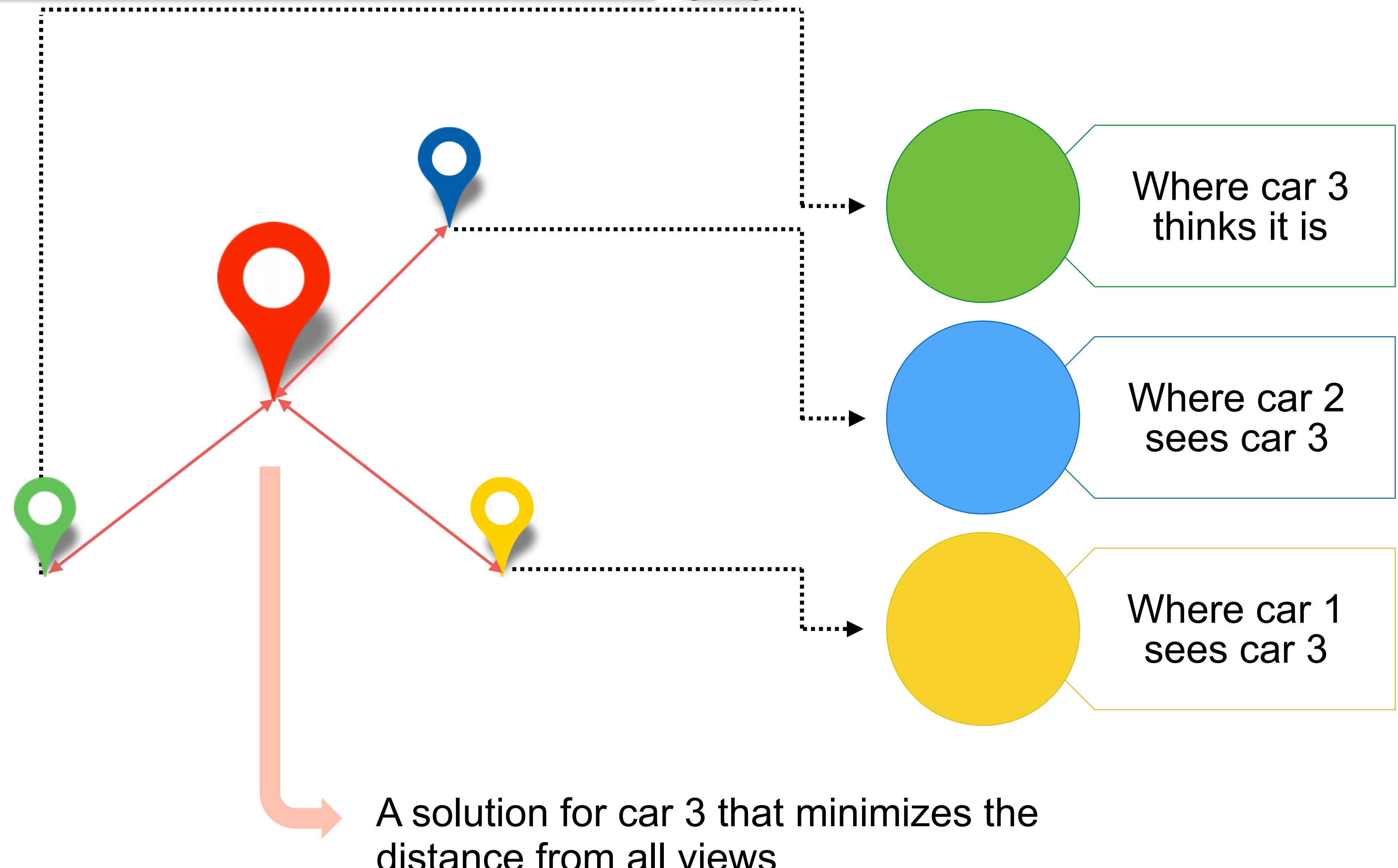
Optimization: objective function



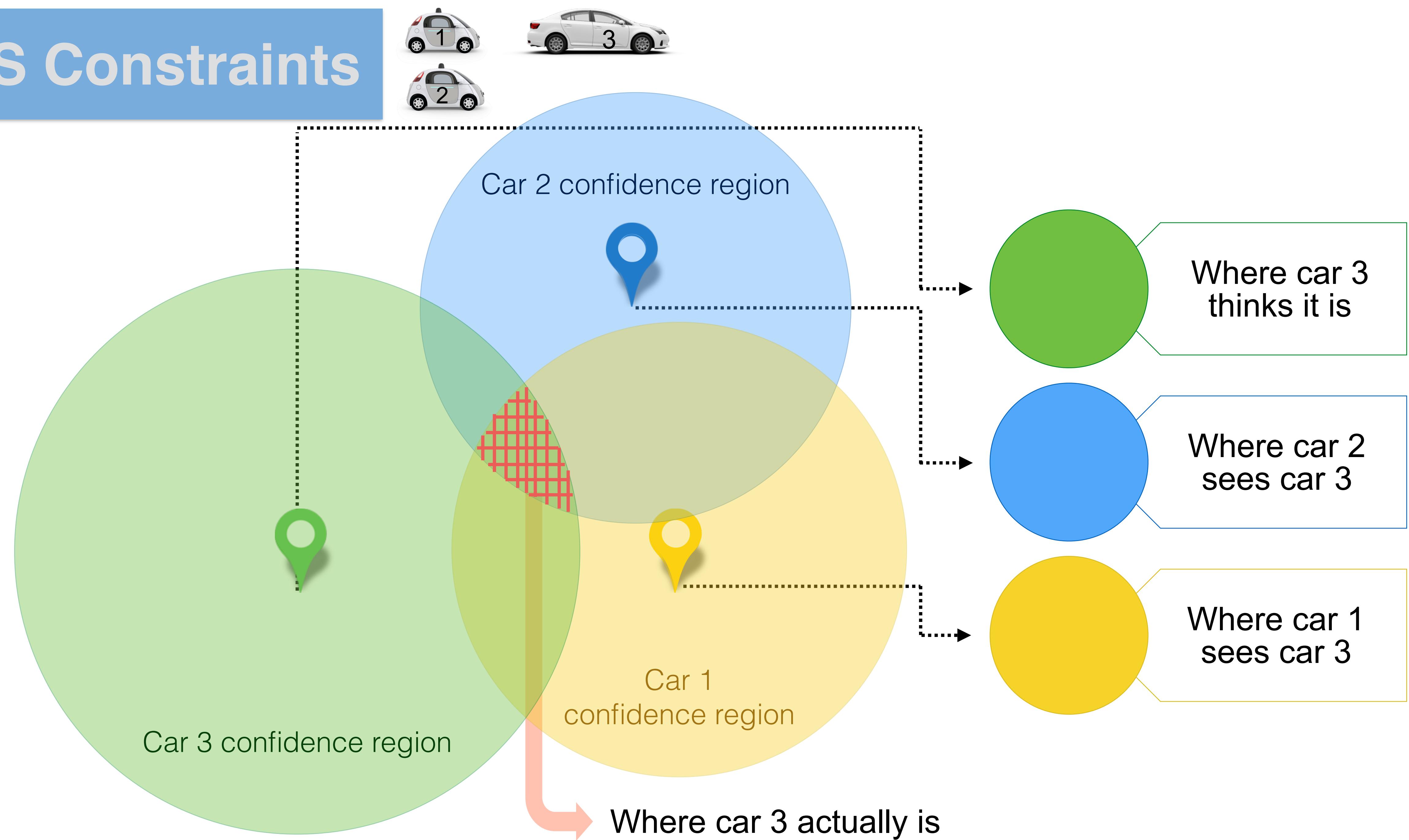
Optimization: objective function



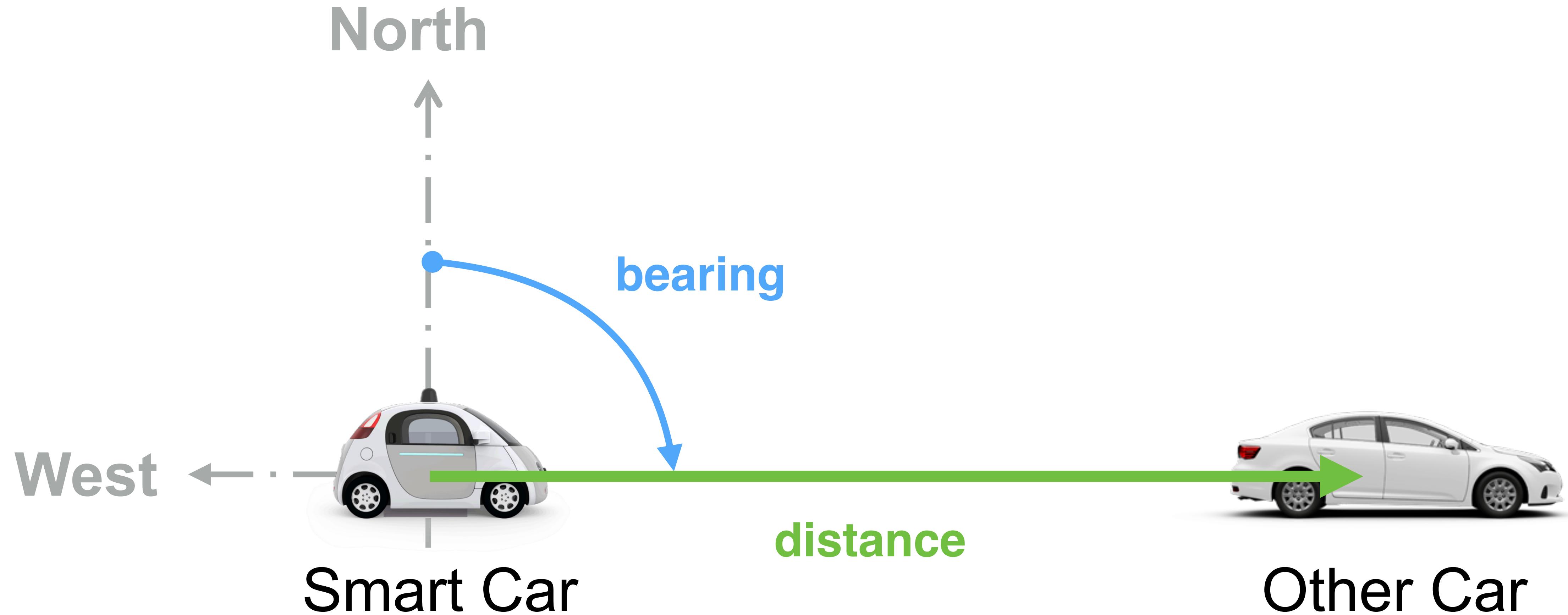
Optimization: objective function



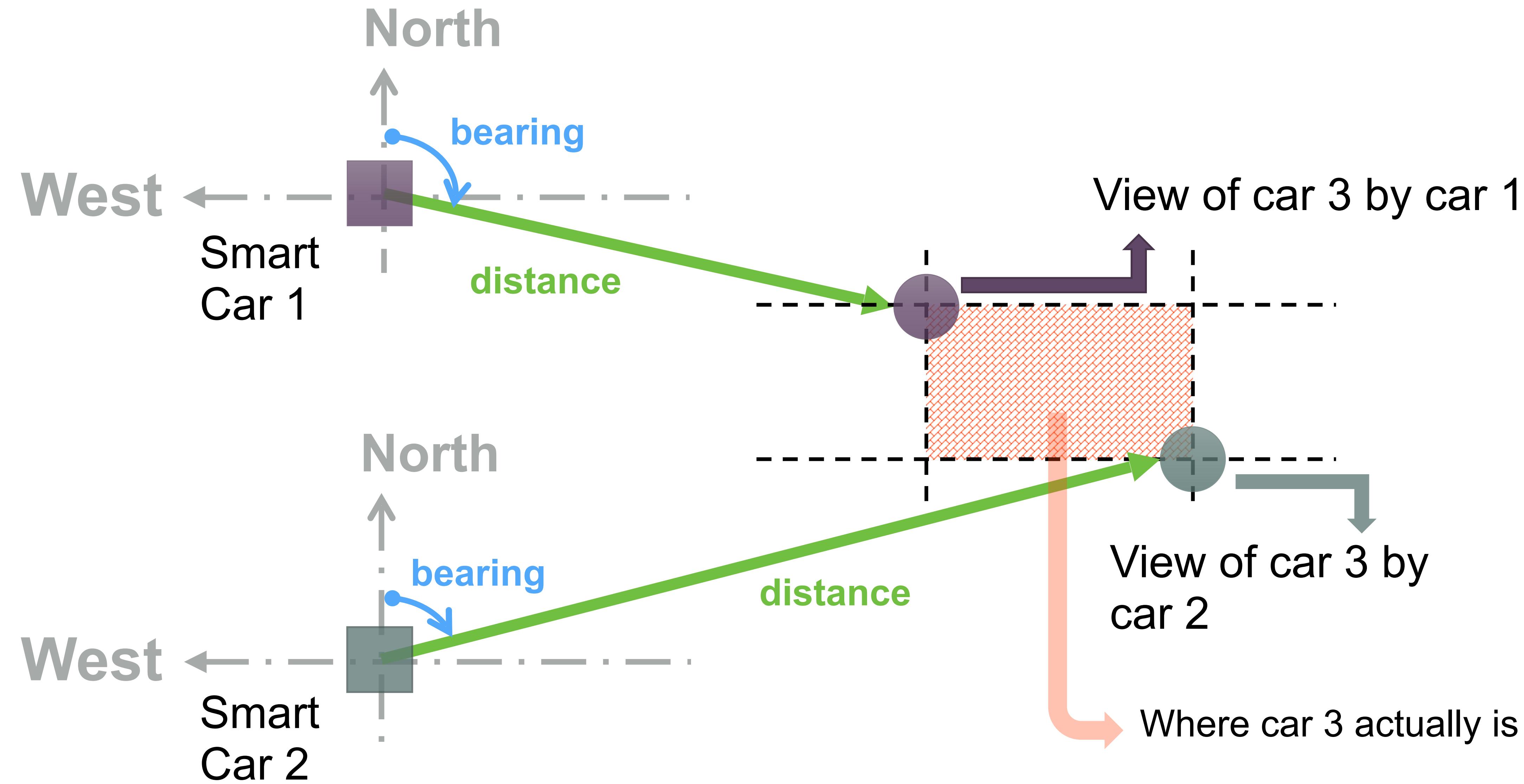
GPS Constraints



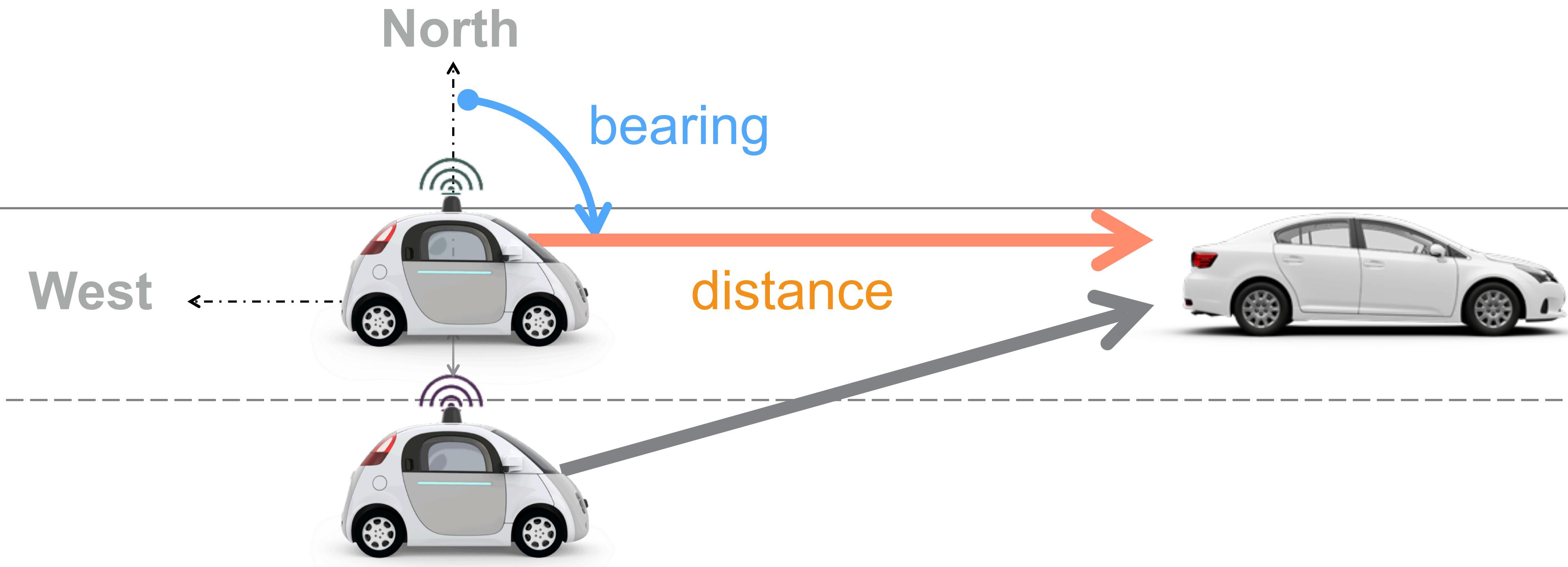
Angle and Distance Constraints



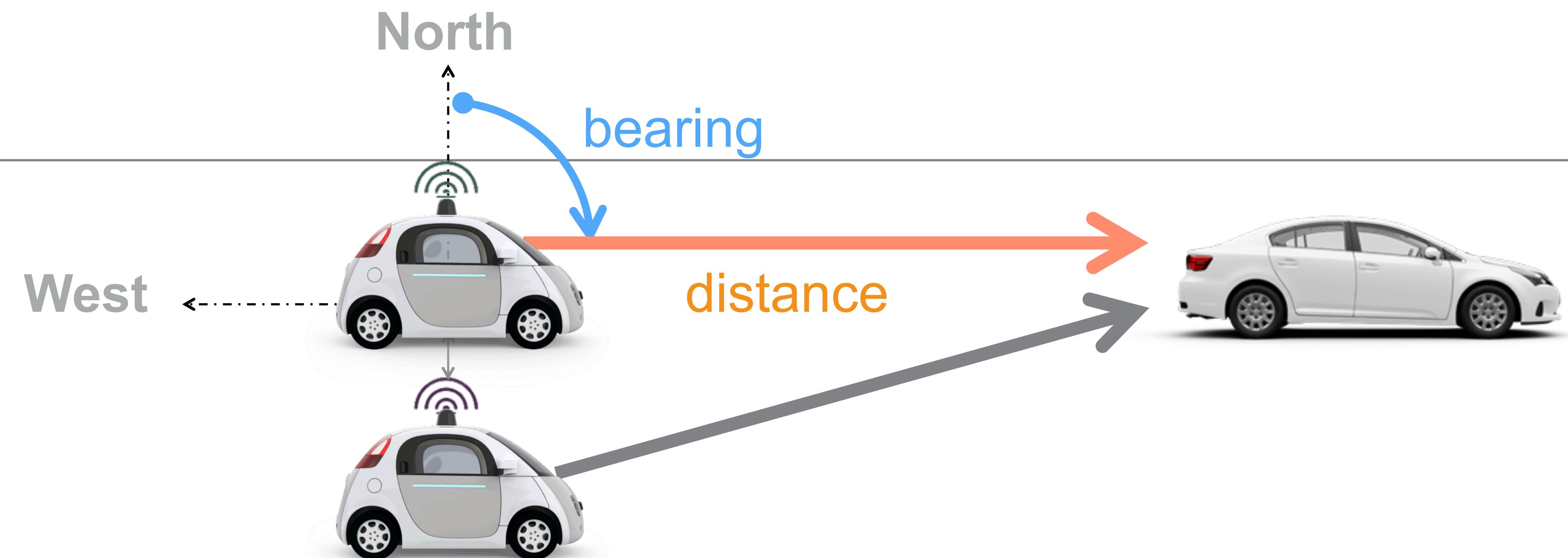
Angle and Distance Constraints



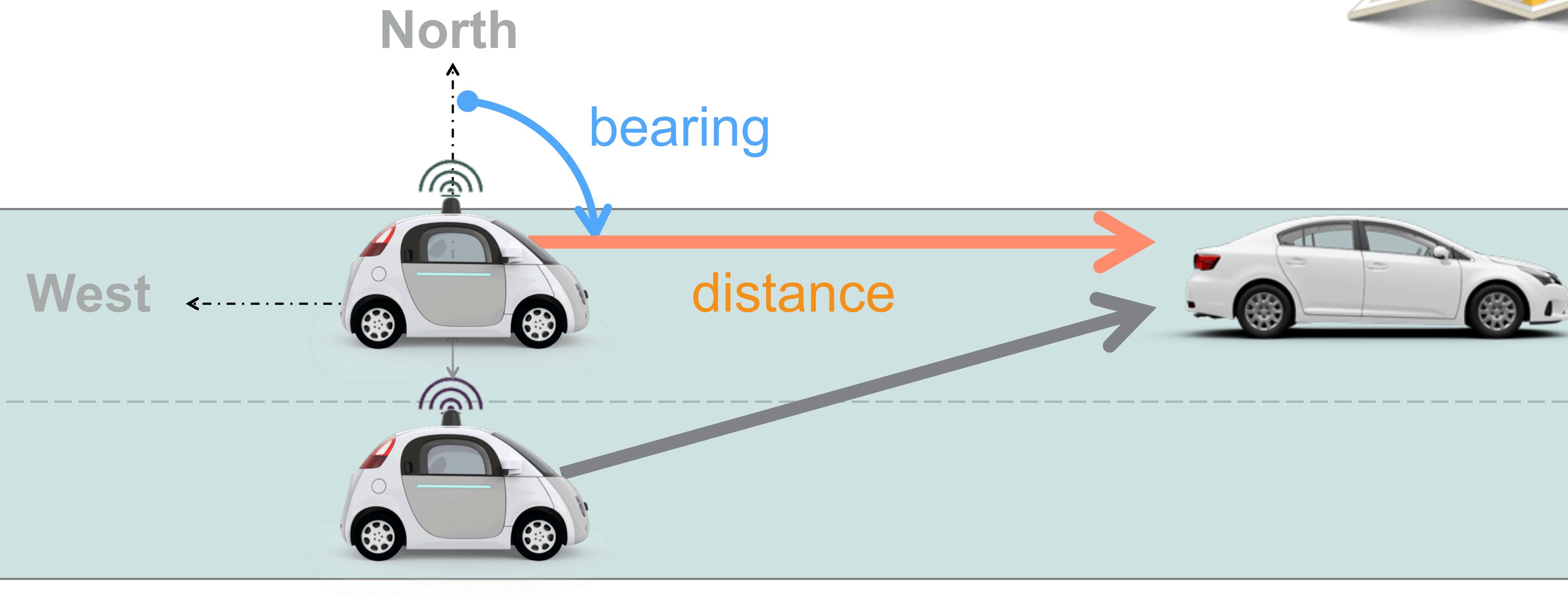
Road Constraints



Road Constraints



Road Constraints

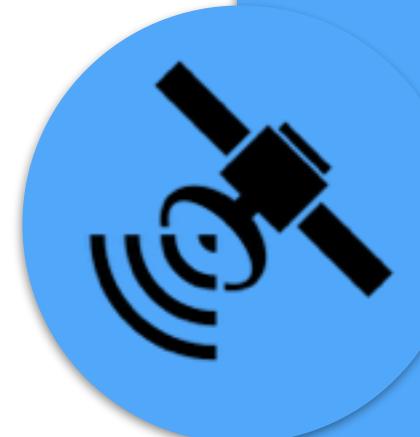


evaluation

Positioning Approaches



CoDrive



GPS

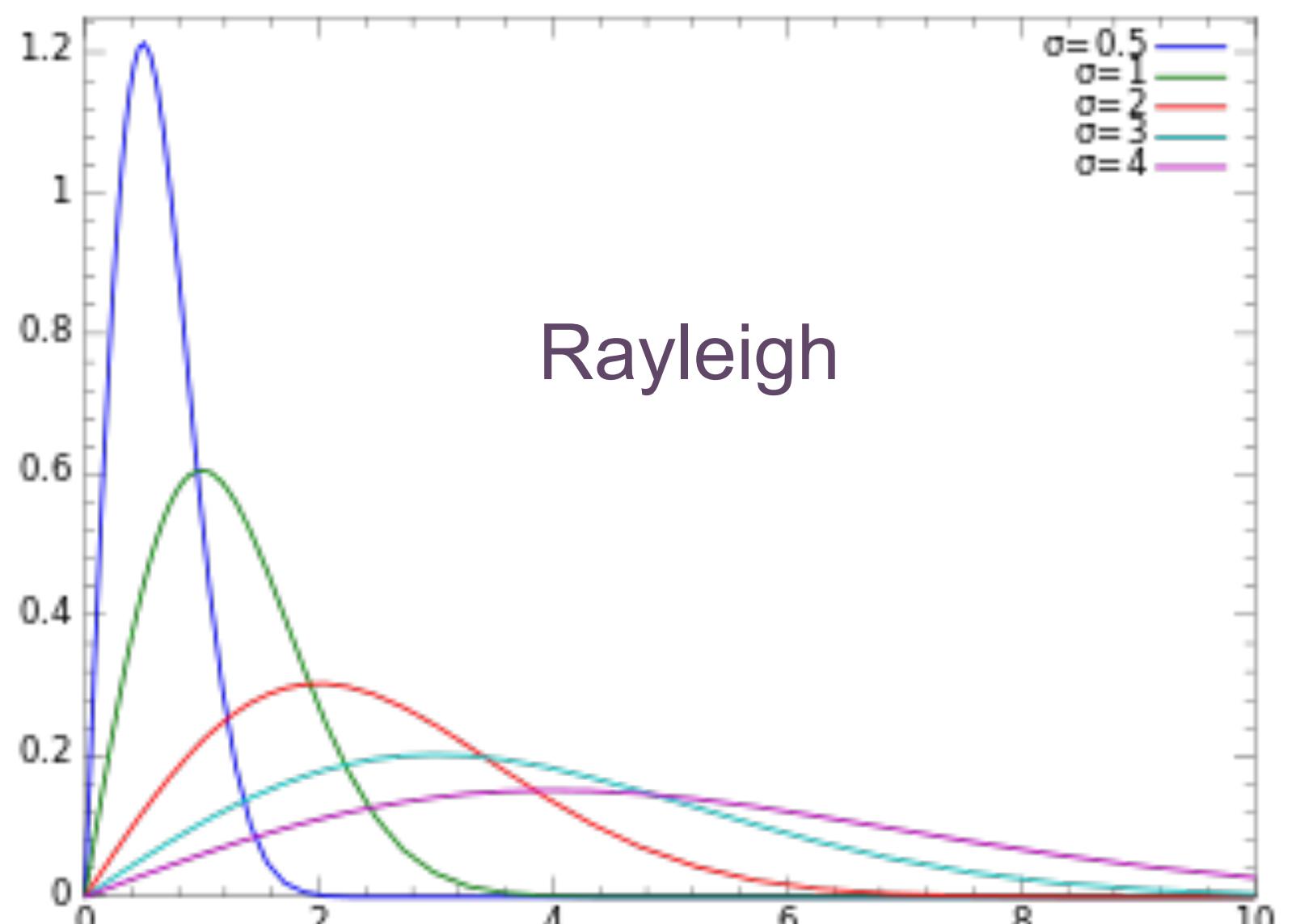


Map-Matching



CoDrive w/o
optimization (CWO)

Positioning Approaches



CoDrive

GPS

Map-Matching

CoDrive w/o
