MATLAB EXPO

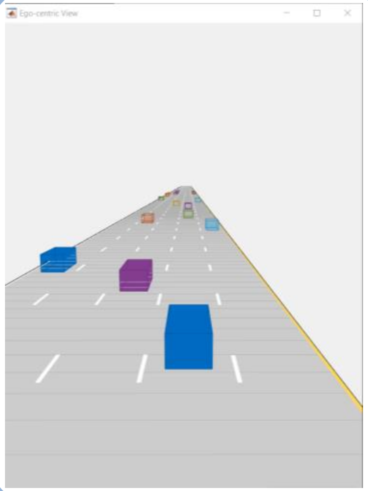
Sensor Fusion and Navigation for Autonomous Systems Using MATLAB & Simulink

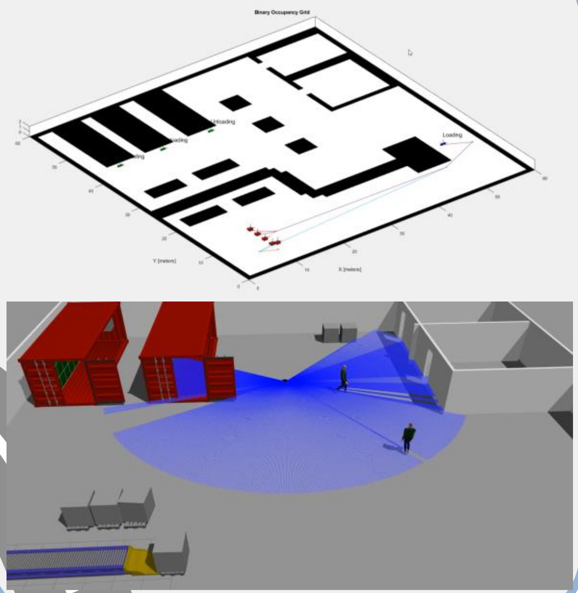
MathWorks®

Smart autonomous package delivery

Manufacturer

① Autonomous Driving





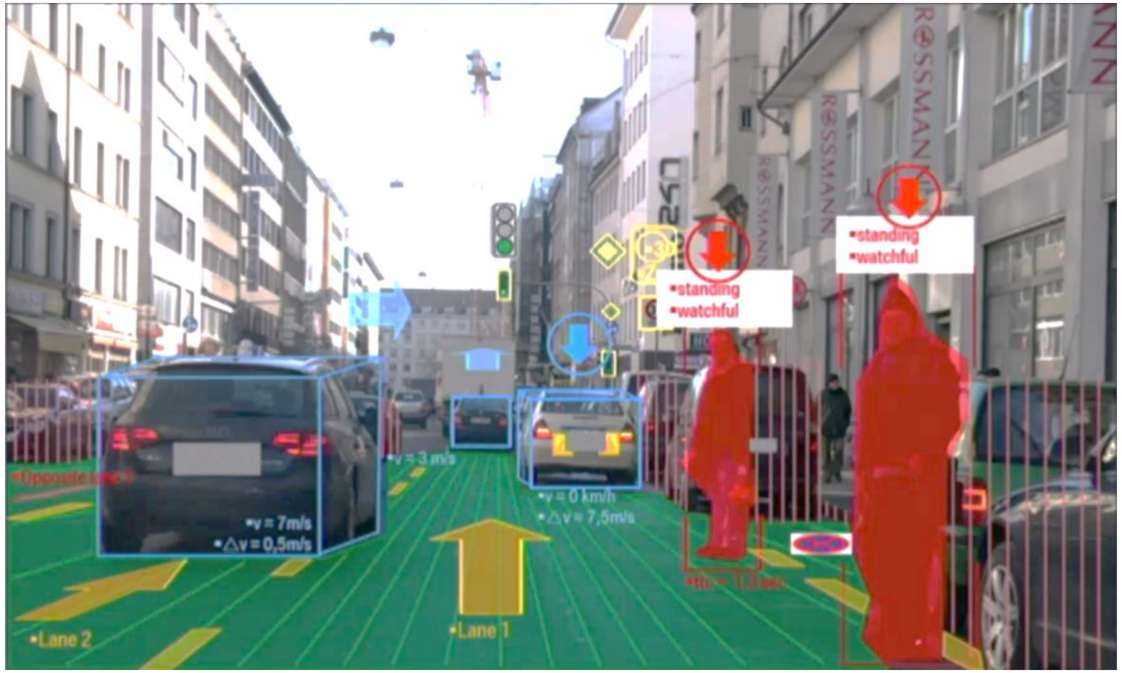
② Warehouse Automation

③ Last Mile Delivery

Consumer

Capabilities of an Autonomous System

Perception



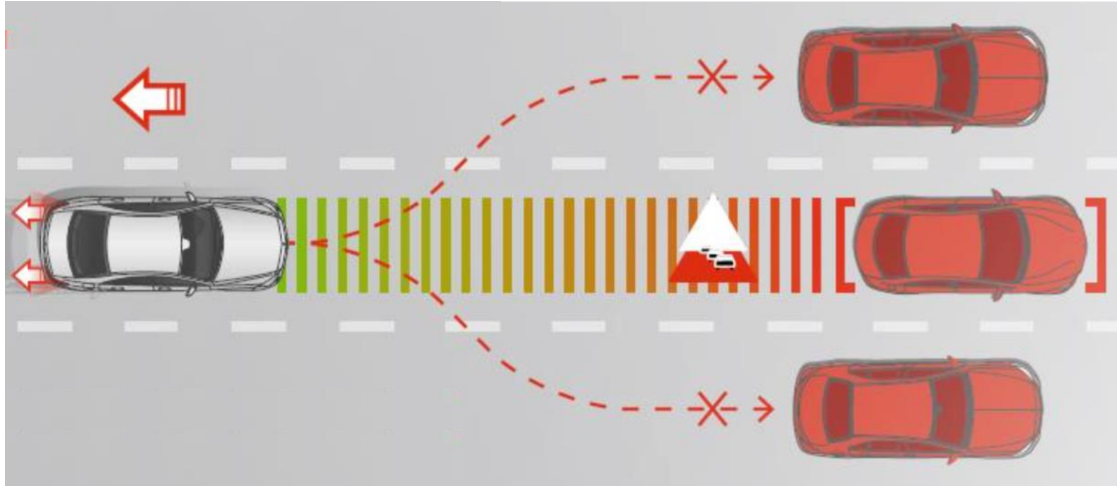
Some common Perception tasks

- Design localization algorithms
- Design environment mapping algorithms
- Design SLAM algorithms
- Design fusion and tracking algorithms
- Label sensor data
- Design deep learning networks
- Design radar algorithms
- Design vision algorithms
- Design lidar algorithms
- Generate C/C++ code