optimization (CWO)

Positioning Approaches



CoDrive



GPS



Map-Matching



CoDrive w/o
optimization (CWO)

Positioning Approaches



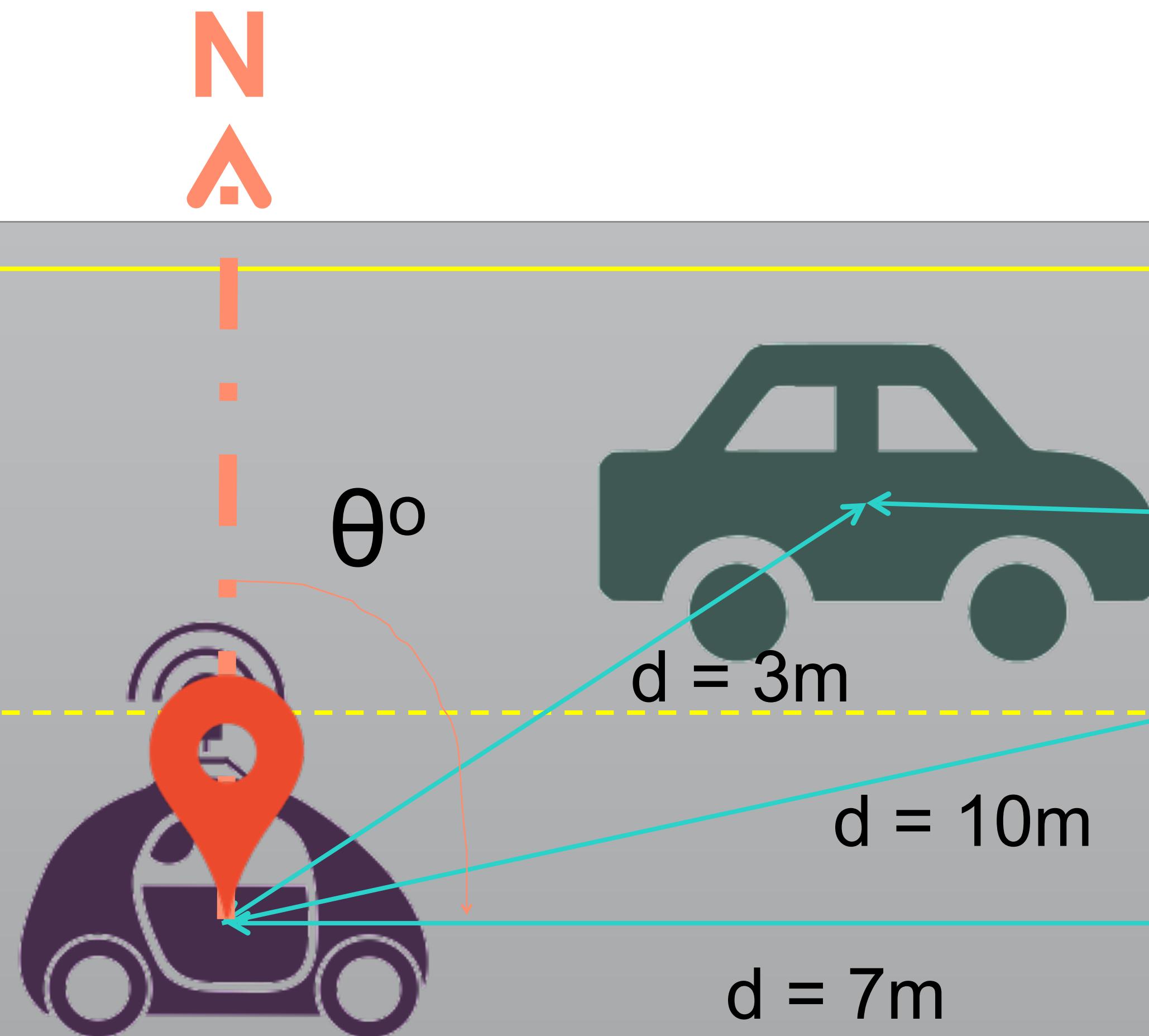
CoDrive

GPS

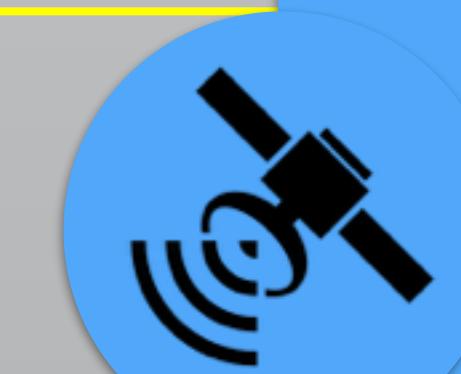
Map-Matching

CoDrive w/o
optimization (CWO)

Positioning Approaches



CoDrive



GPS



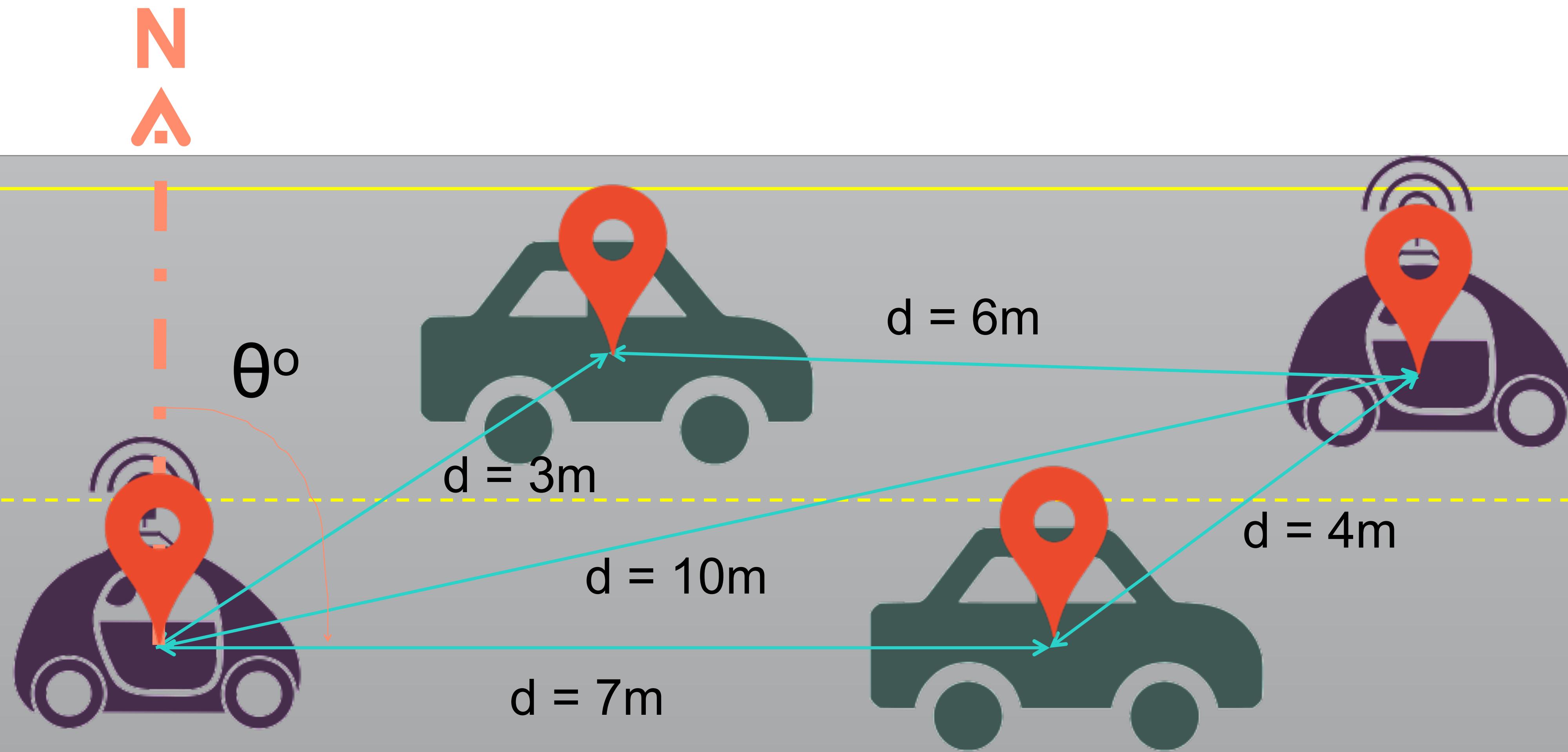
Map-Matching



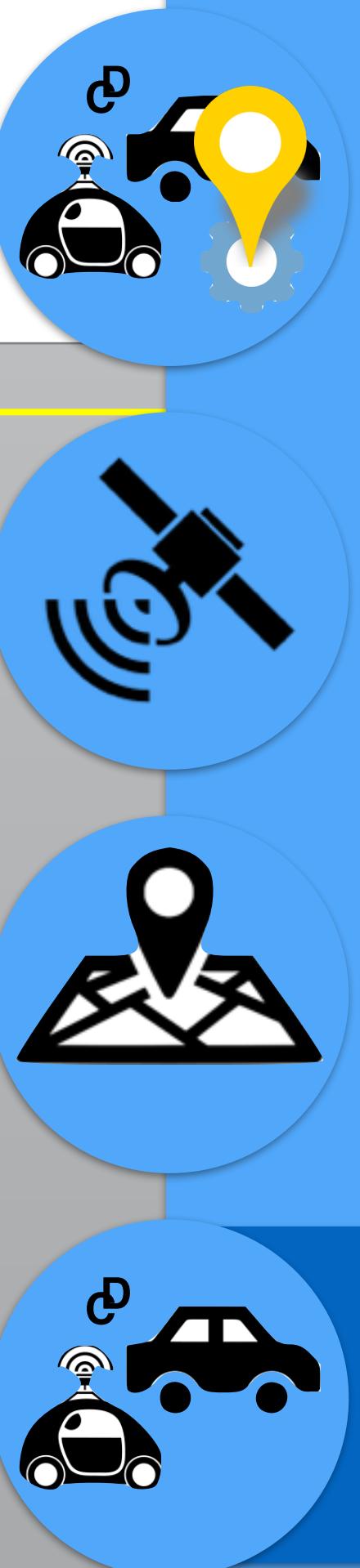
CoDrive w/o
optimization (CWO)

CoDrive w/o optimization

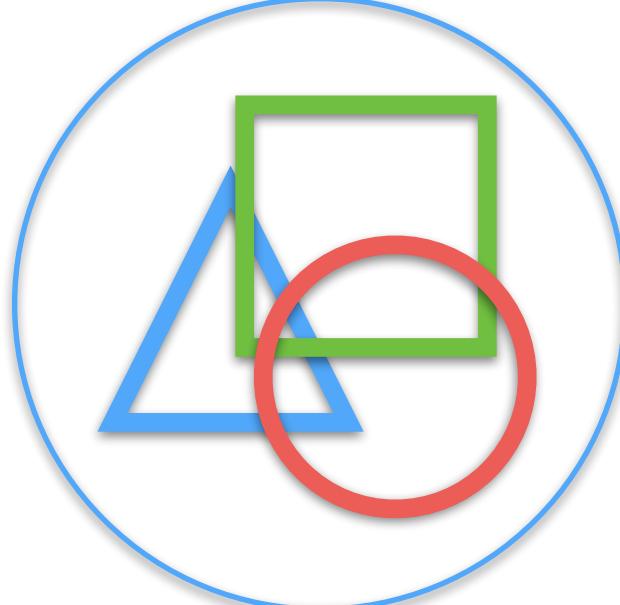
Positioning Approaches



CoDrive w/o optimization



Evaluation Goals



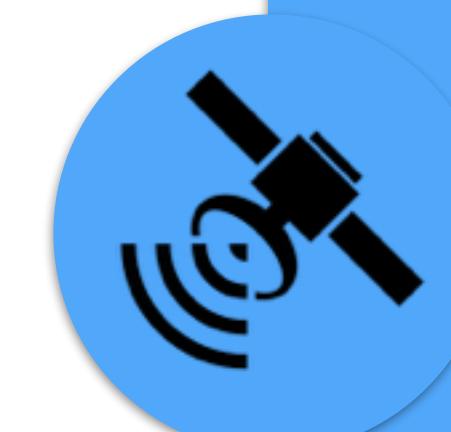
Preserving the shape of the traffic



Reducing Positioning Error



CoDrive



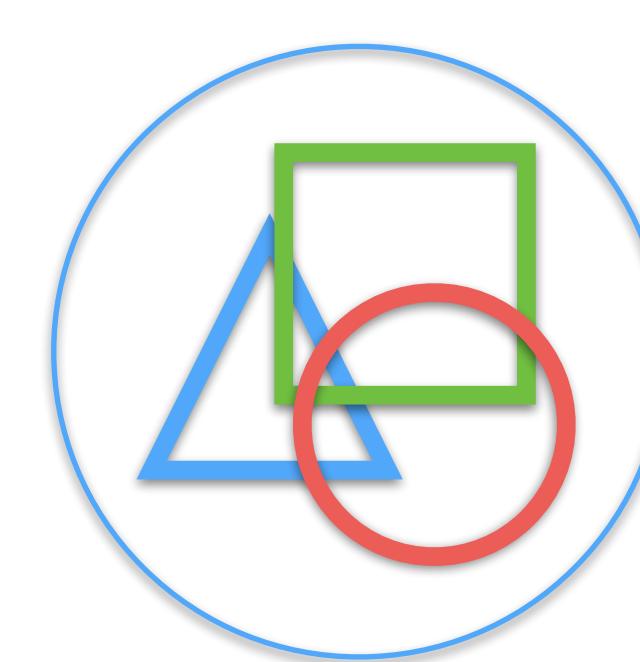
GPS



Map-Matching



CoDrive w/o
optimization (CWO)



2 X



Sensor-rich

GPS ERROR

$$\mu = 3\text{m} \quad \sigma = 1\text{m}$$

13 X



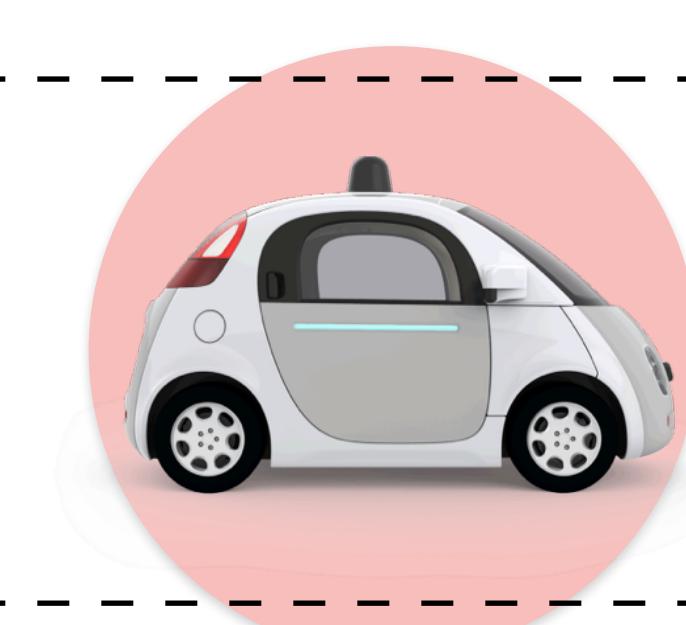
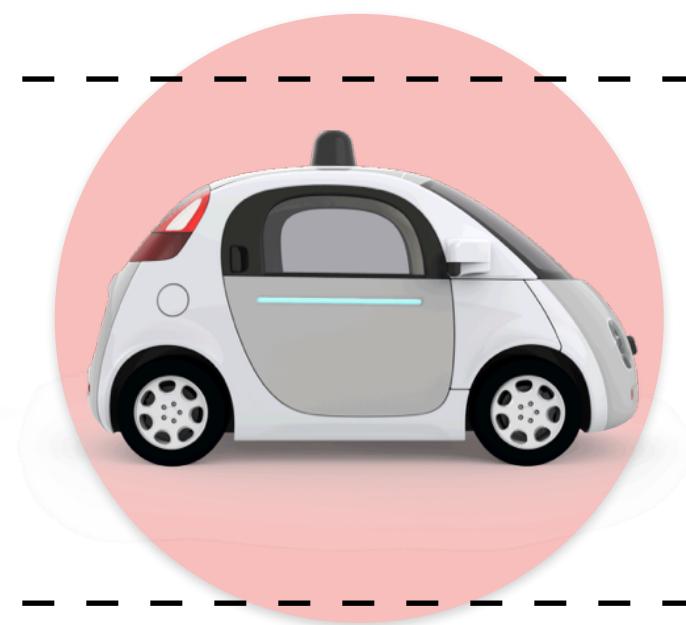
Legacy

GPS ERROR

$$\mu = 6\text{m} \quad \sigma = 2.5\text{m}$$



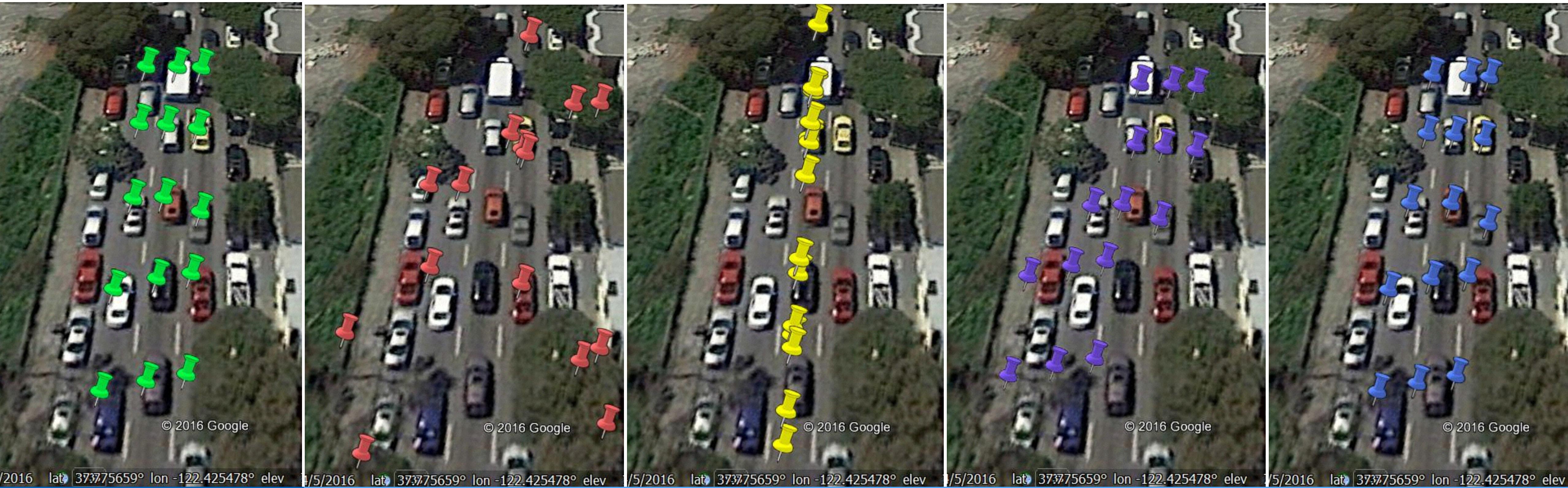
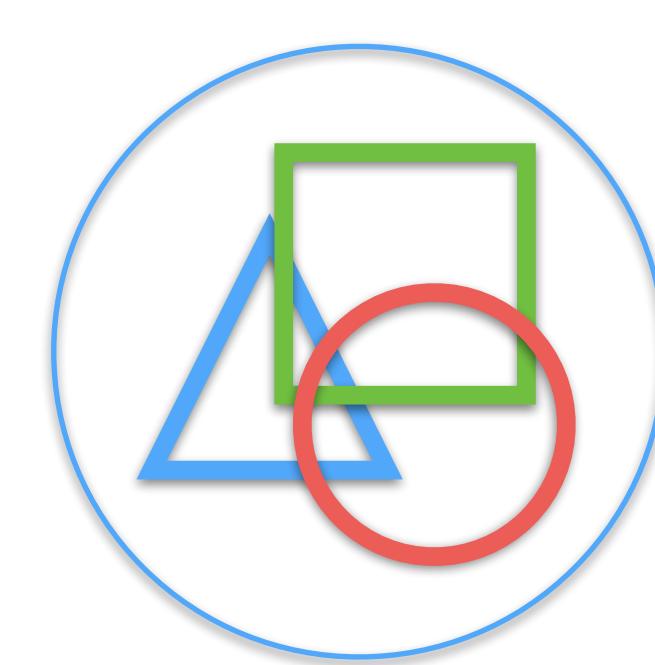
1



2



3



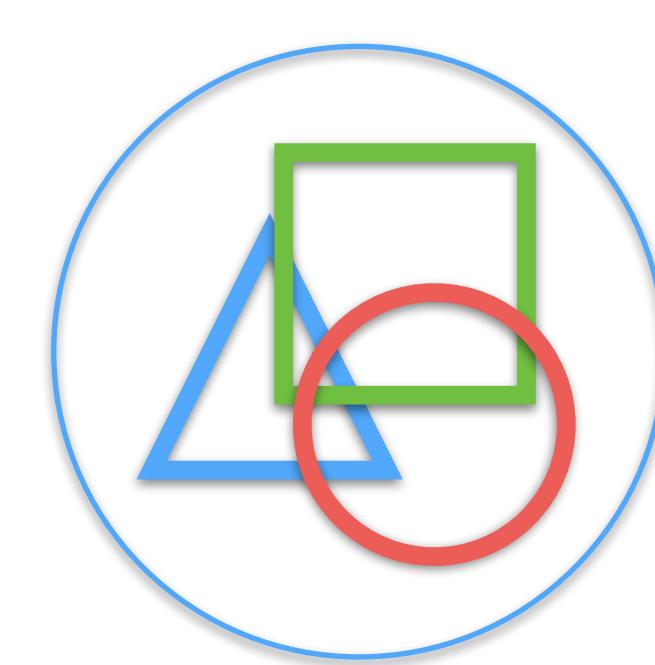
Ground Truth

GPS

Map-Matching

CoDrive w/o
opt

CoDrive



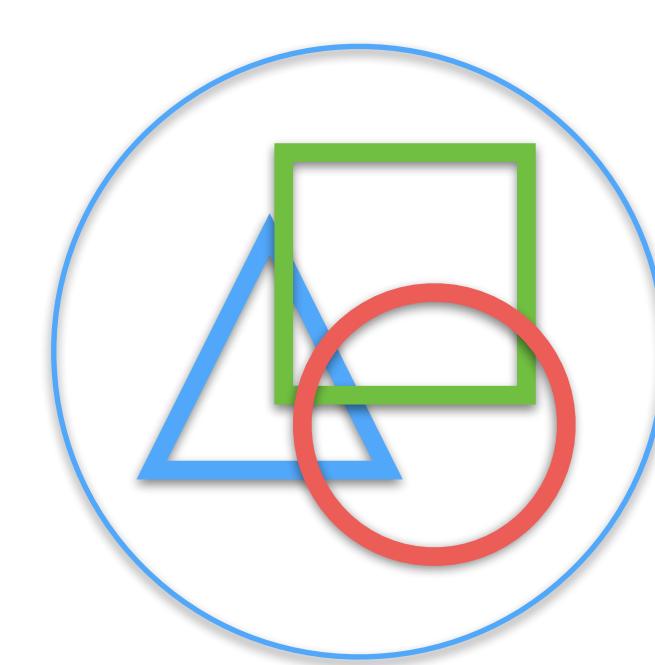
Ground Truth

GPS

Map-Matching

CoDrive w/o
opt

CoDrive



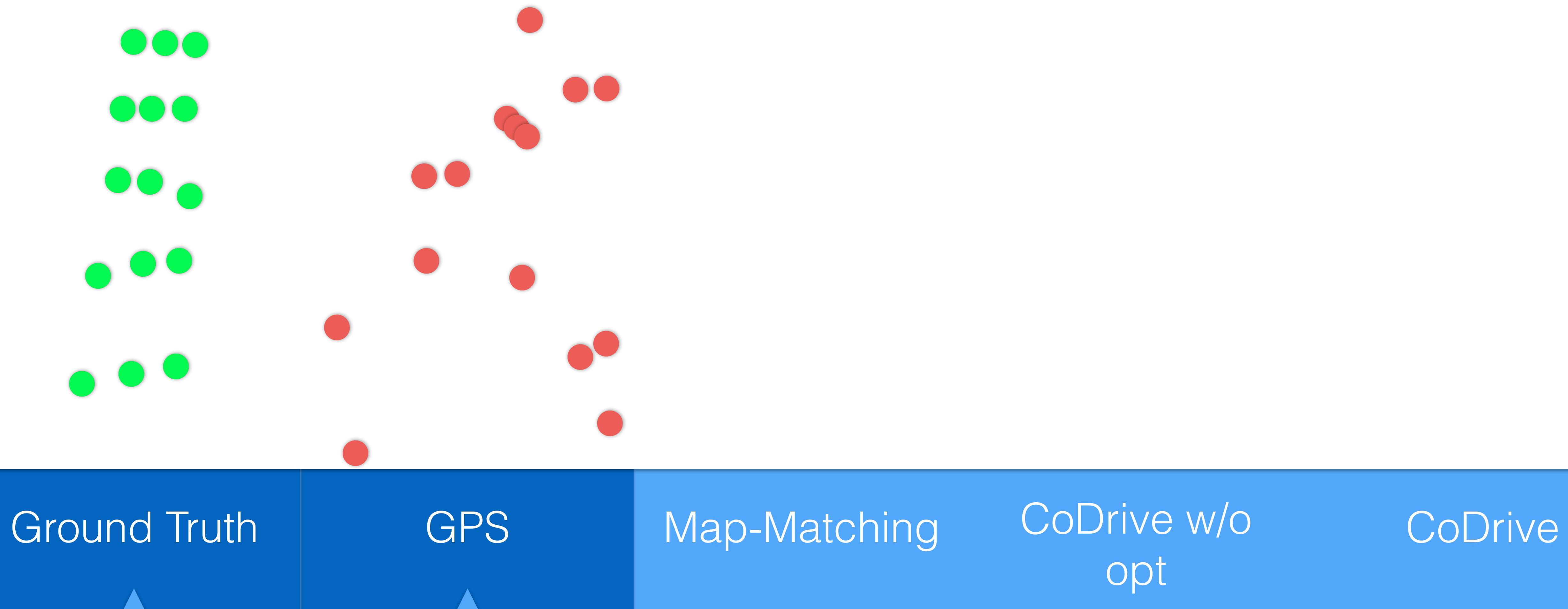
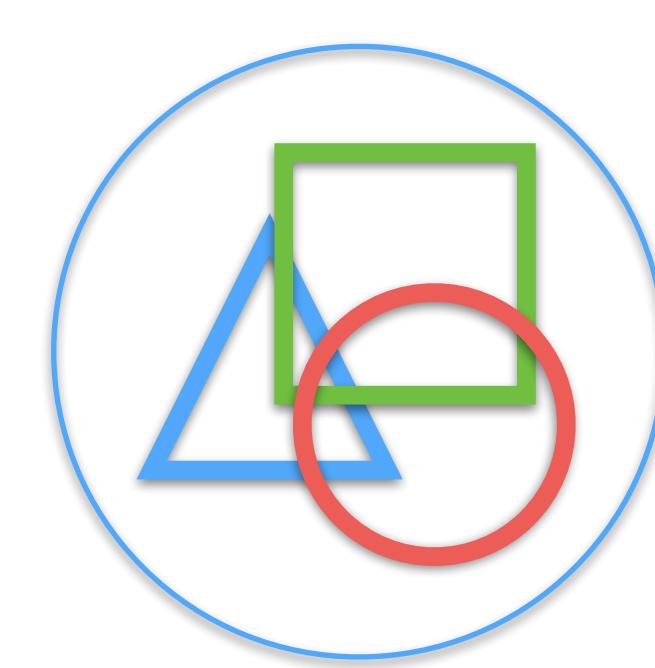
Ground Truth

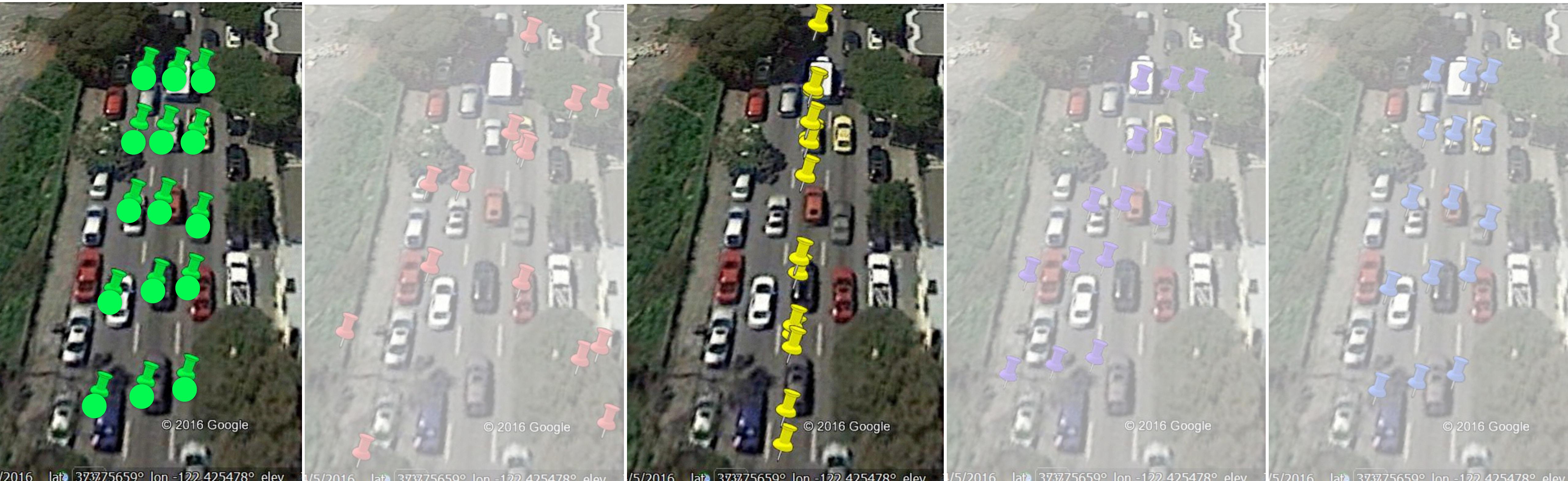
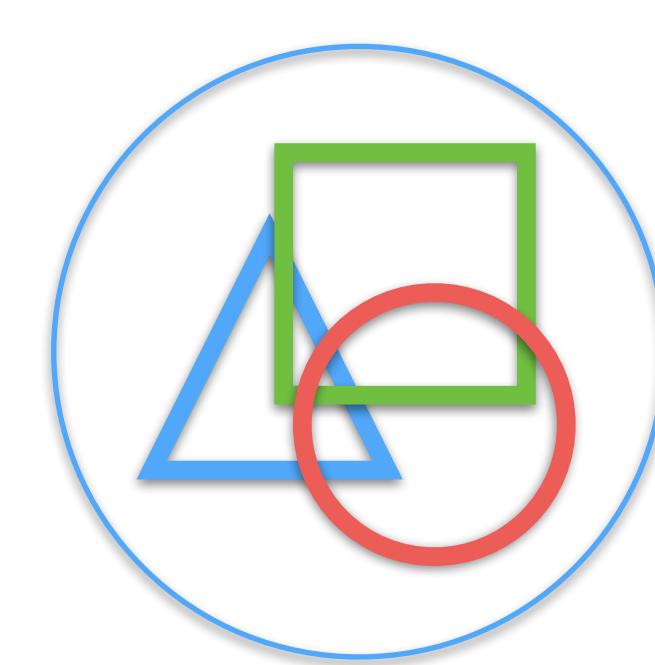
GPS