Capabilities of an Autonomous System

Perception

Planning



Some common Planning **tasks**

- Visualize street maps
- Connect to HERE HD Live Map
- Design local and global path planners
- Design vehicle motion behavior planners
- Design trajectory generation algorithms
- Generate C/C++ code

Capabilities of an Autonomous System

Perception

↓

Planning

↓

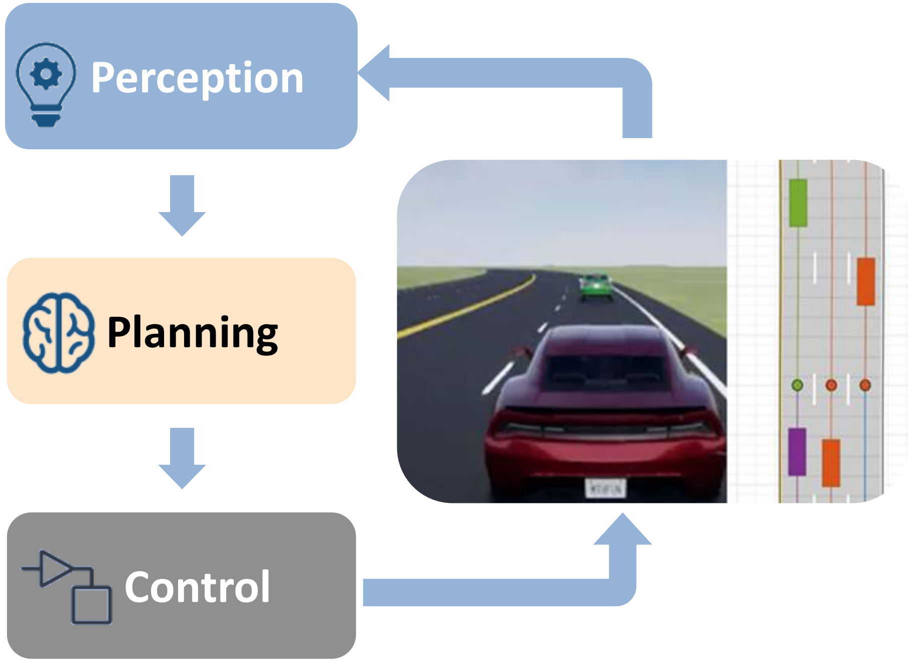
Control

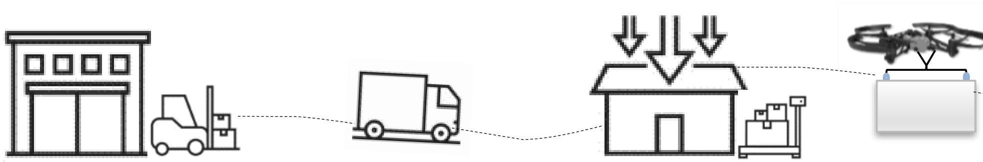
Some common Control tasks

- Connect to recorded and live CAN data
- Design reinforcement learning networks
- Model vehicle dynamics
- Automate regression testing
- Prototype on real-time hardware
- Design path tracking controllers
- Design model-predictive controllers
- Generate production C/C++ code
- Generate AUTOSAR code
- Certify for ISO26262

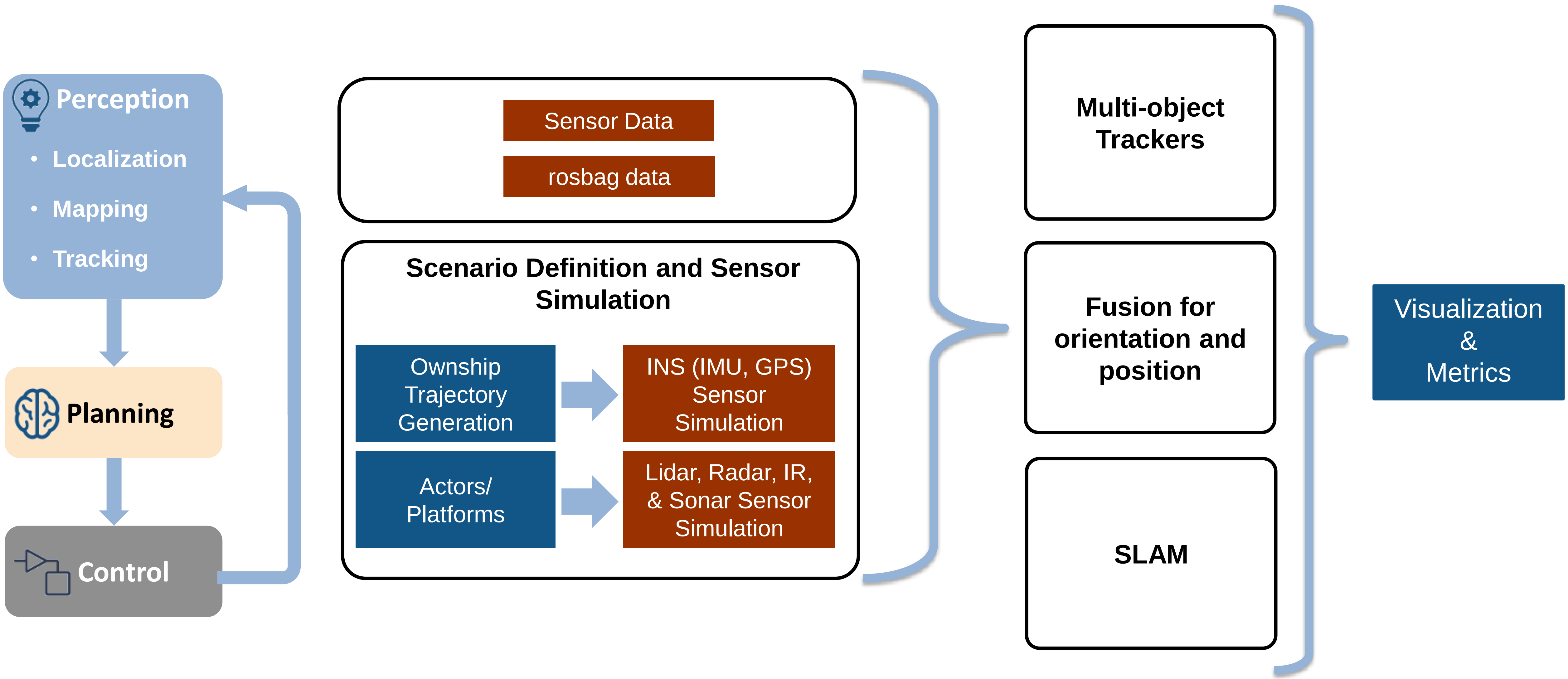
In this talk, you will learn

- Reference workflow for autonomous navigation systems development
- MATLAB and Simulink capabilities to design, simulate, test, deploy algorithms for sensor fusion and navigation algorithms
  - Perception algorithm design
  - Fusion sensor data to maintain situational awareness
  - Mapping and Localization
  - Path planning and path following control

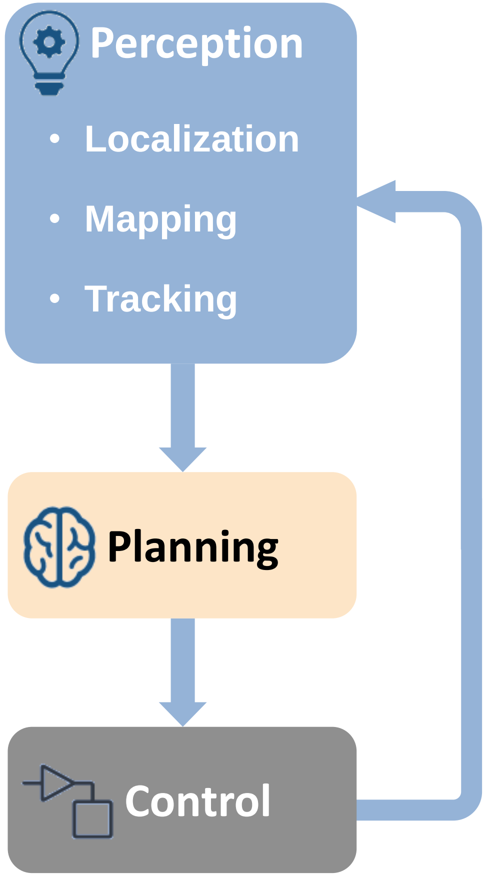




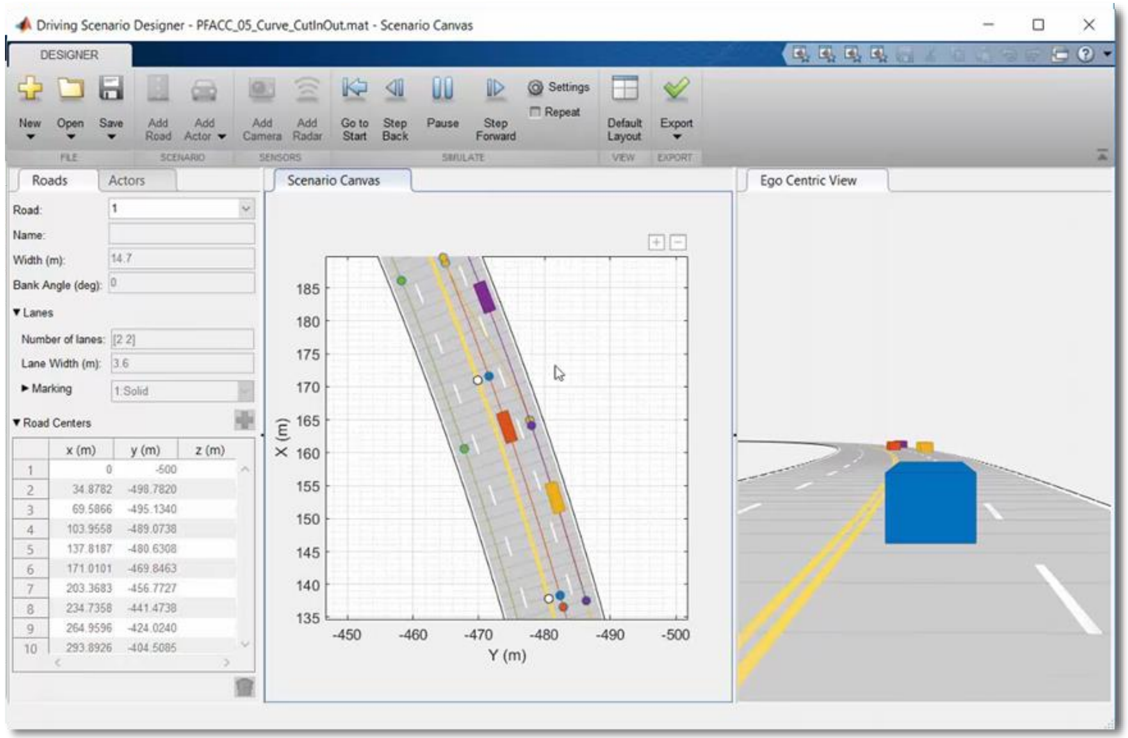
Many options to bring sensor data to perception algorithms



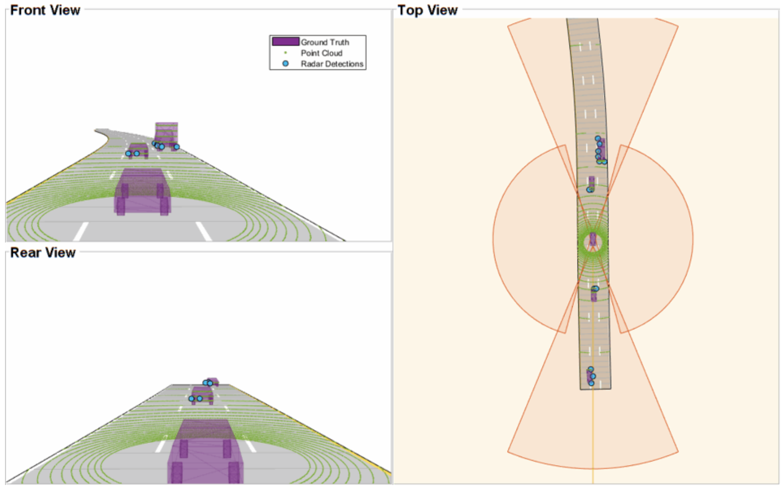
Live data can be augmented for a more robust testbench