Map-Matching

CoDrive w/o
opt

CoDrive





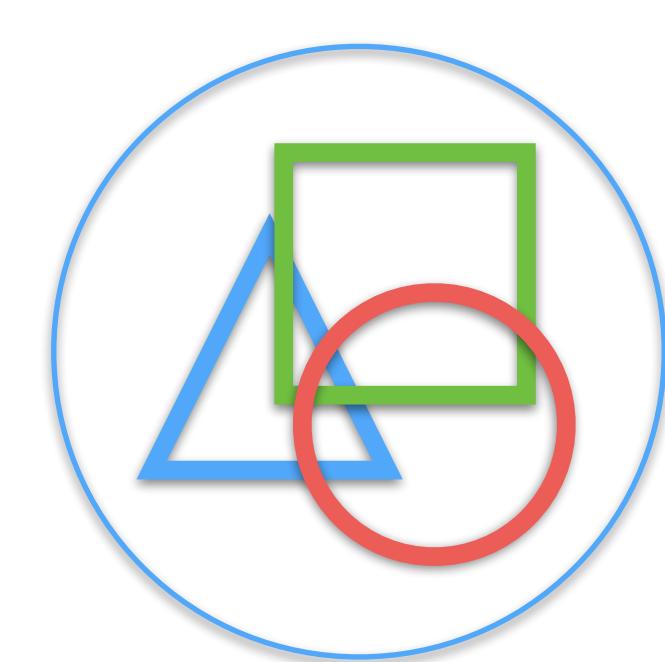
Ground Truth

GPS

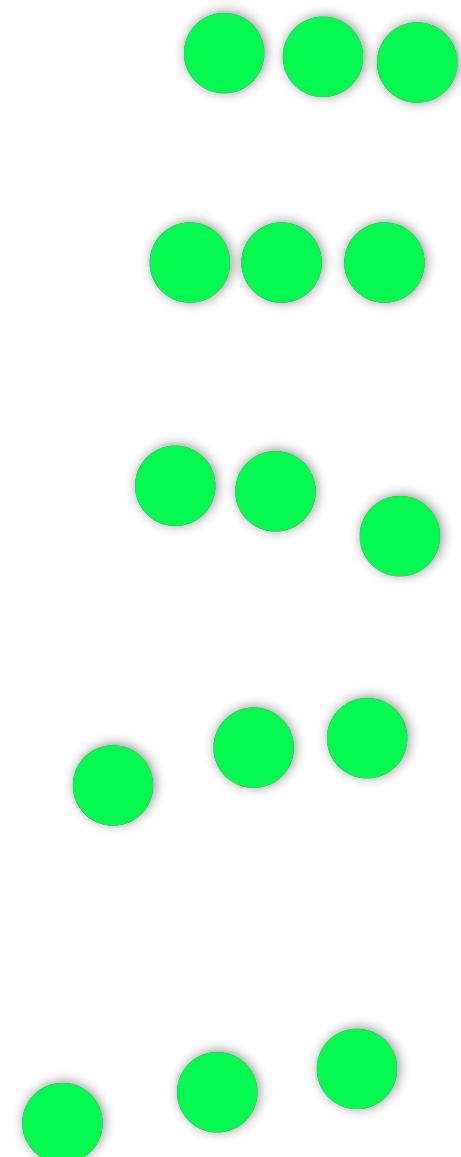
Map-Matching

CoDrive w/o
opt

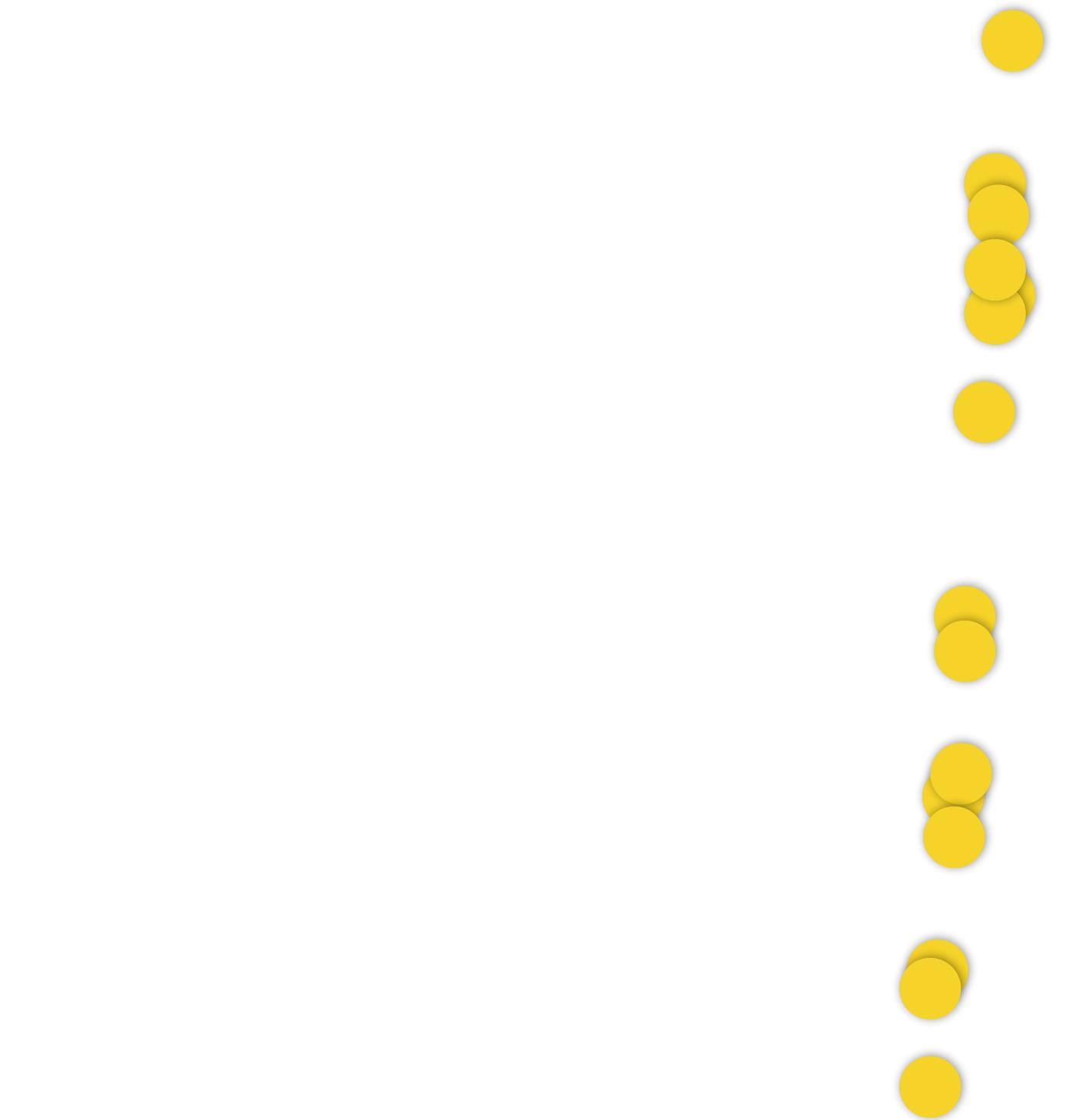
CoDrive



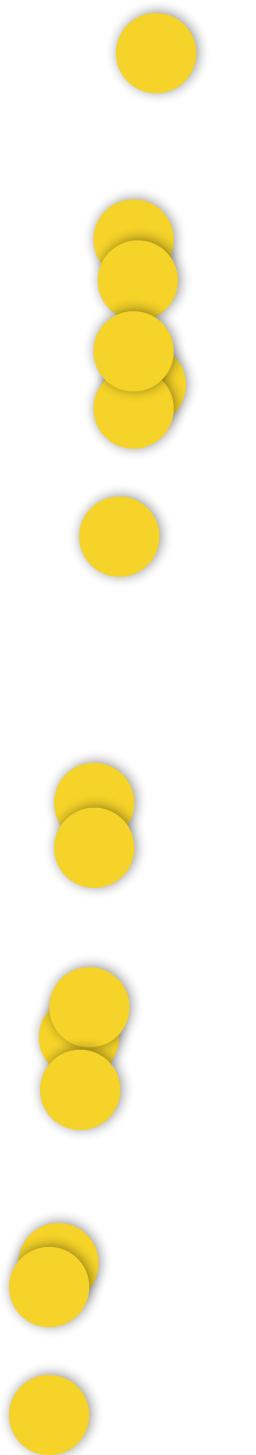
Ground Truth



GPS

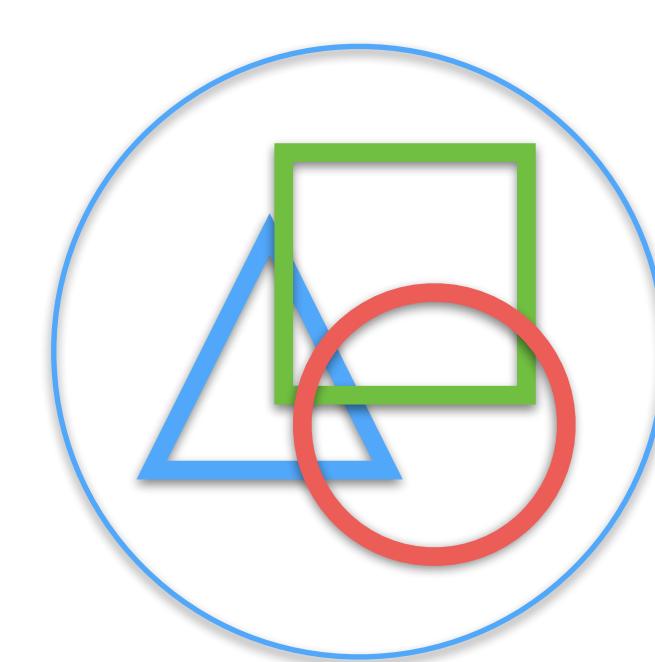


Map-Matching



CoDrive w/o
opt

CoDrive



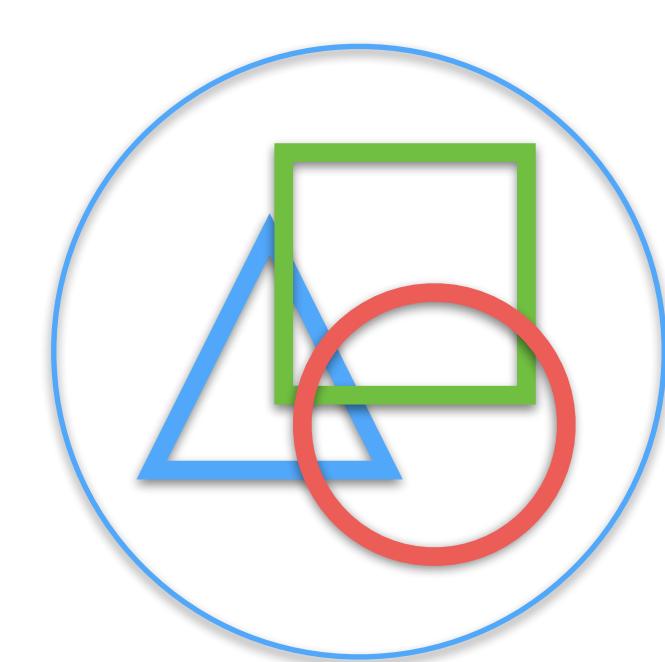
Ground Truth

GPS

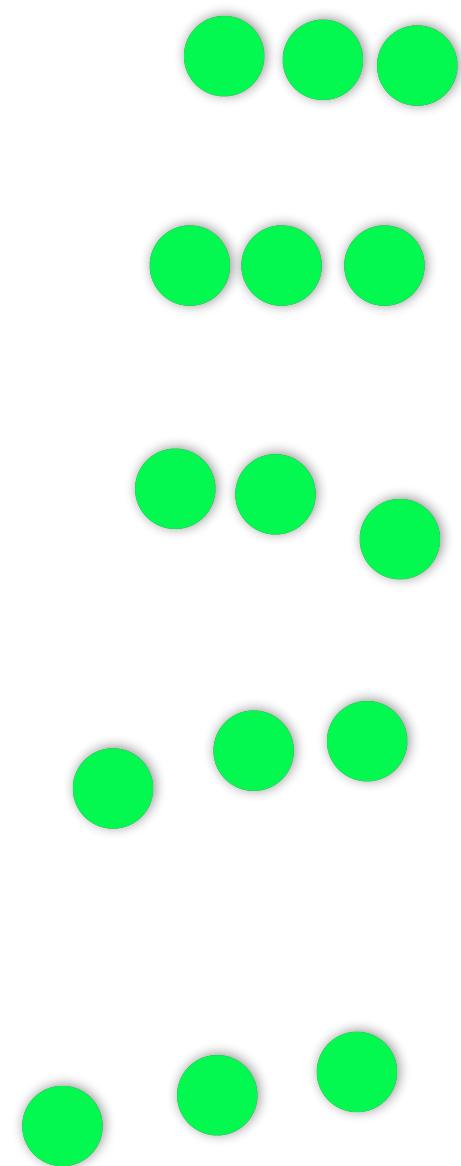
Map-Matching

CoDrive w/o
opt

CoDrive



Ground Truth



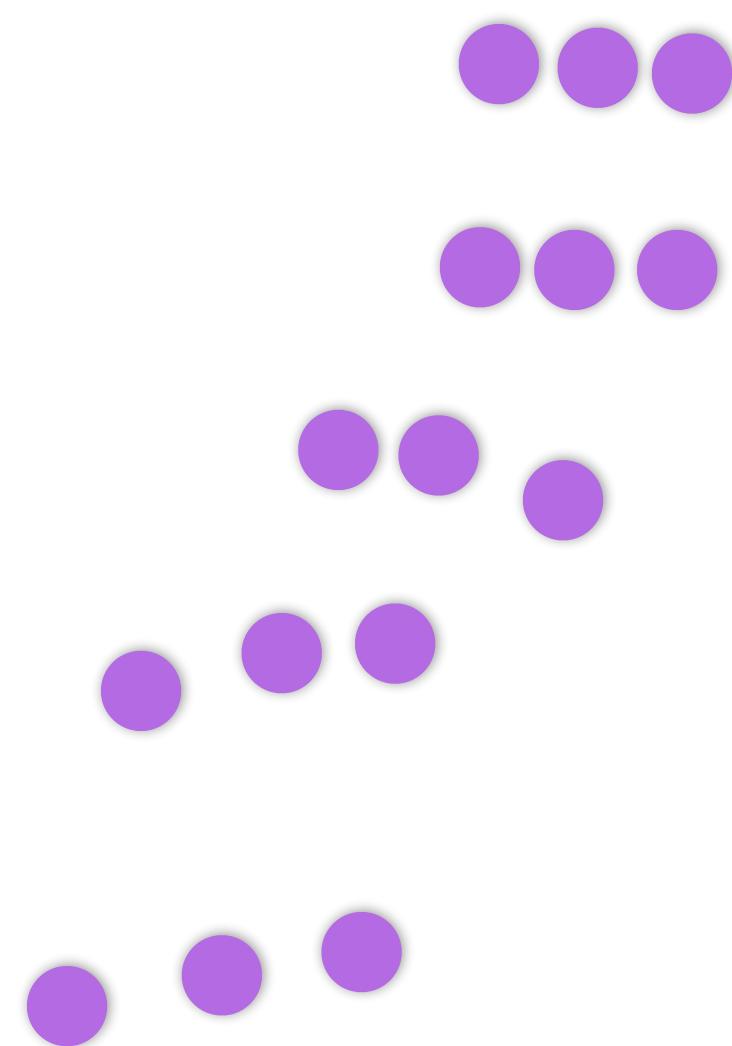
GPS



Map-Matching

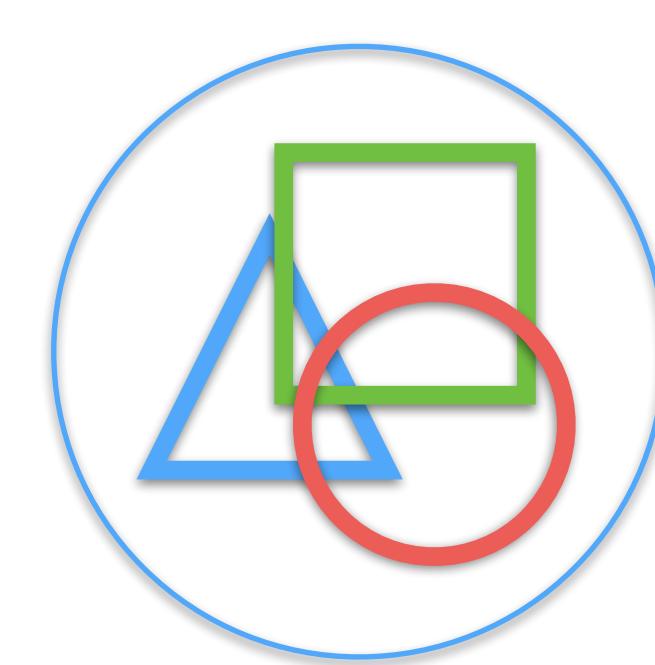


CoDrive w/o
opt



CoDrive





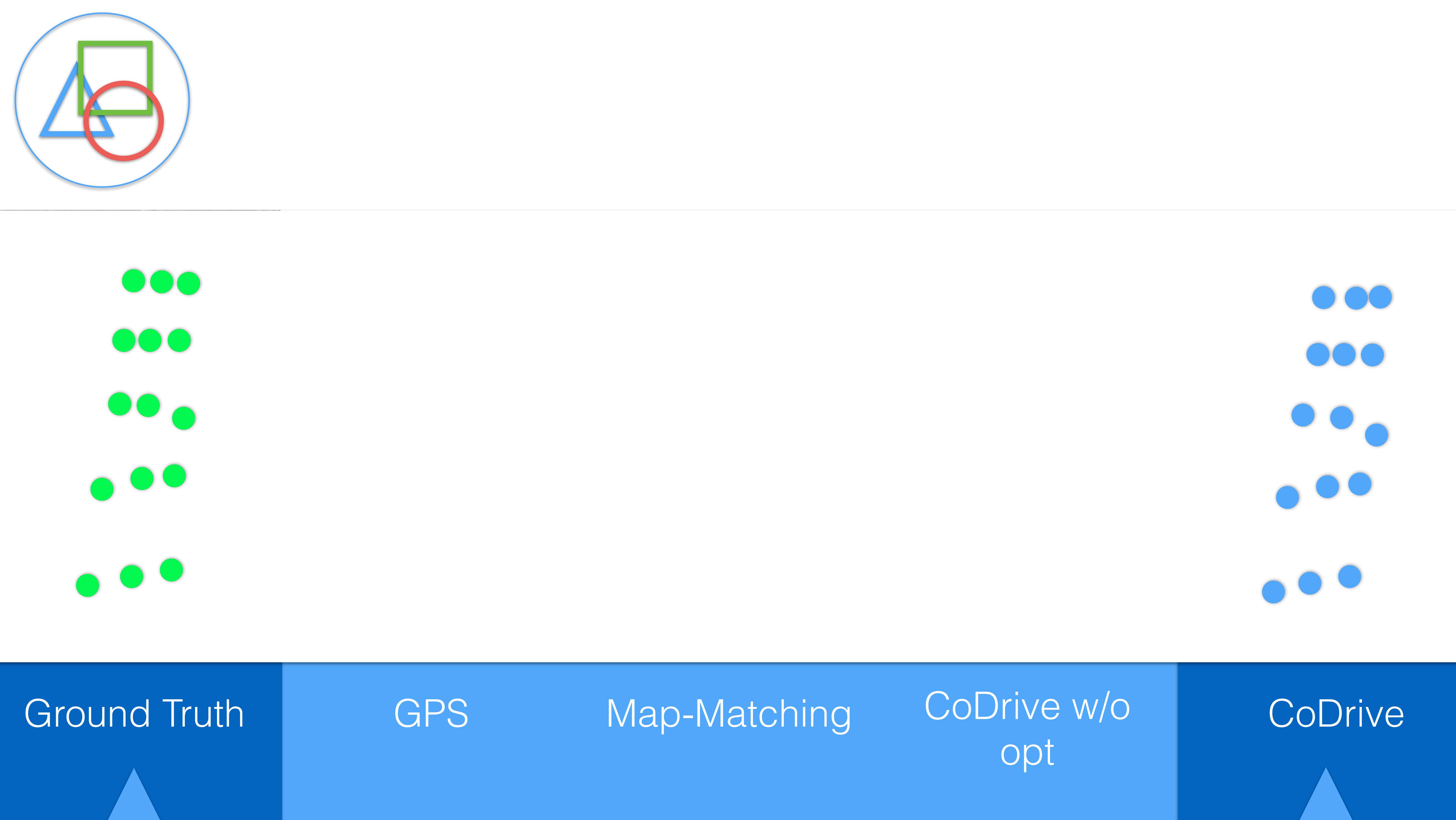
Ground Truth

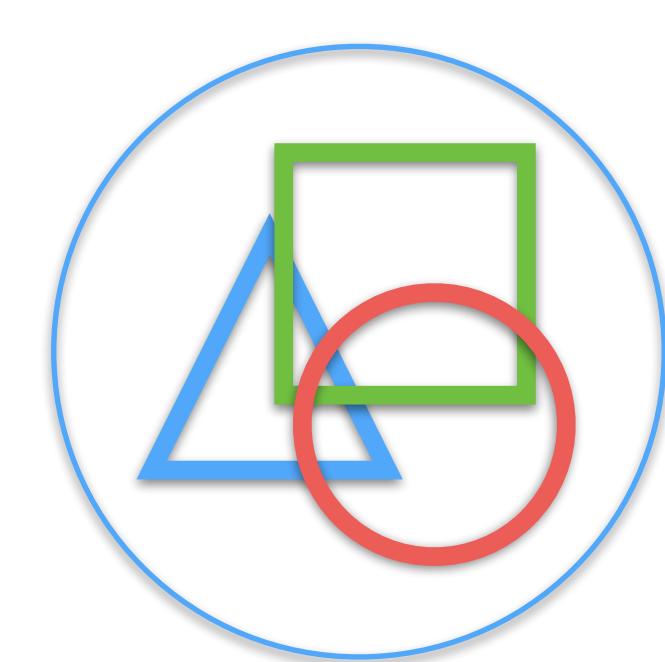
GPS

Map-Matching

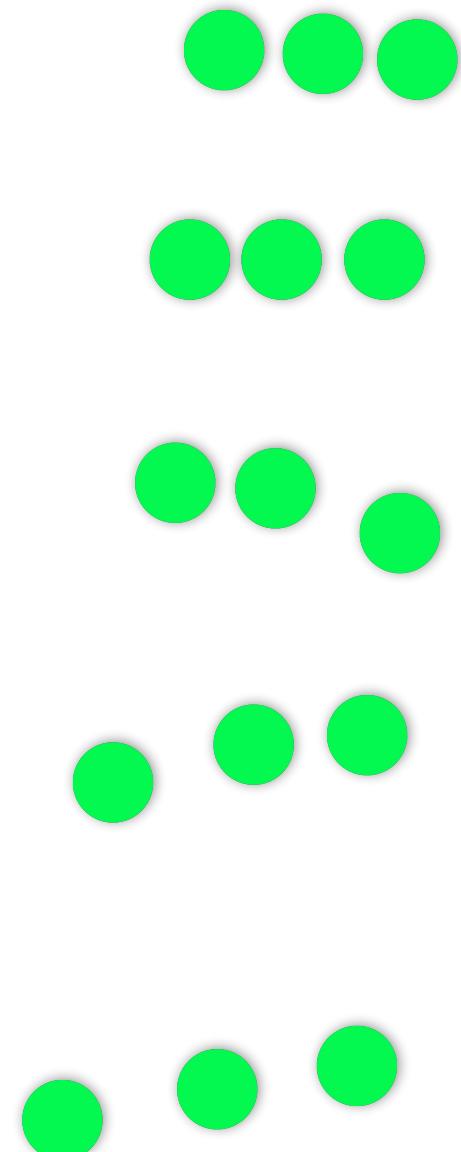