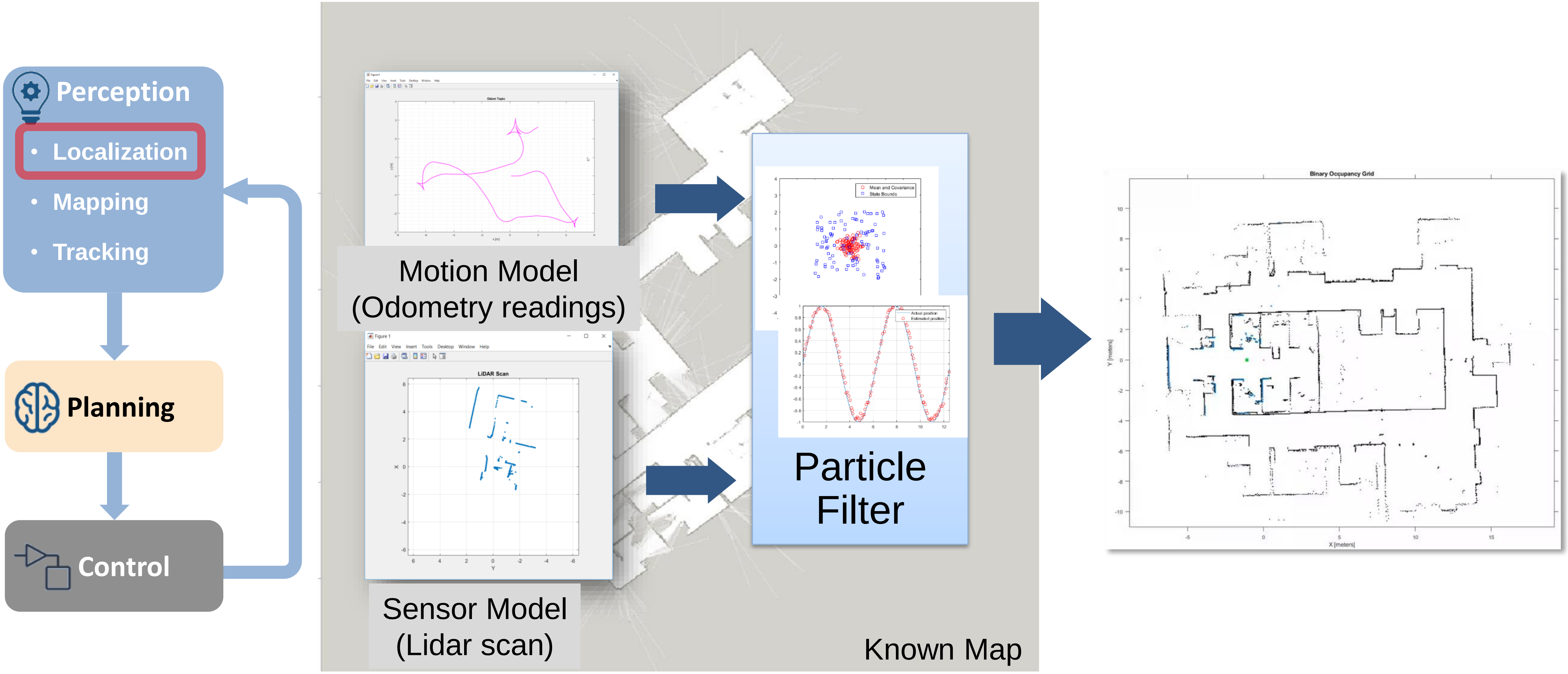
Define scenarios



Simulate sensors

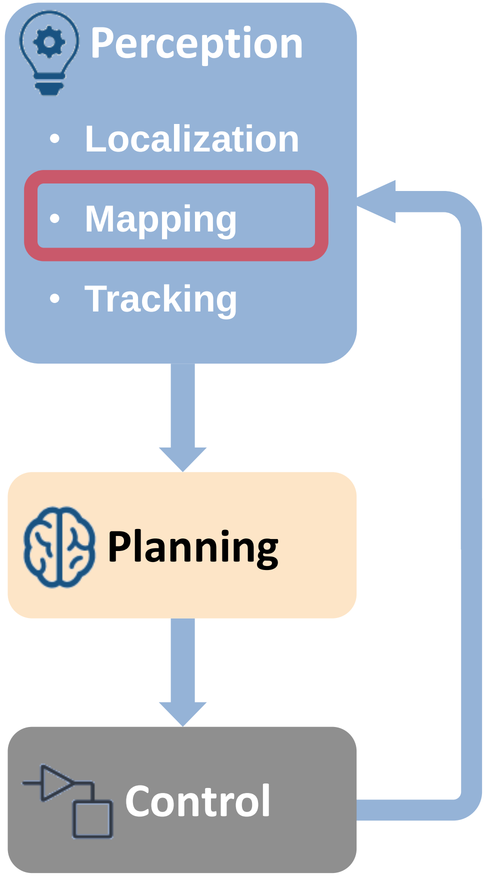


Estimate the pose using Monte Carlo Localization



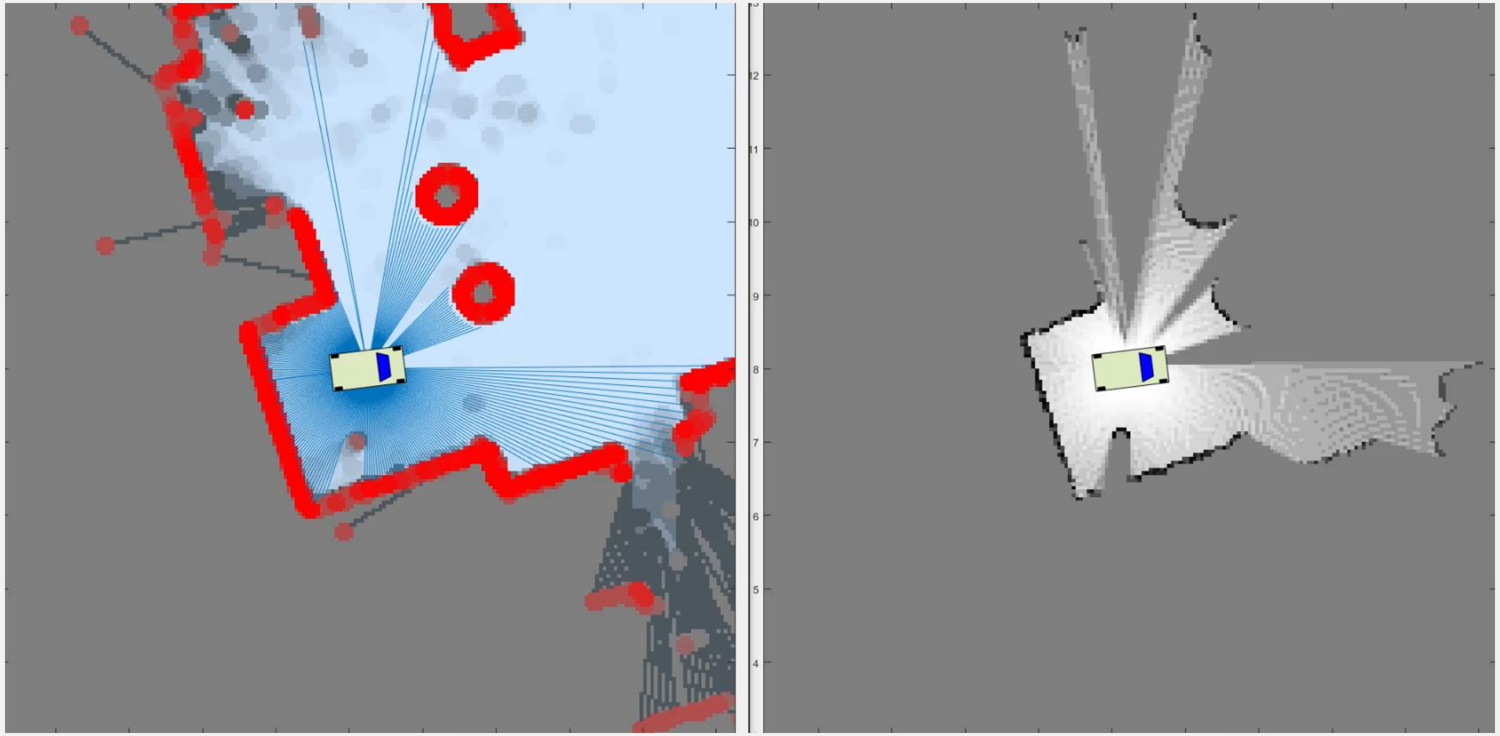
What is the world around me?