CoDrive w/o
opt

CoDrive

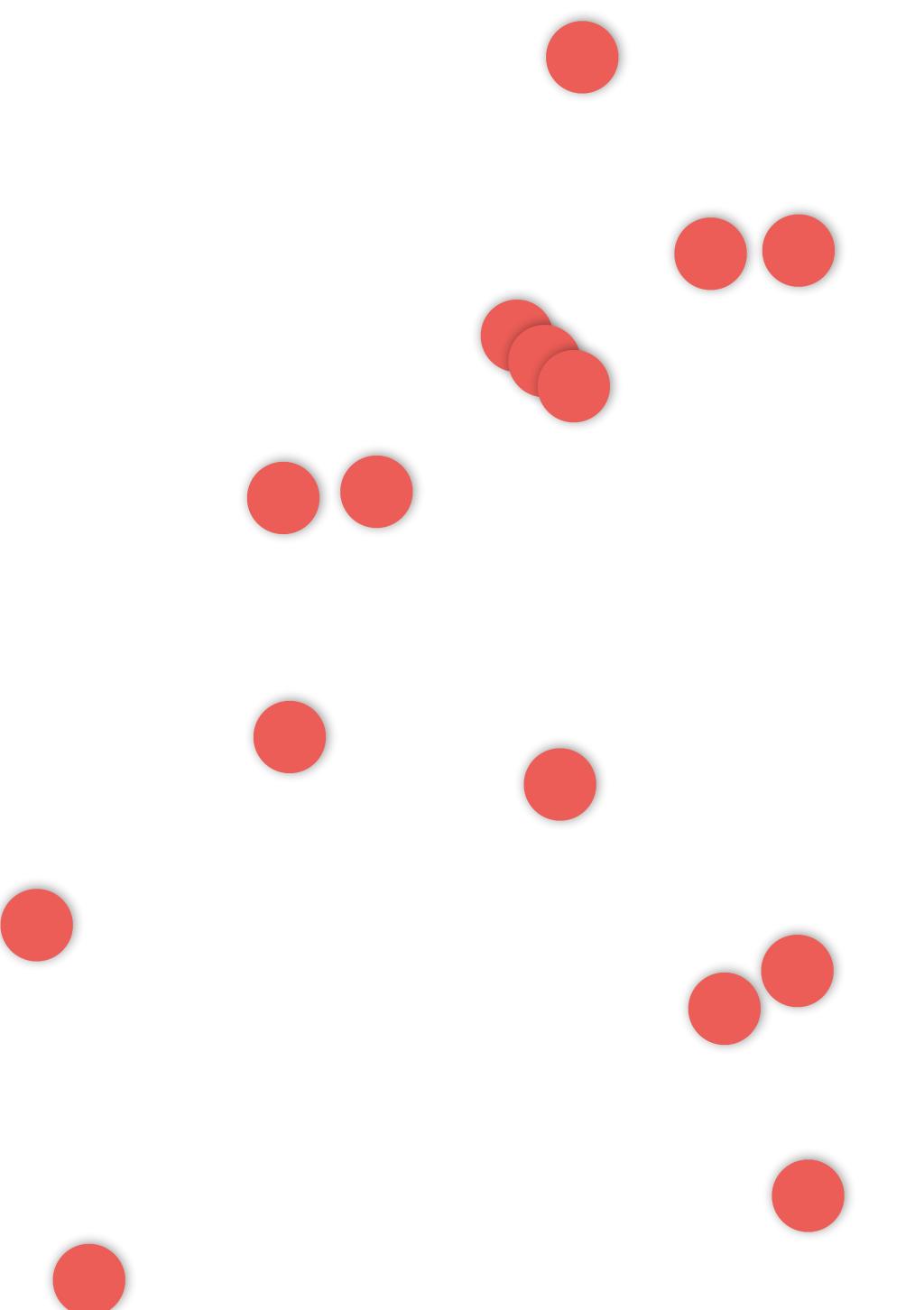




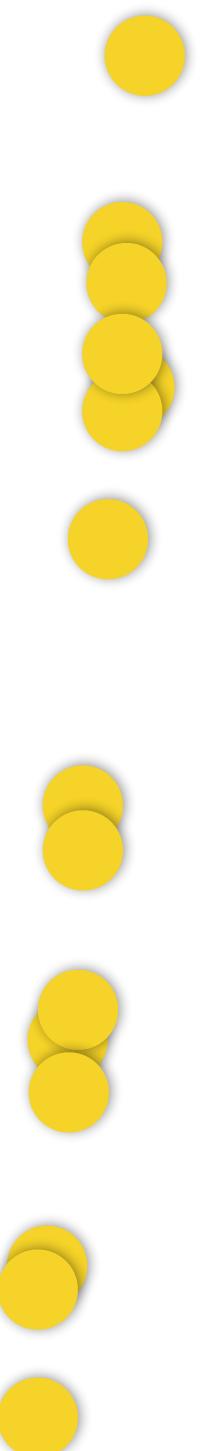
Ground Truth



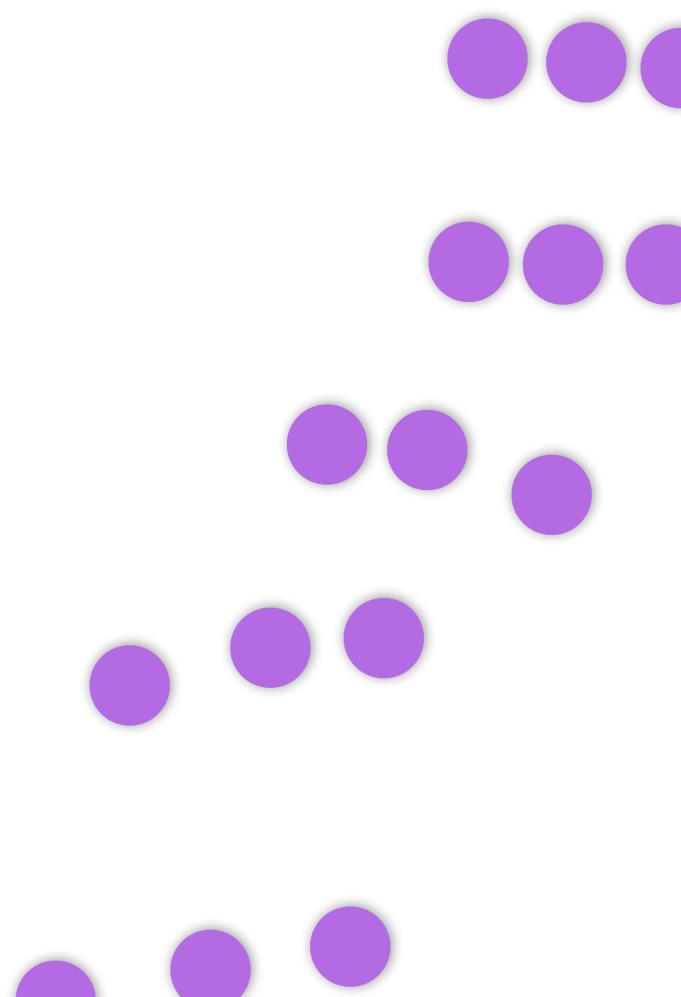
GPS



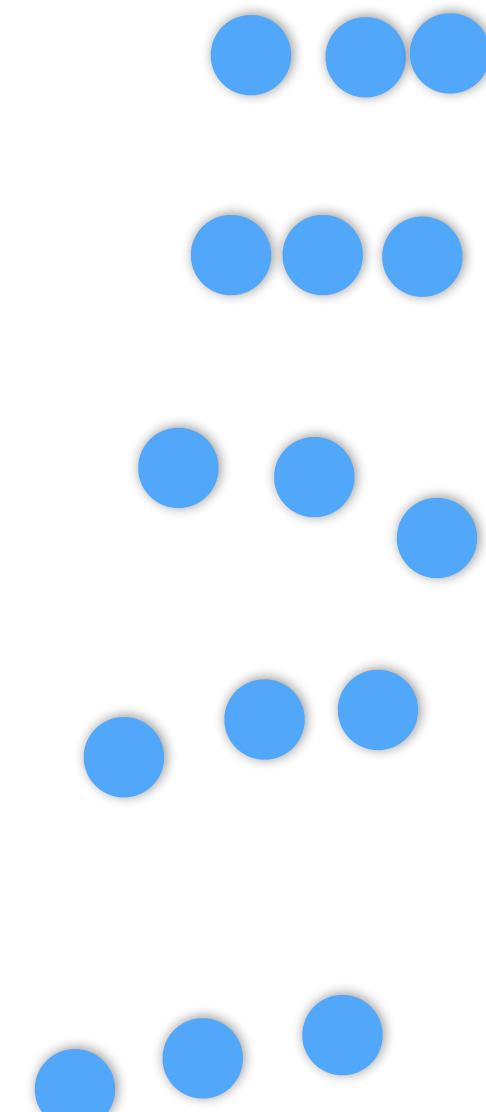
Map-Matching



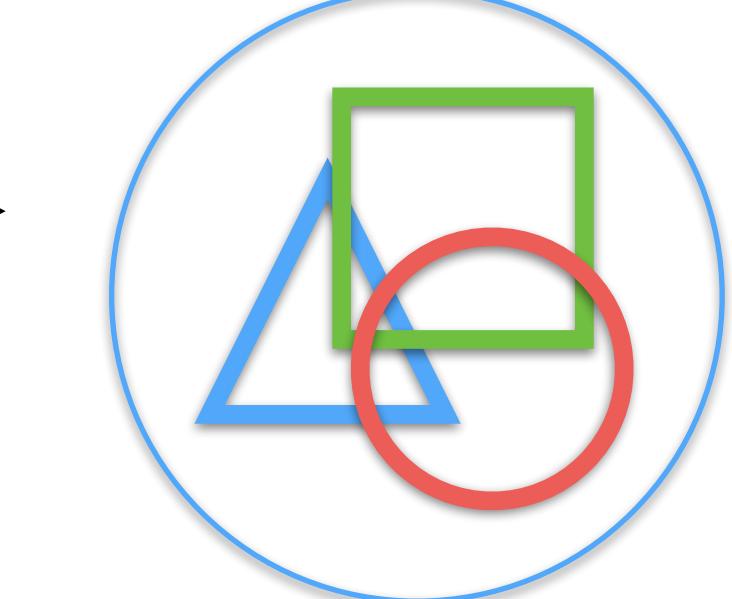
CoDrive w/o
opt



CoDrive



Evaluation Goals



Preserving the shape of the traffic

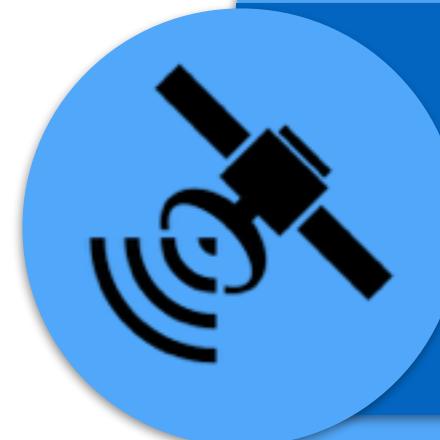


Reducing Positioning Error

Positioning Approaches



CoDrive



GPS

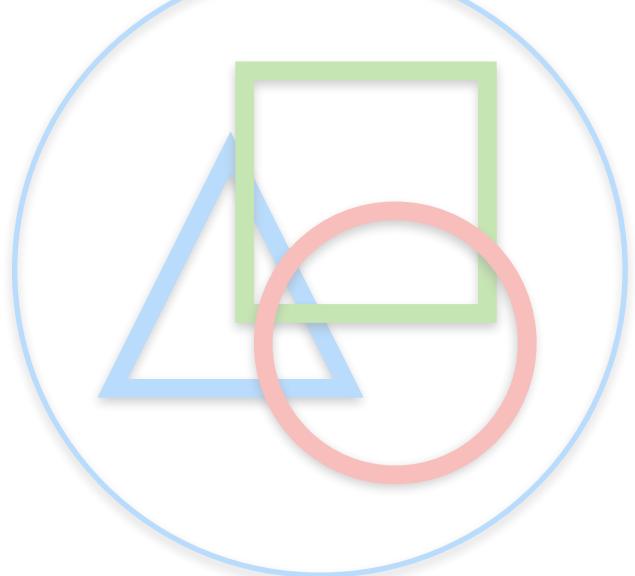


Map-Matching



CoDrive w/o
optimization (CWO)

Evaluation Goals



Preserving the shape of the traffic

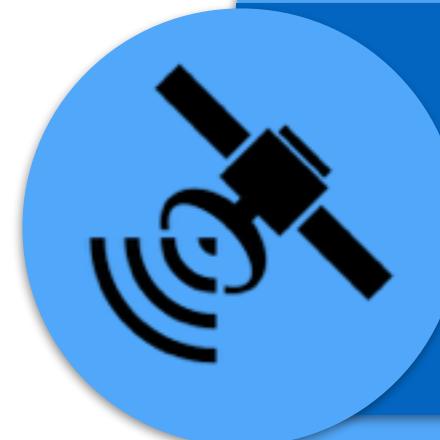


Reducing Positioning Error

Positioning Approaches



CoDrive



GPS



Map-Matching

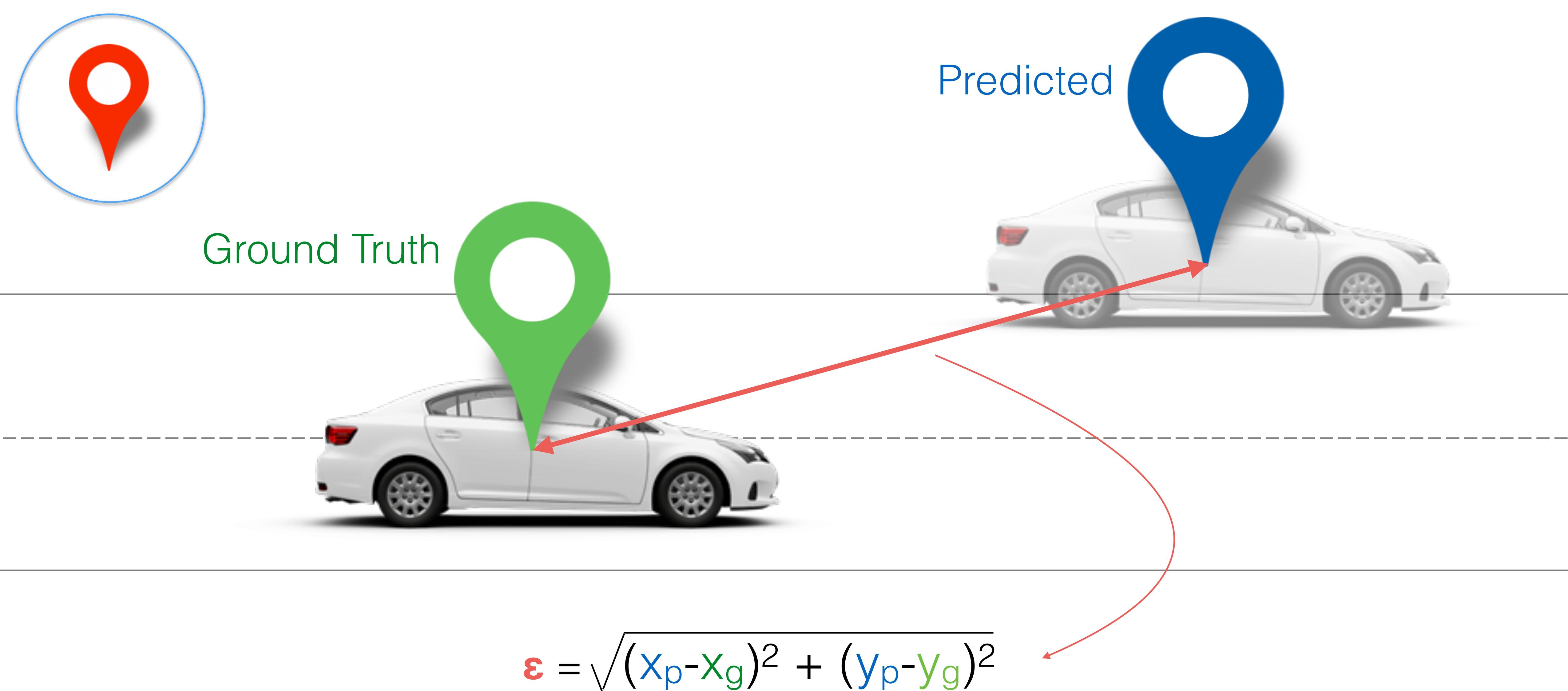


CoDrive w/o
optimization (CWO)