Egocentric occupancy maps



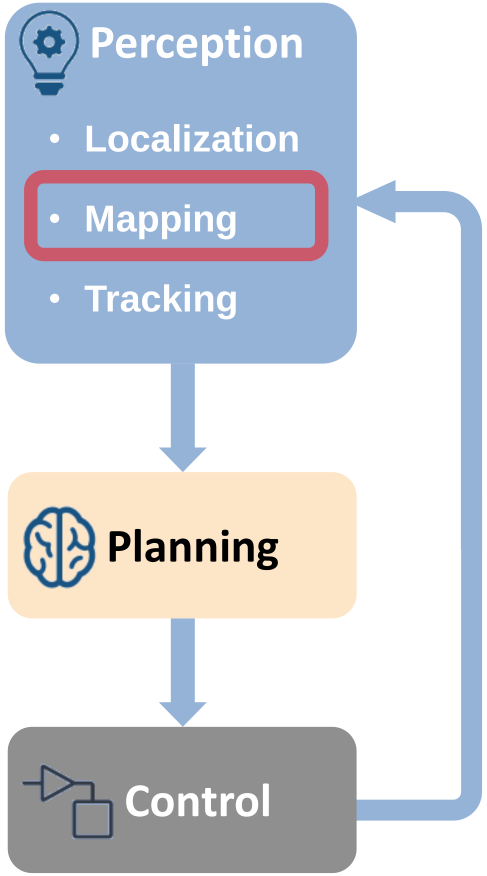
Dynamic Environment

– Support dynamic environment changes
– Synchronization between global and local maps

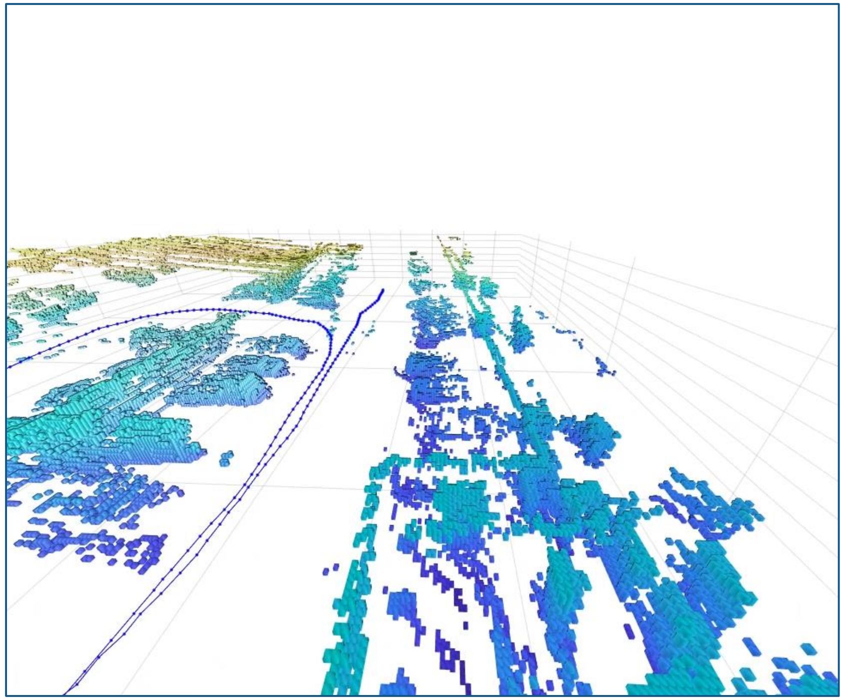


What is the world around me?