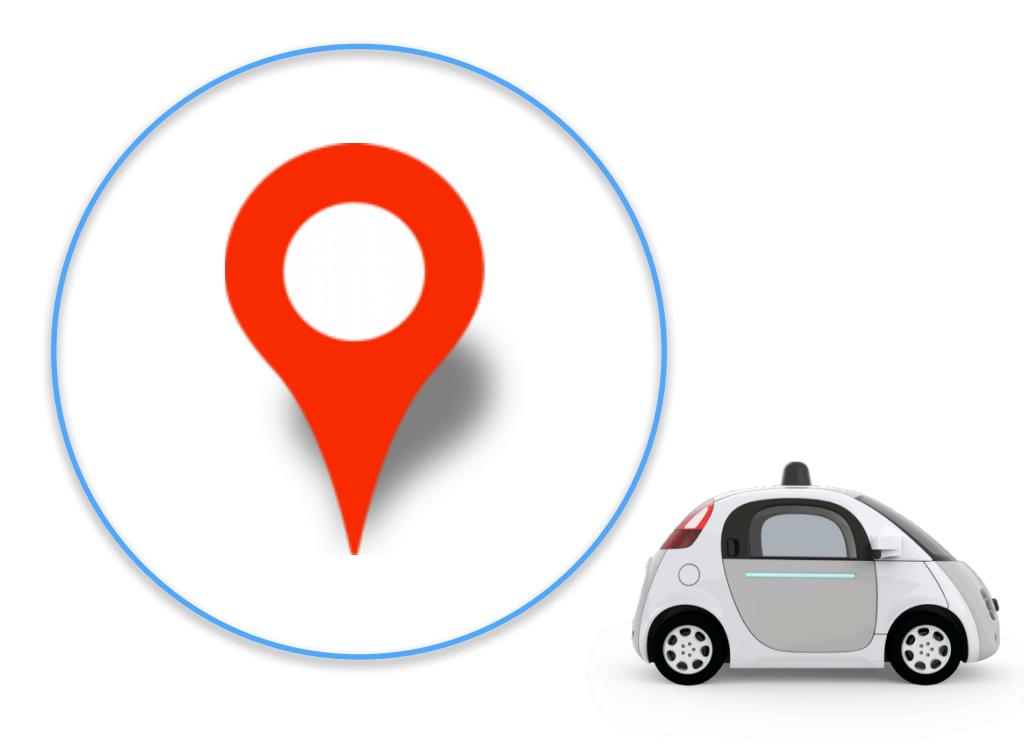
Ground Truth





$$\epsilon = \sqrt{(x_p - x_g)^2 + (y_p - y_g)^2}$$





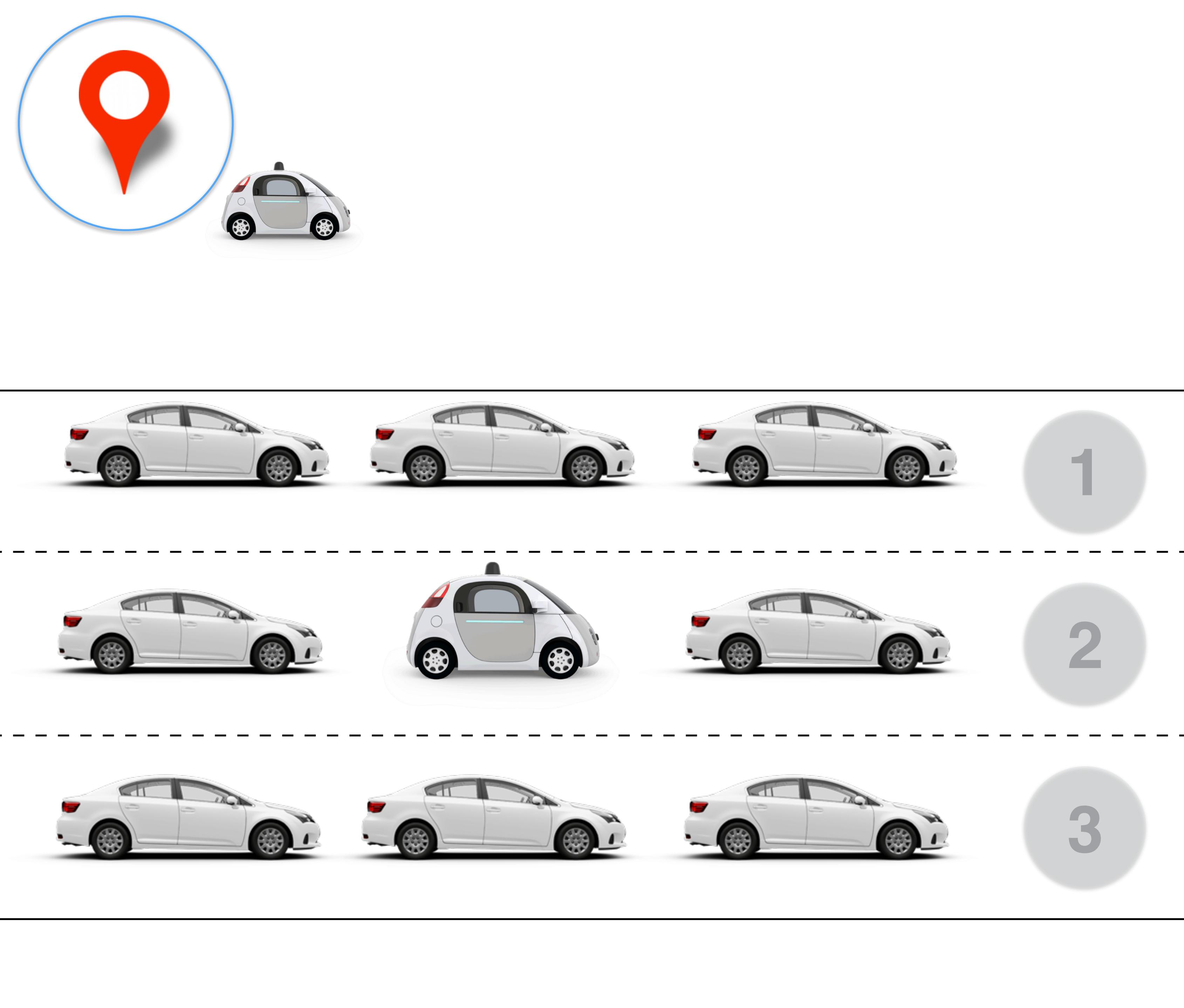
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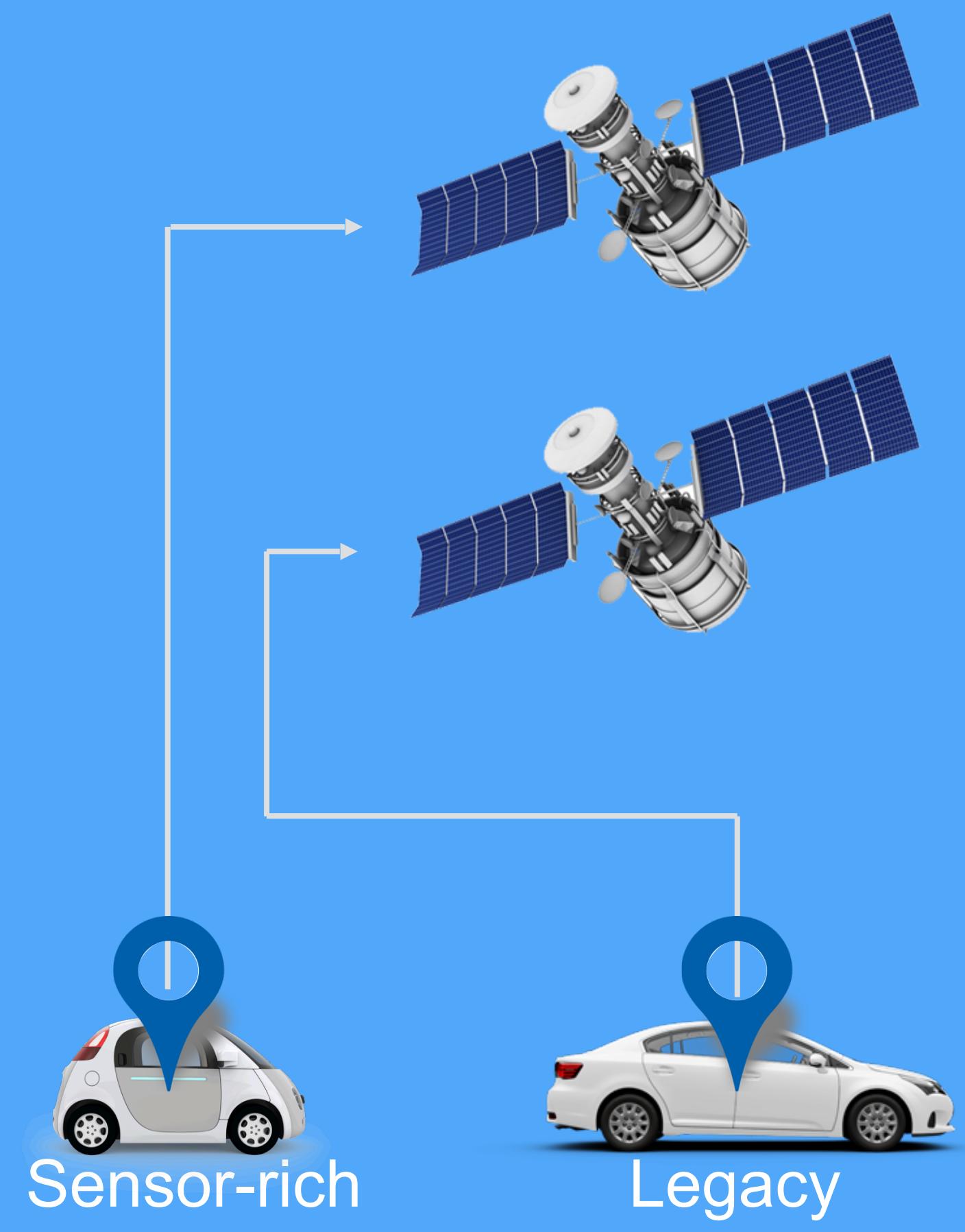
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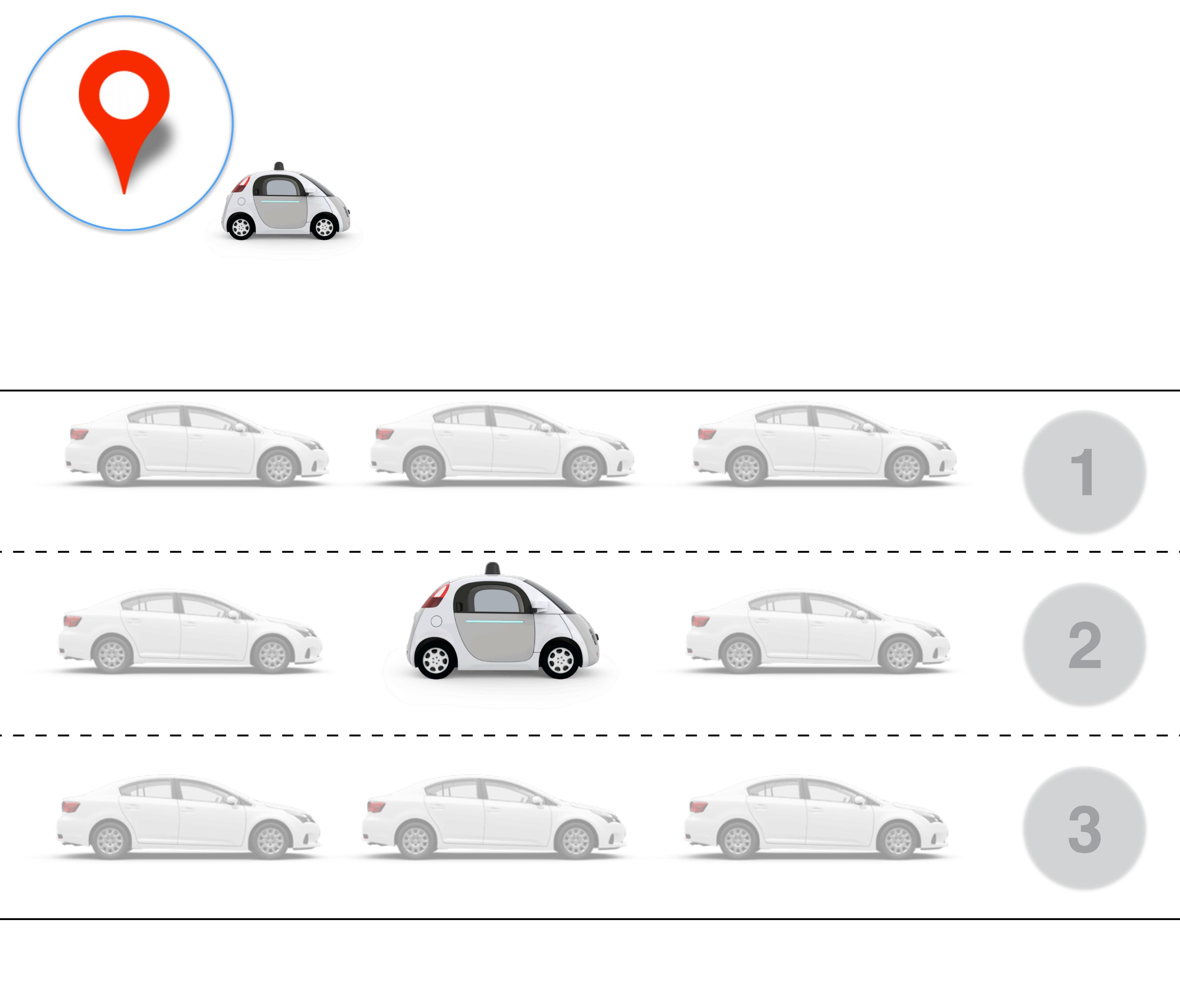


Baseline

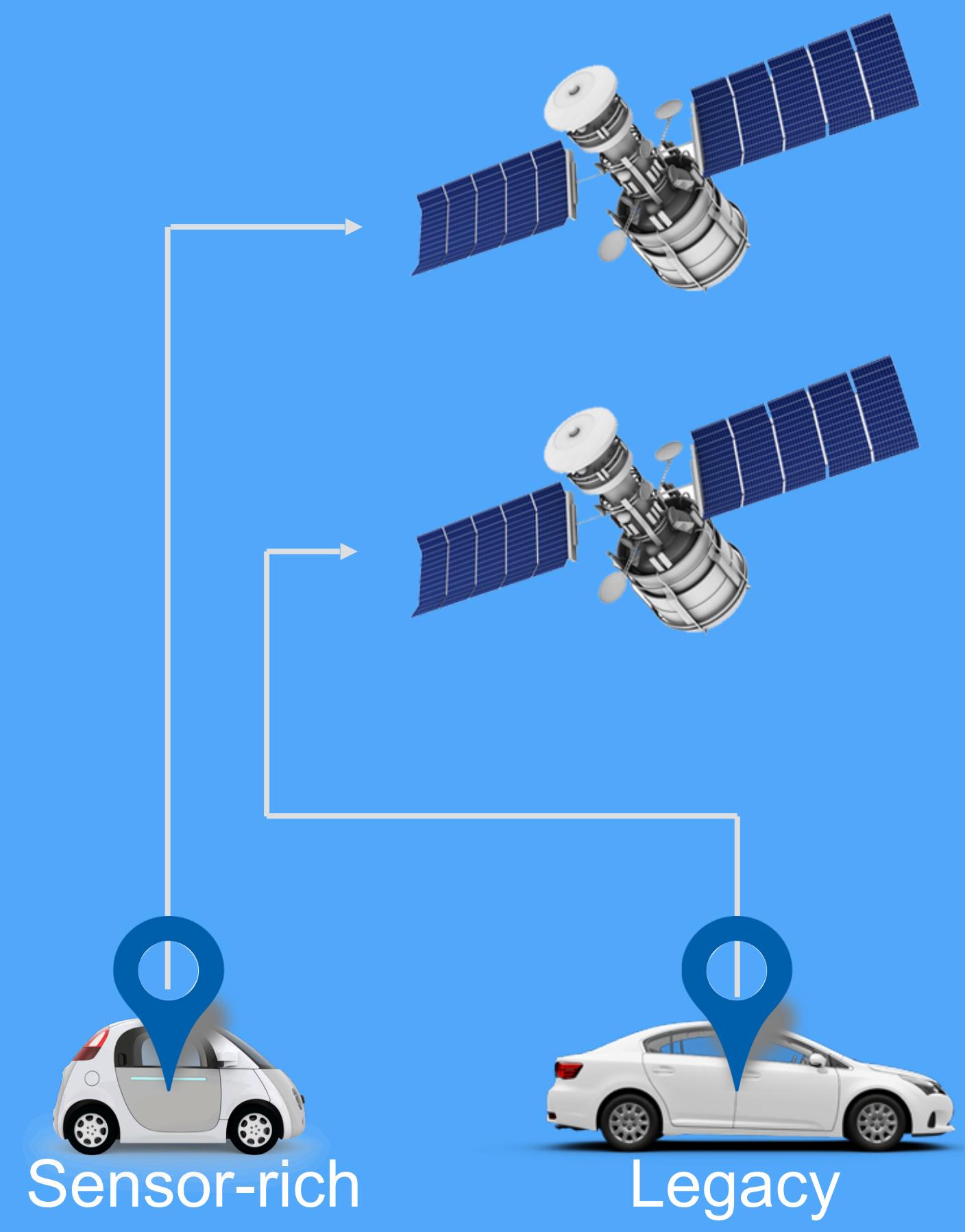


Sensor-rich

Legacy

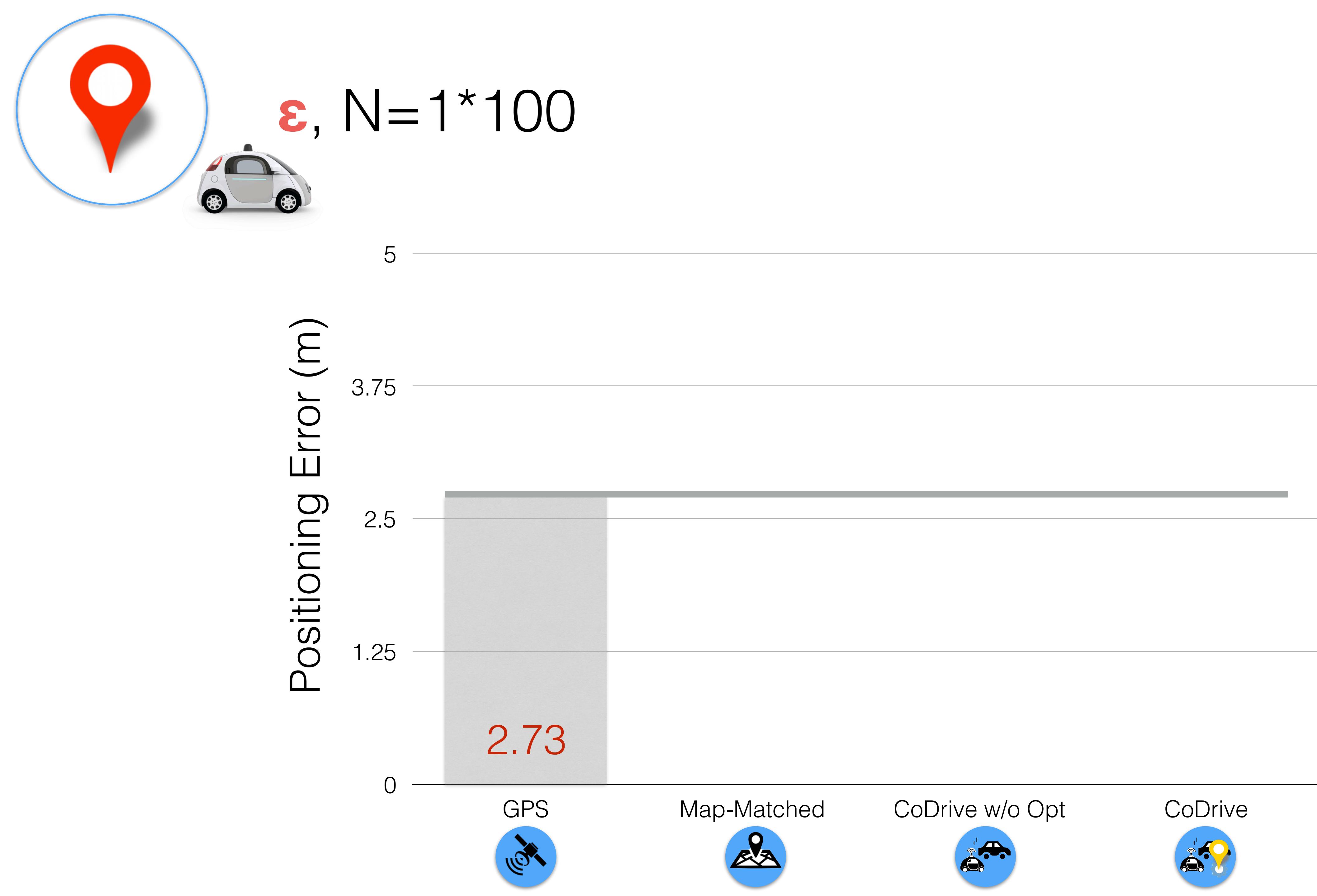


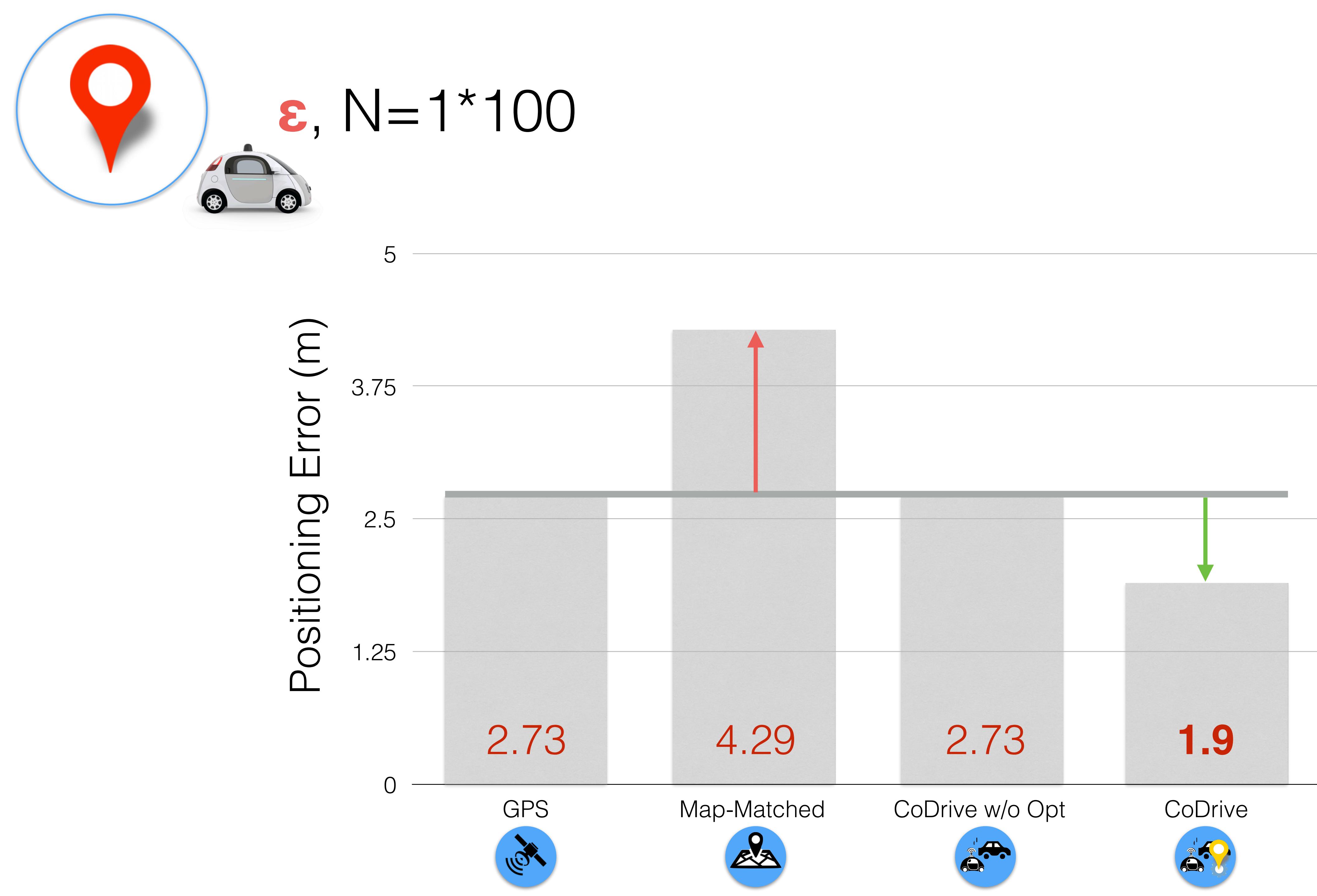
Baseline

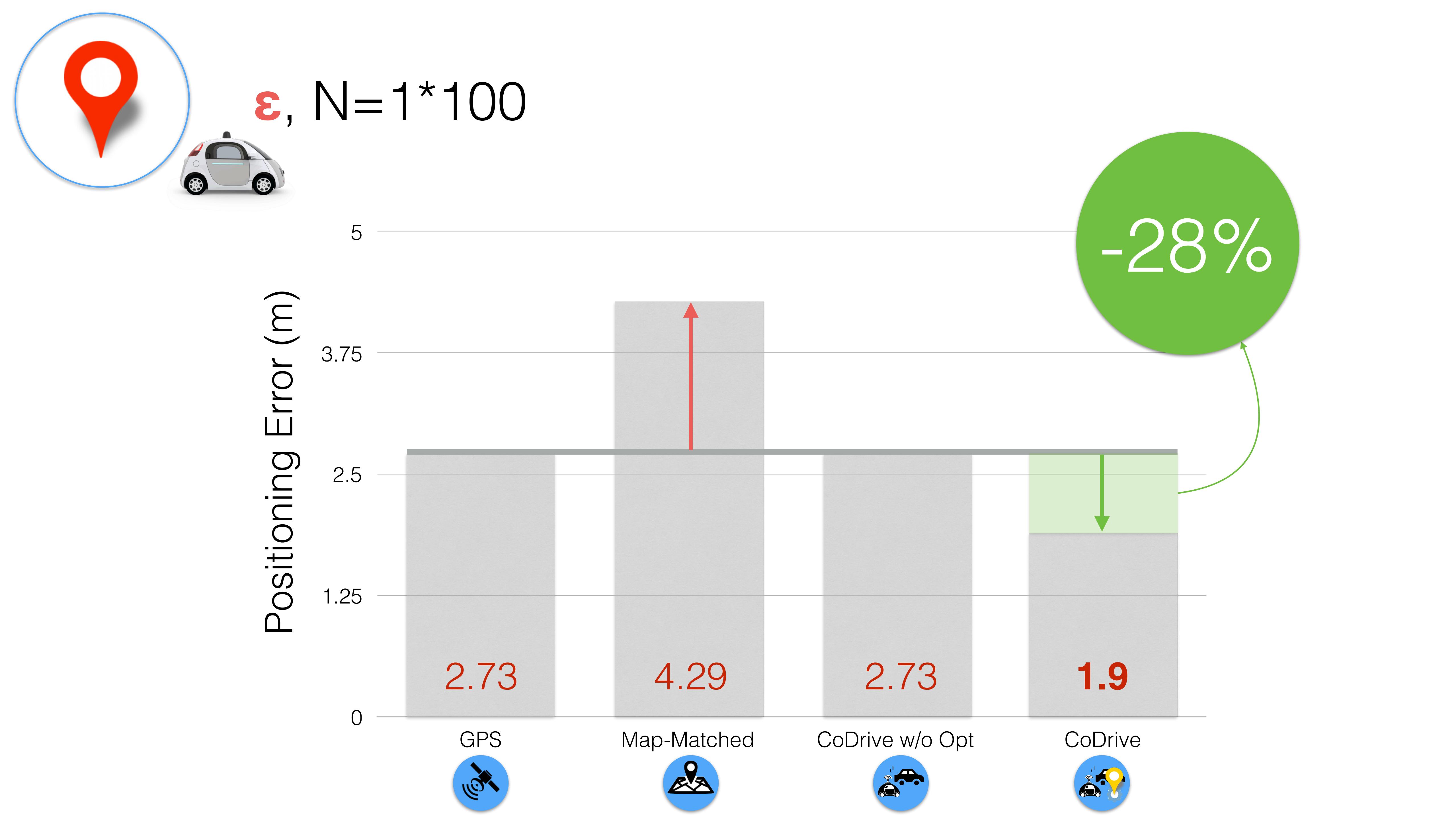


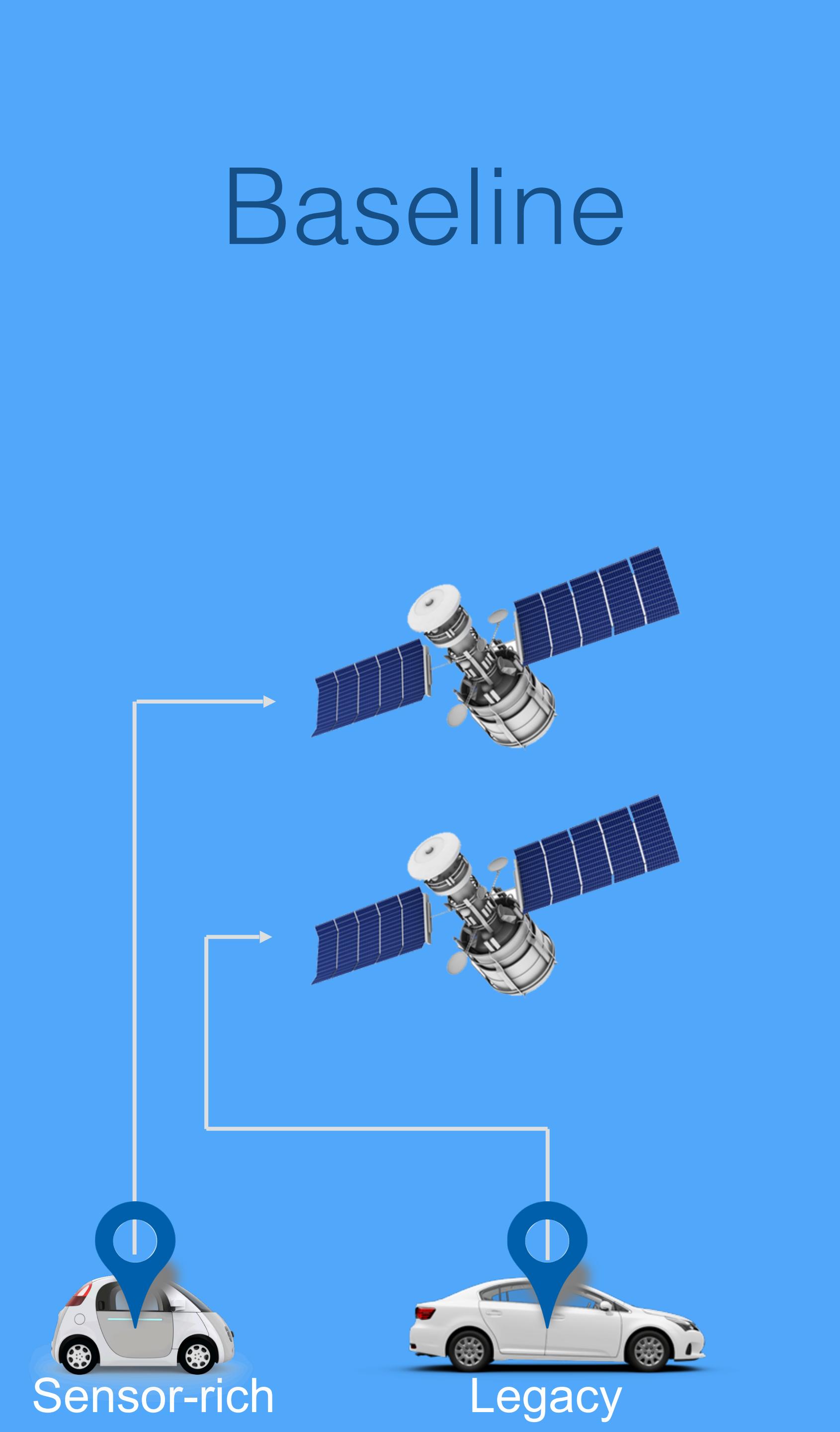
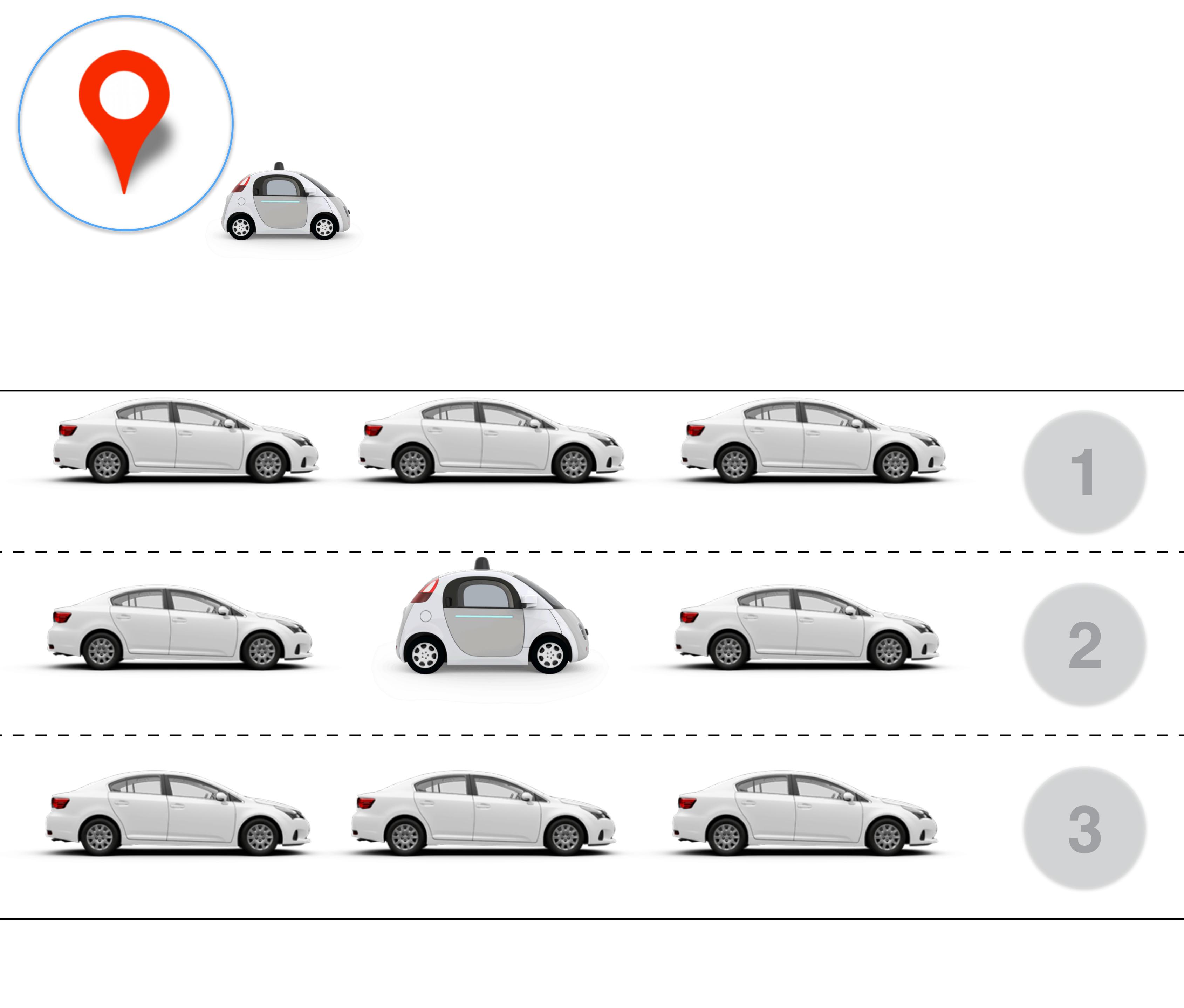
Sensor-rich

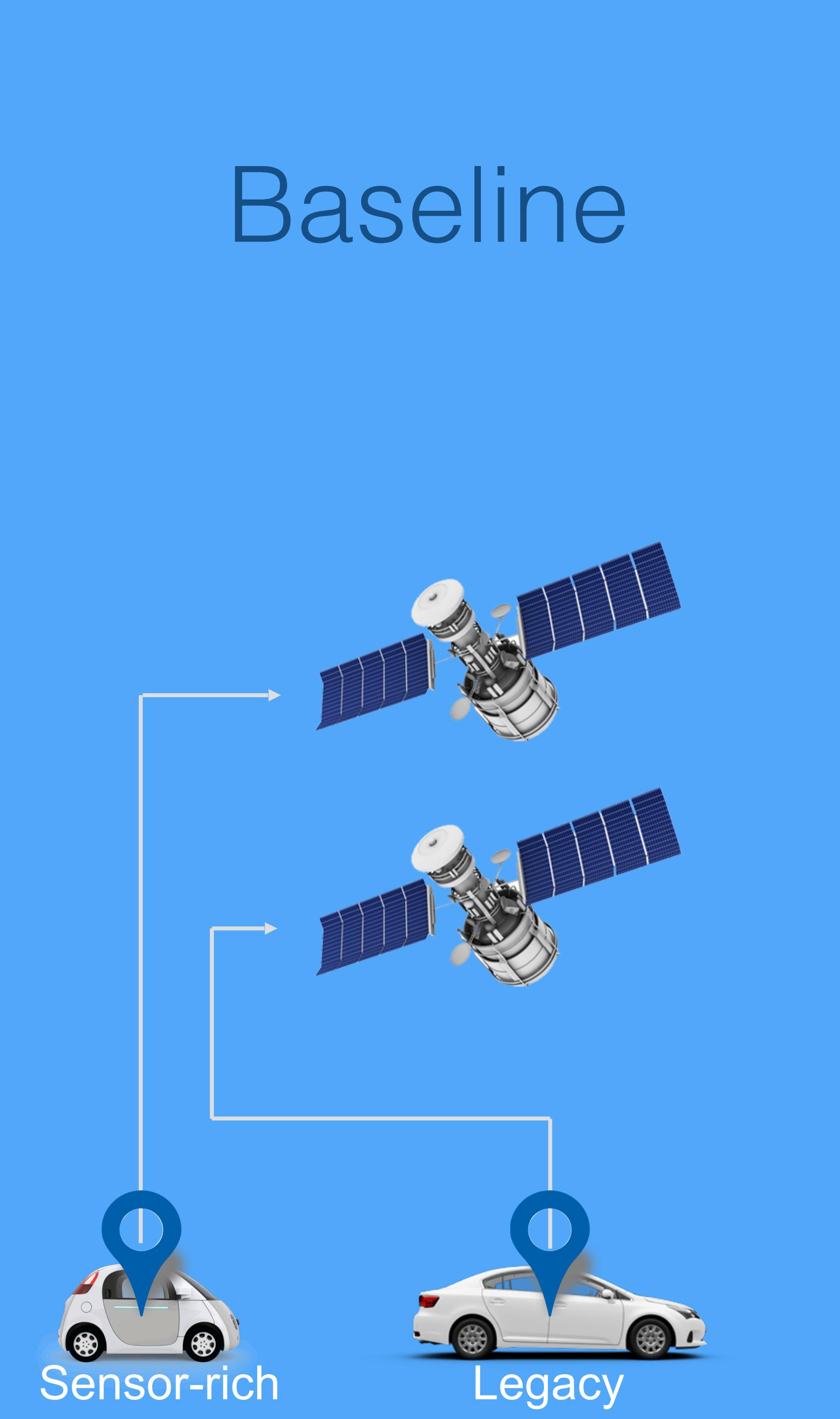
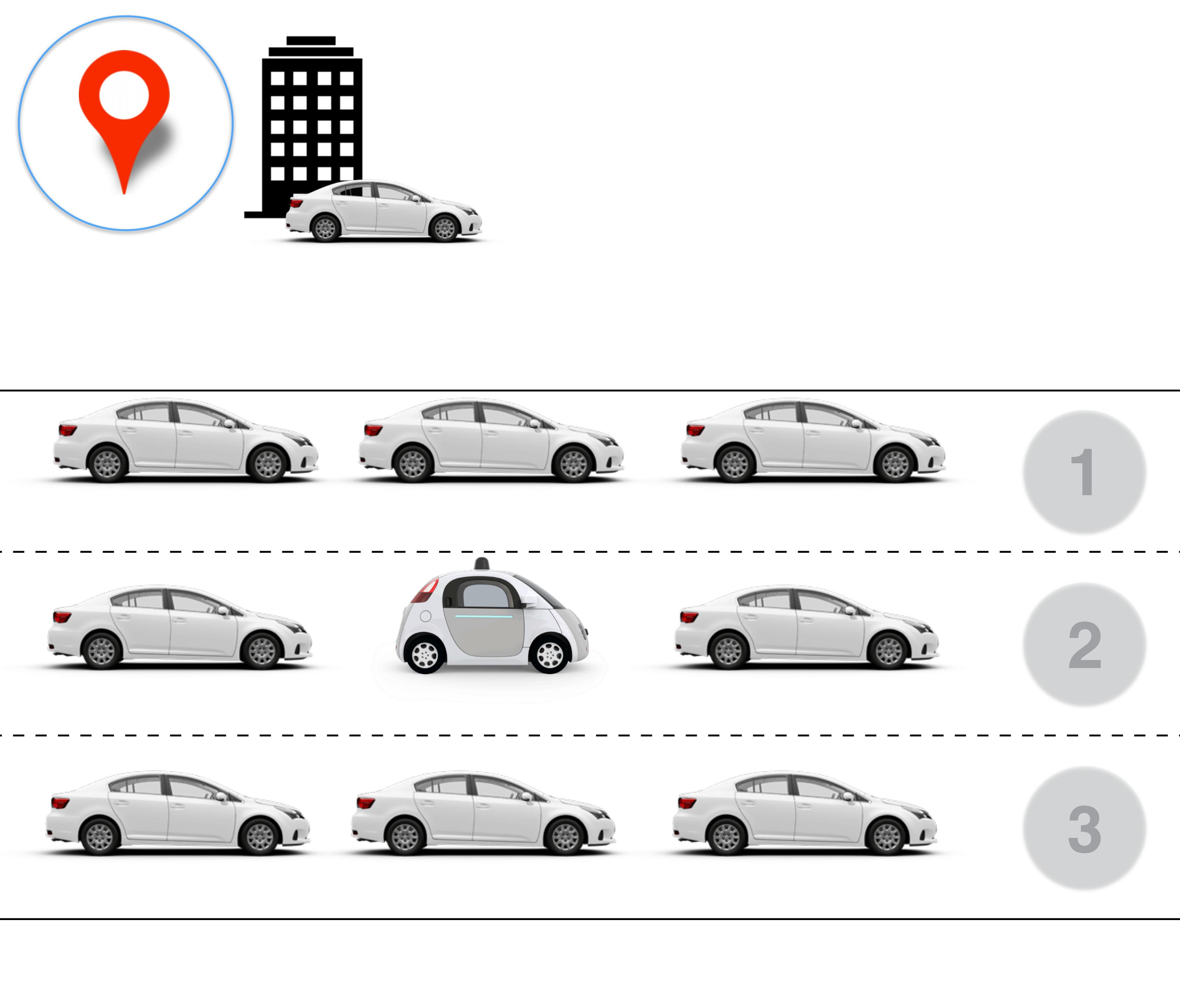
Legacy