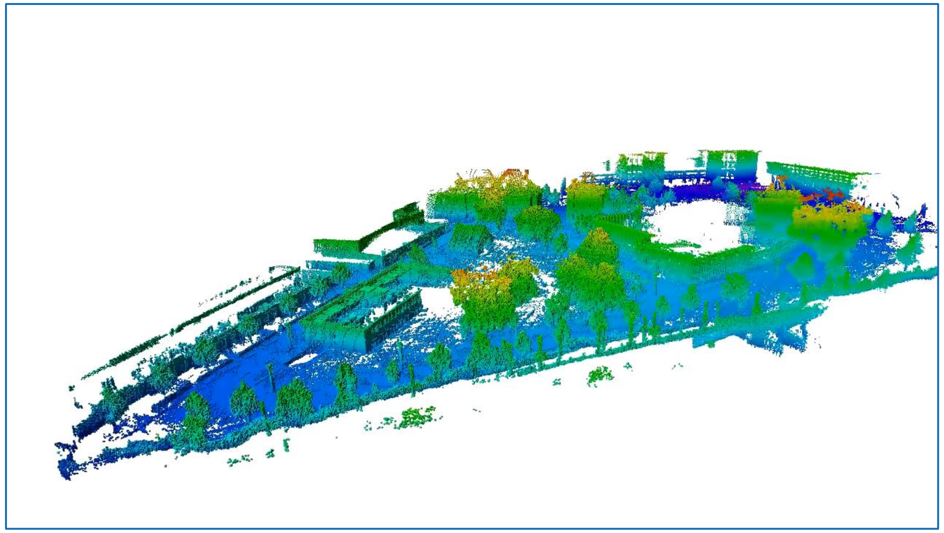
3D Occupancy Map



3D map for Autonomous Driving

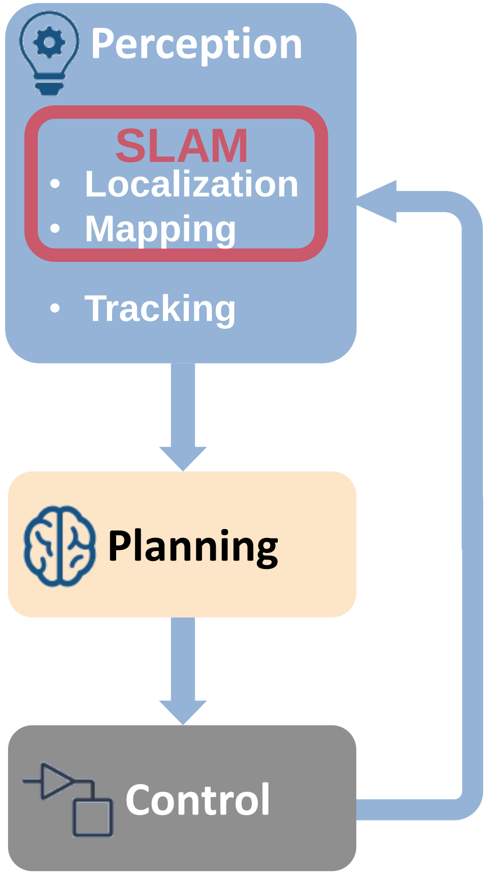


3D map for UAV motion planning

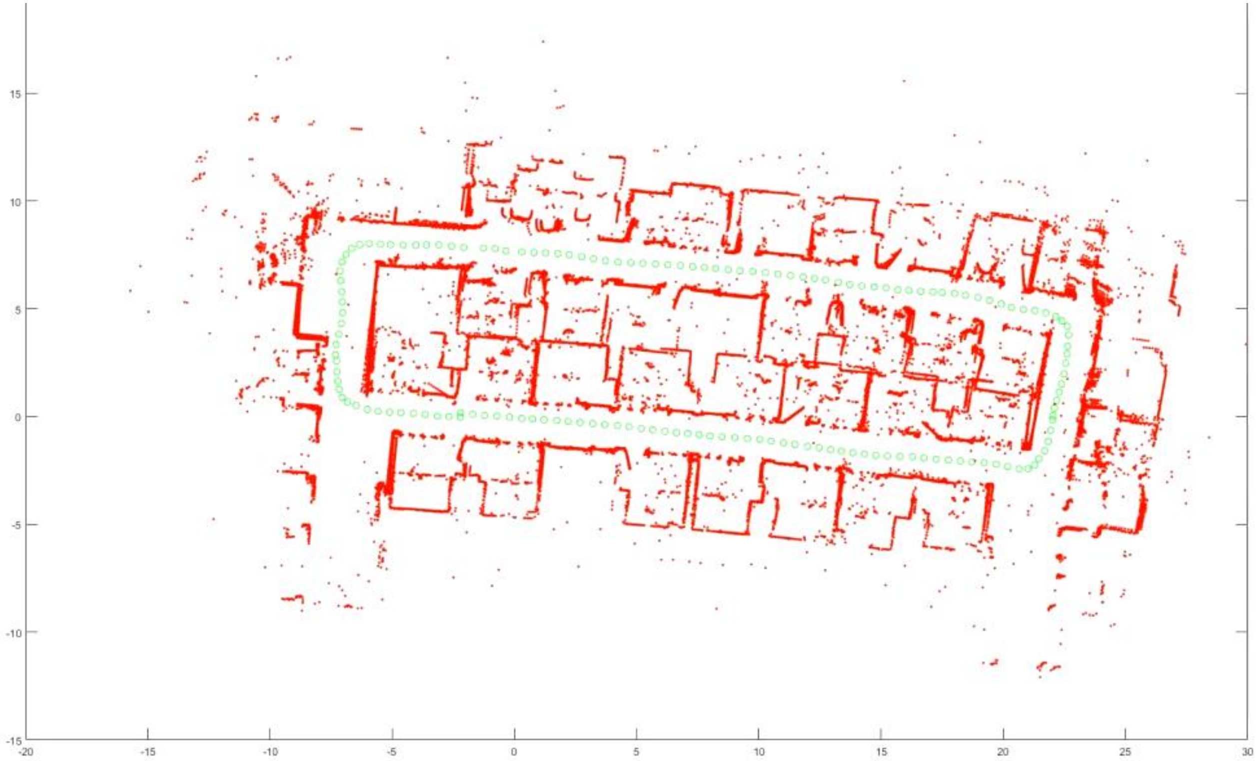


Where am I in the unknown environment?

Simultaneous Localization and Mapping (SLAM)



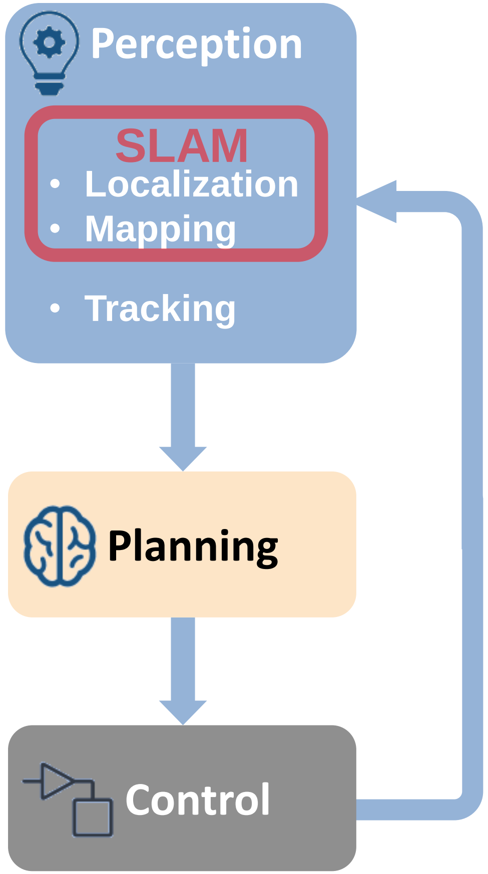
2D Lidar SLAM

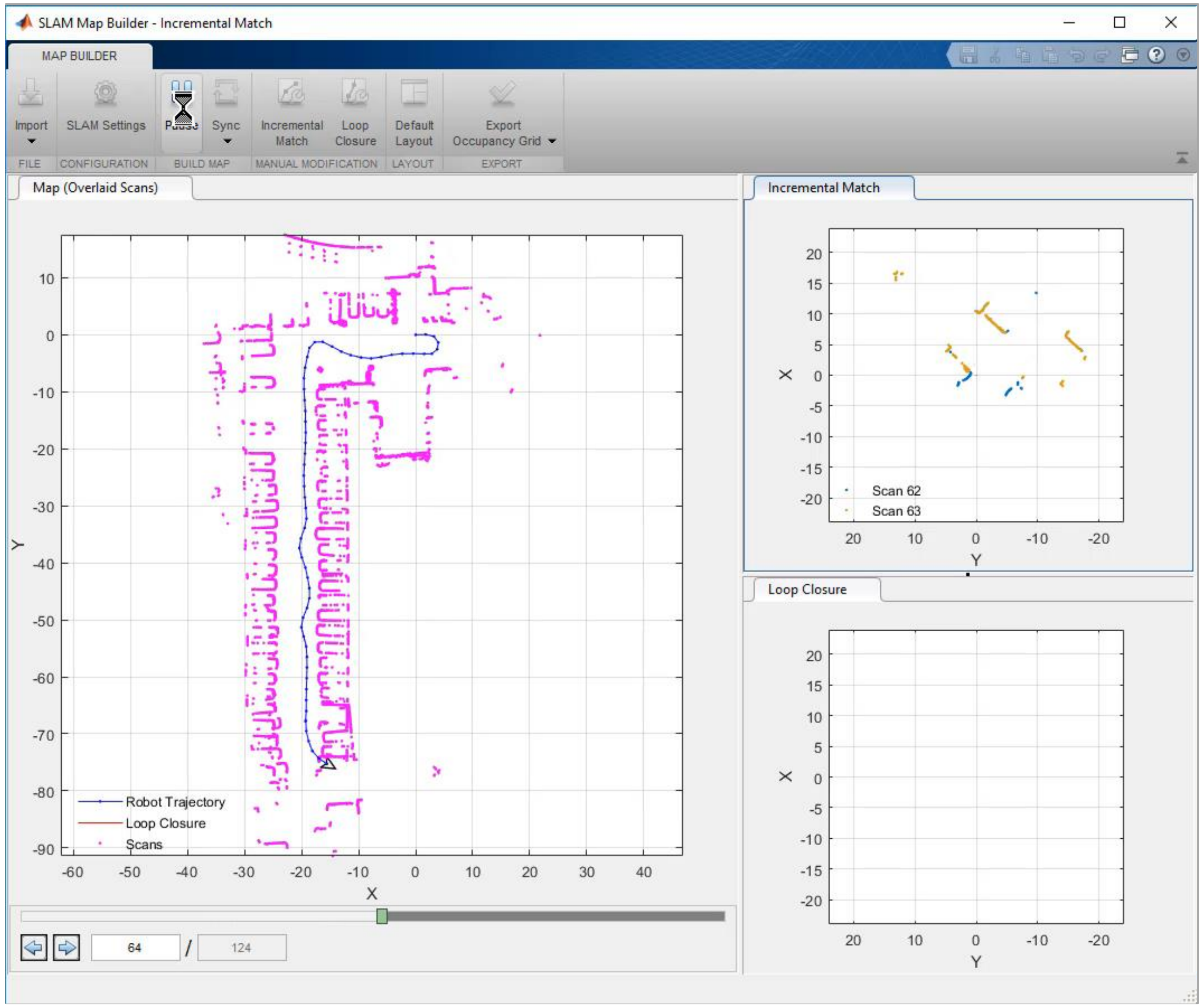


Build a map of an unknown environment while simultaneously keeping track of robot's pose.

Simultaneous Localization and Mapping

SLAM Map Builder App (2D only)





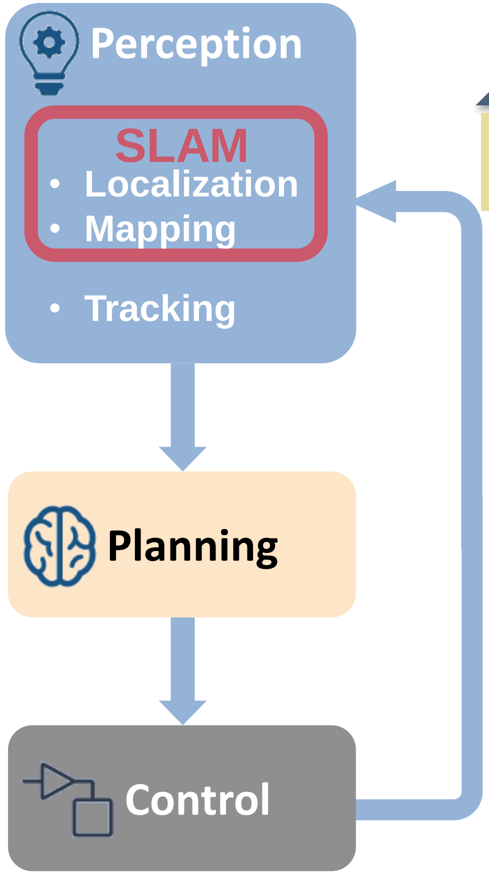
App enables more interactive and user-friendly workflow