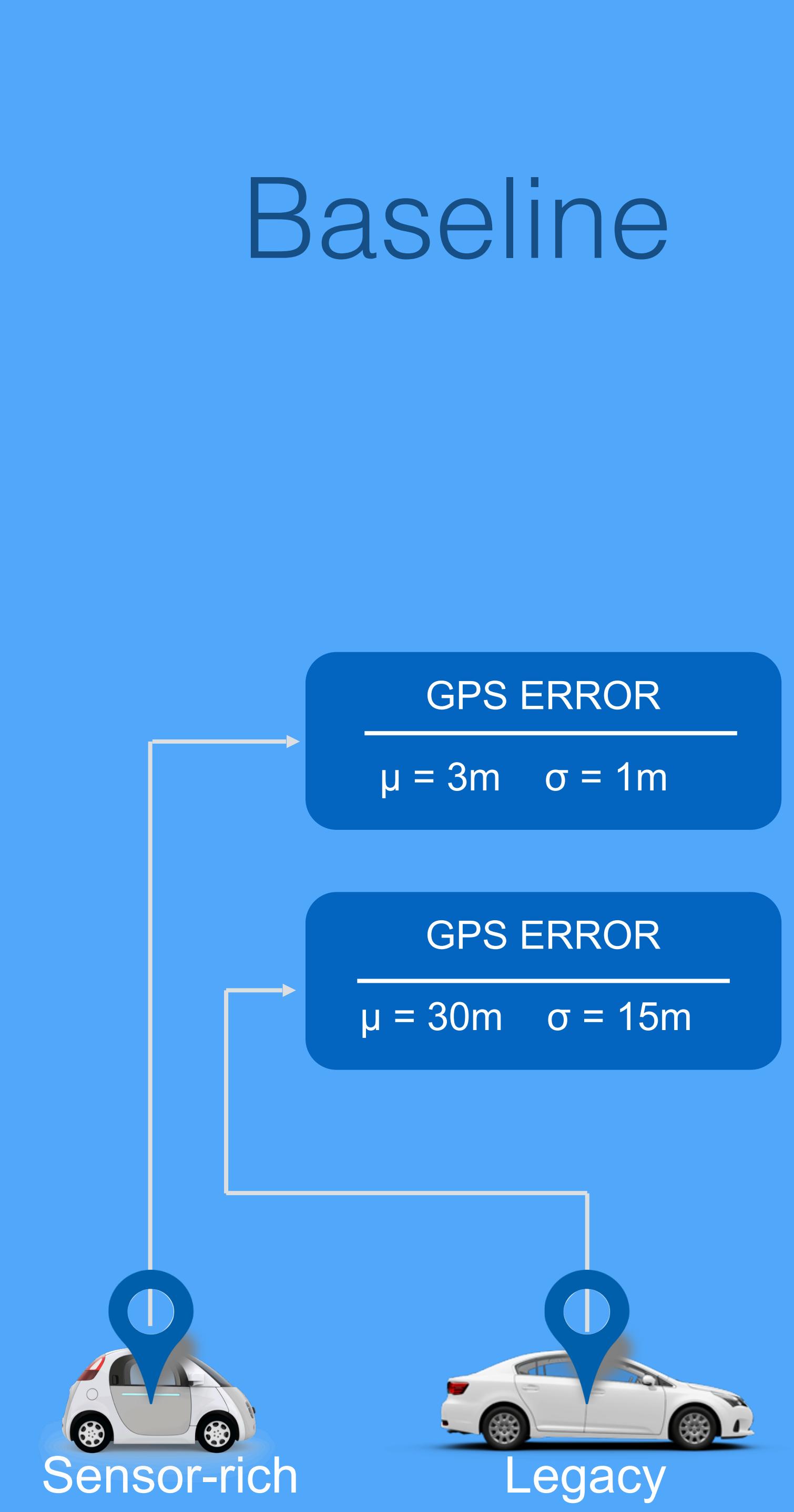
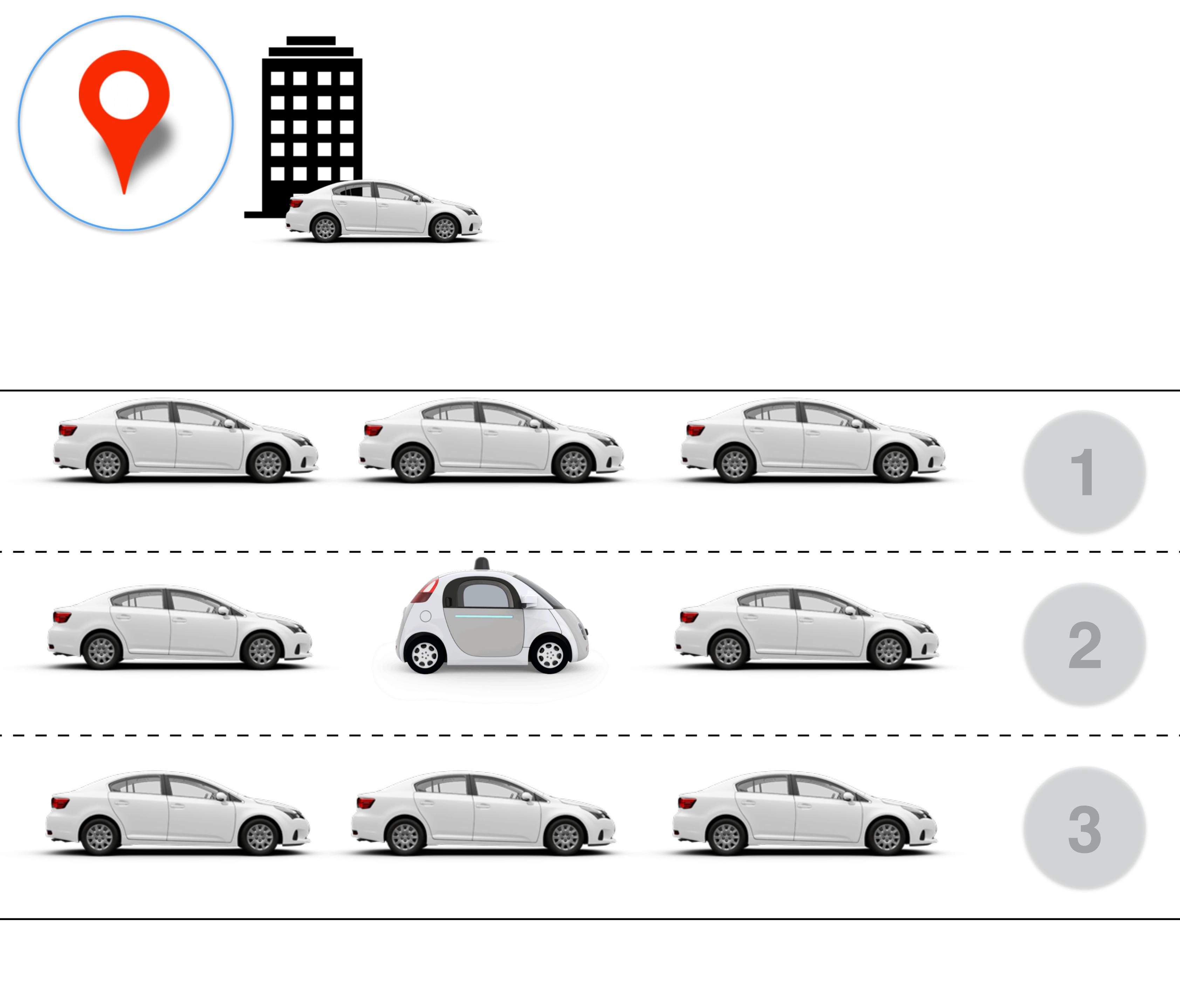


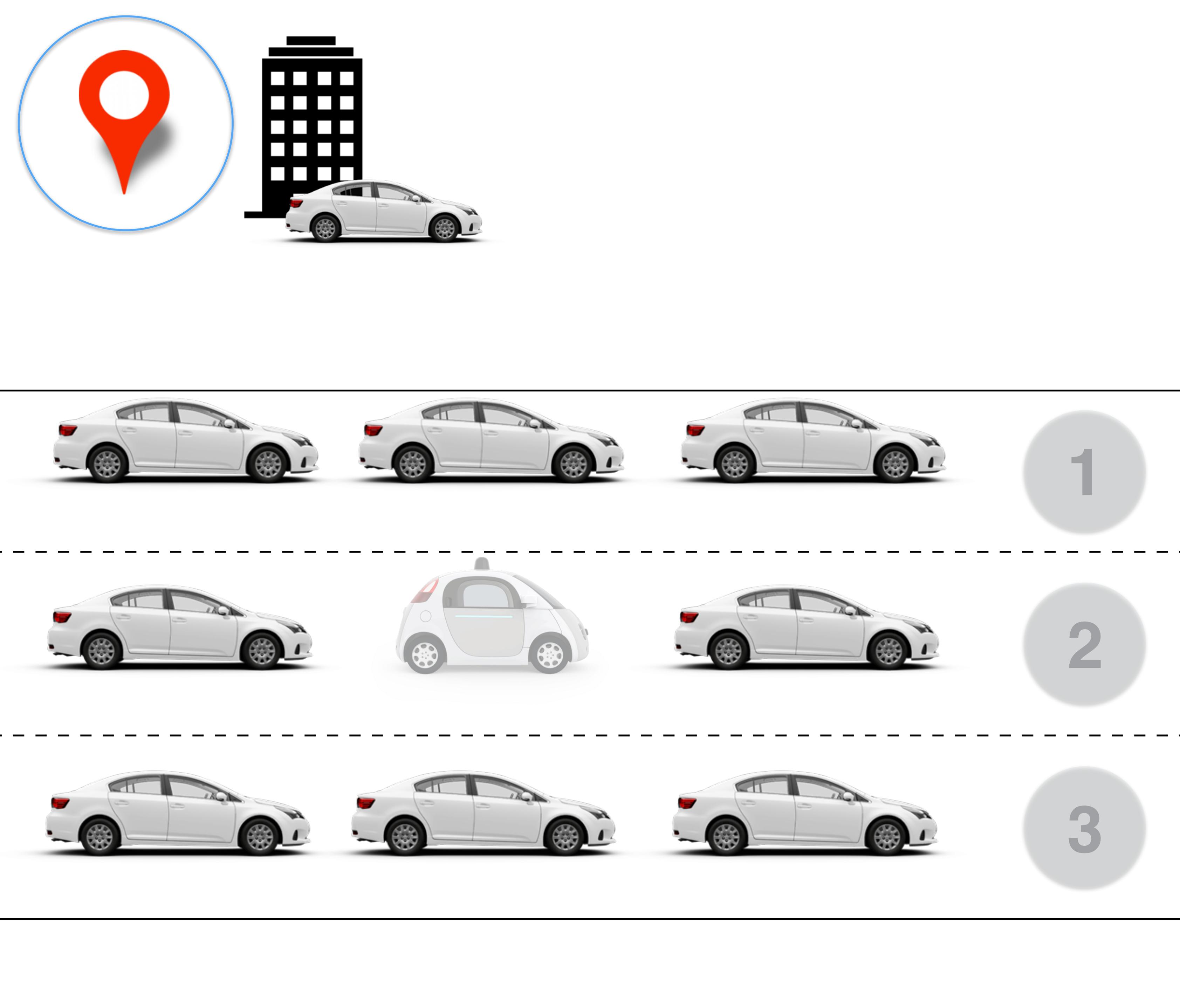












Baseline

GPS ERROR

$$\mu = 3m \quad \sigma = 1m$$

GPS ERROR

$$\mu = 30m \quad \sigma = 15m$$

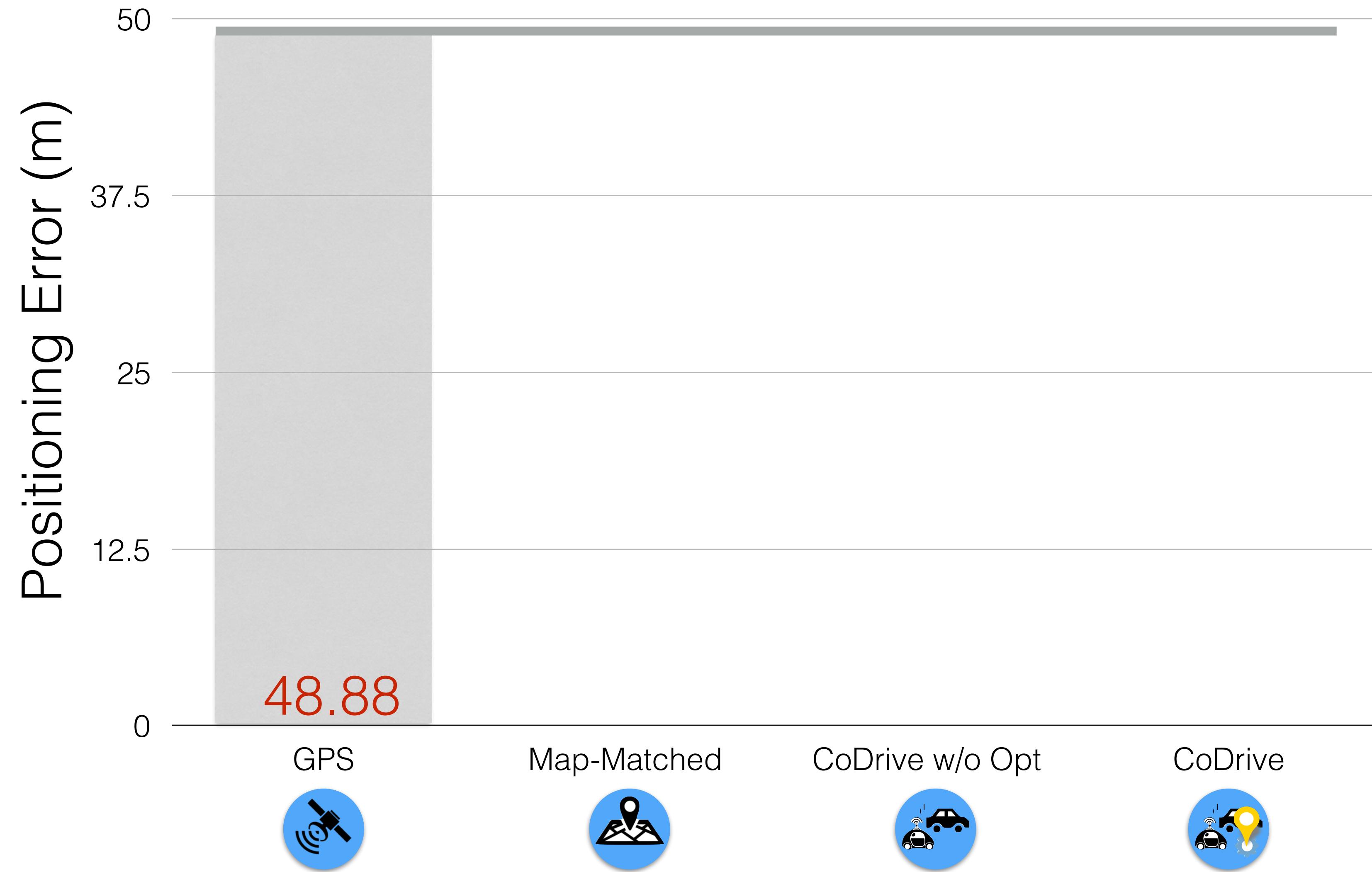


Sensor-rich

Legacy

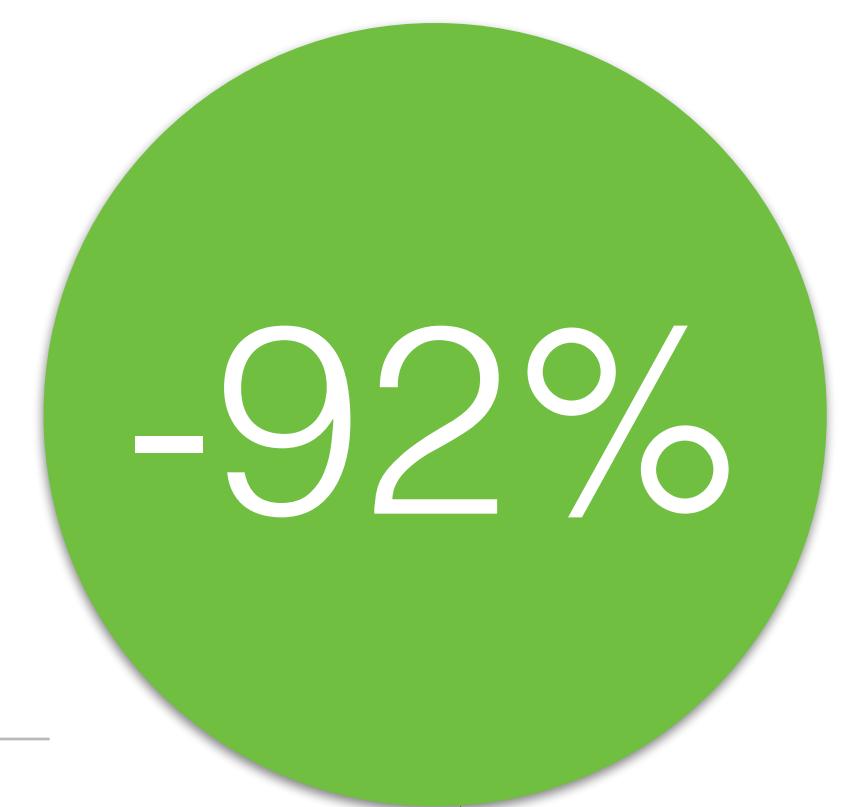
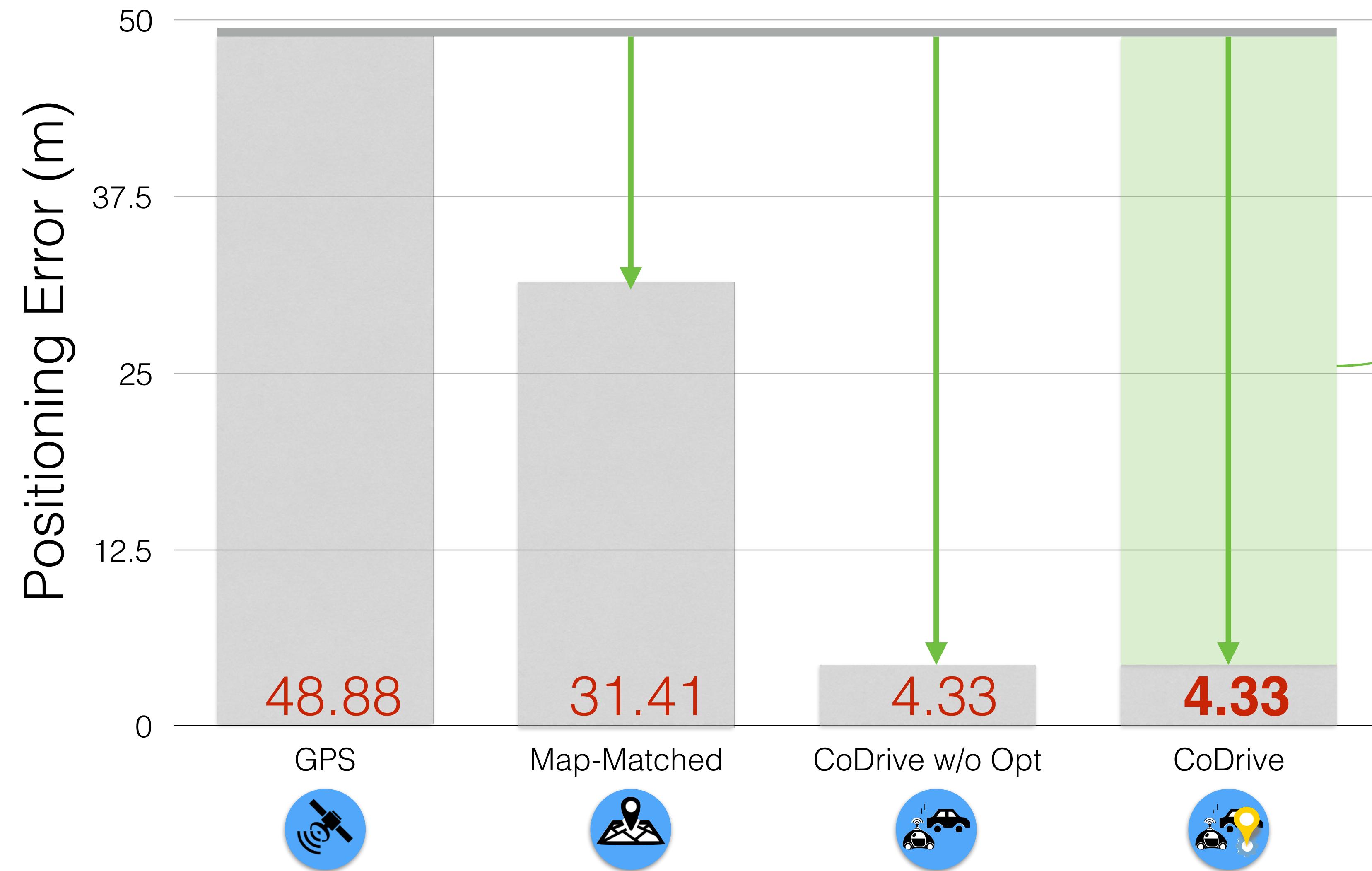


ϵ , N=8*100





ϵ , N=8*100



Other Experiments



Traffic topologies



Road Segments



Parametrized GPS error



Summary

- Built a **sensor car mount** that can be utilized to emulate sensor-rich cars.
- Implemented an **infrastructure** based on ROS to synchronize and combine streams from visual and distance sensors.
- Designed an **optimization framework** to improve vehicle positioning.
- Extensive evaluation demonstrating **great reductions in GPS positioning error** for both sensor-rich and legacy vehicles.
 - up to **30%** for sensor-rich cars
 - up to **92%** for legacy cars