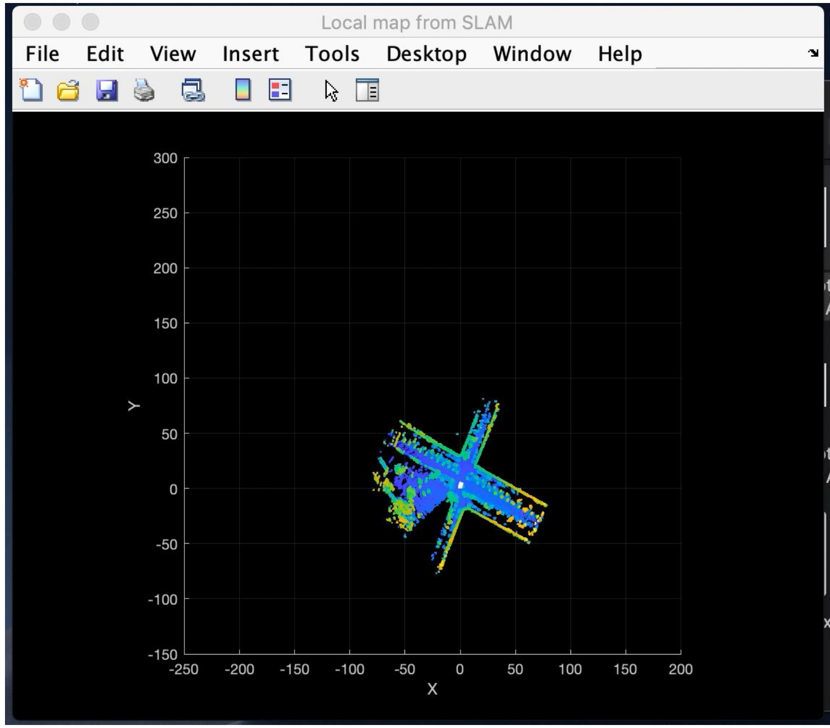
Simultaneous Localization and Mapping

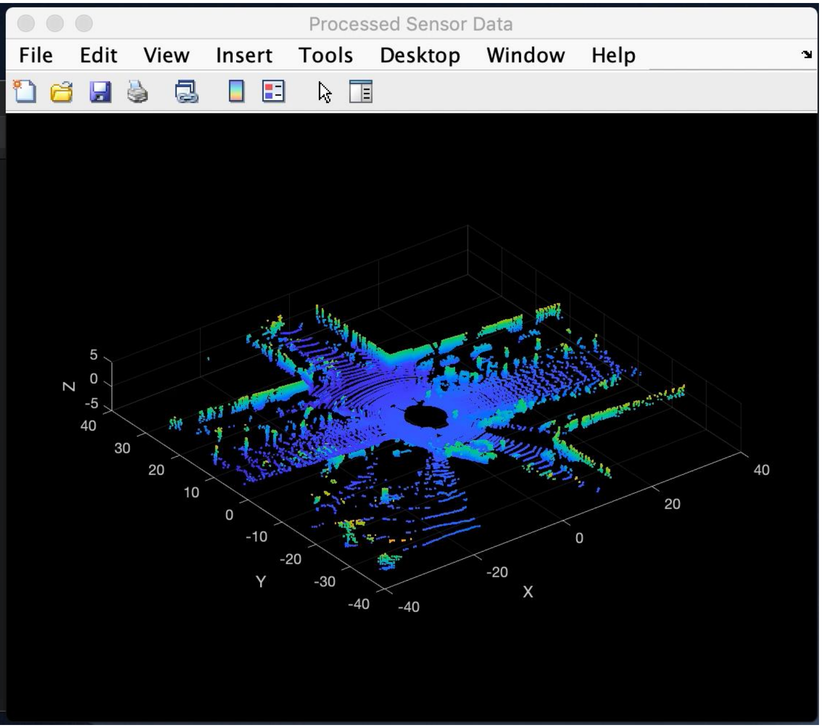
3D Lidar SLAM

Point Cloud Processing → Local Mapping → Loop Closure Detection → Pose Graph Optimization → Map representation

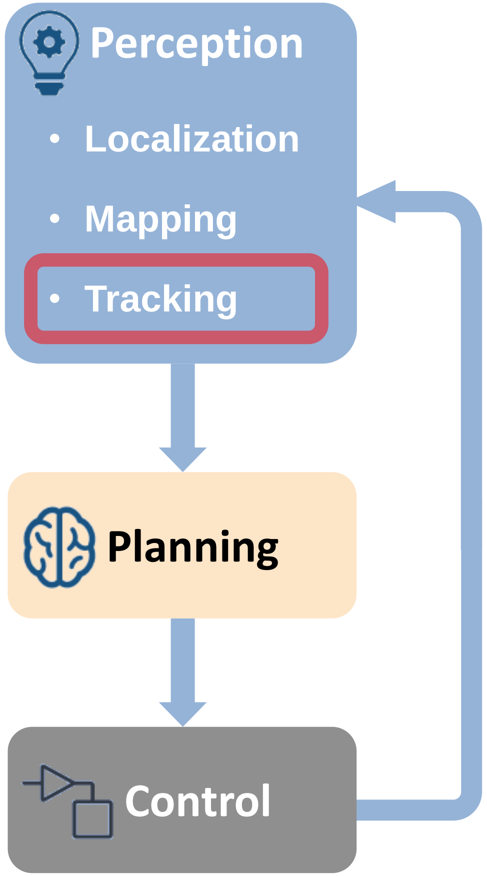
Computer Vision	Navigation



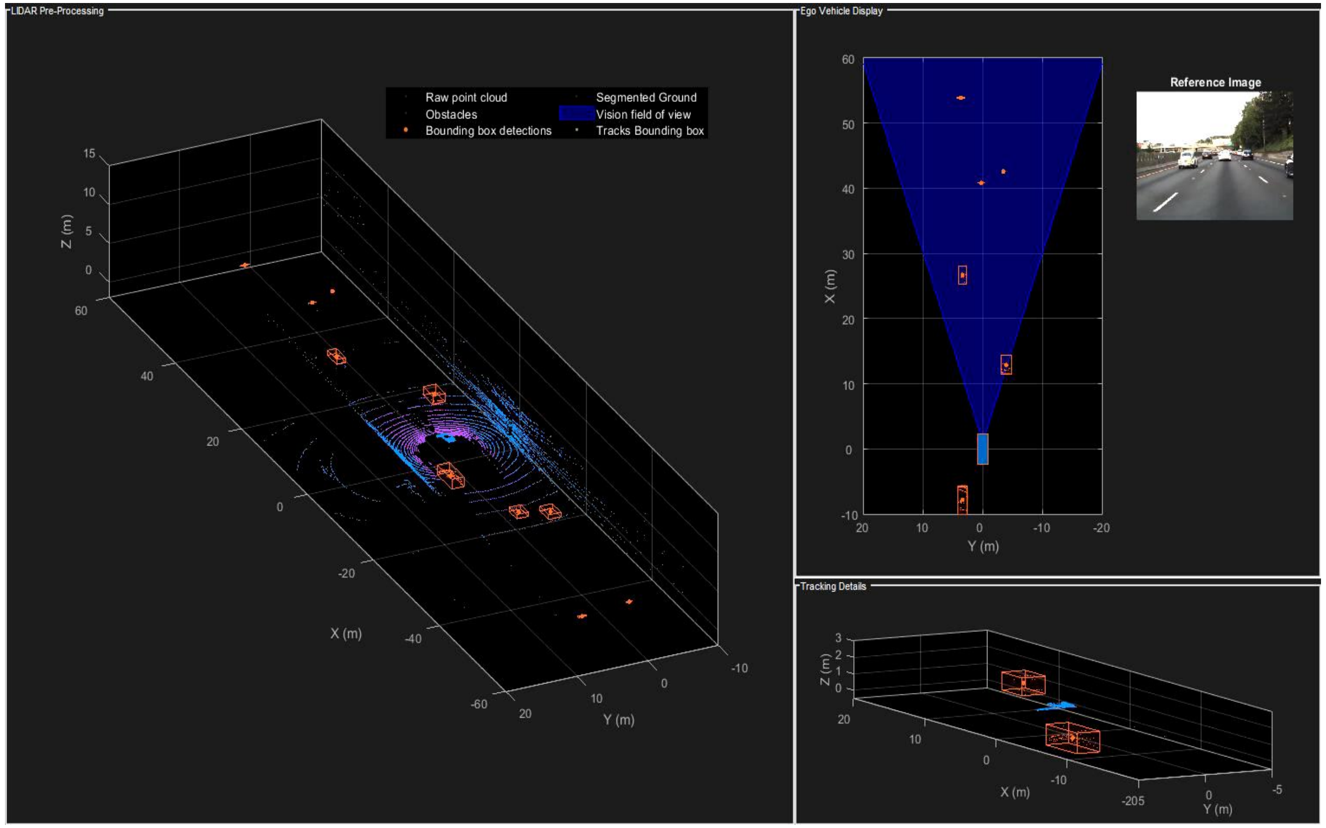




Autonomous systems can track objects from Lidar point clouds

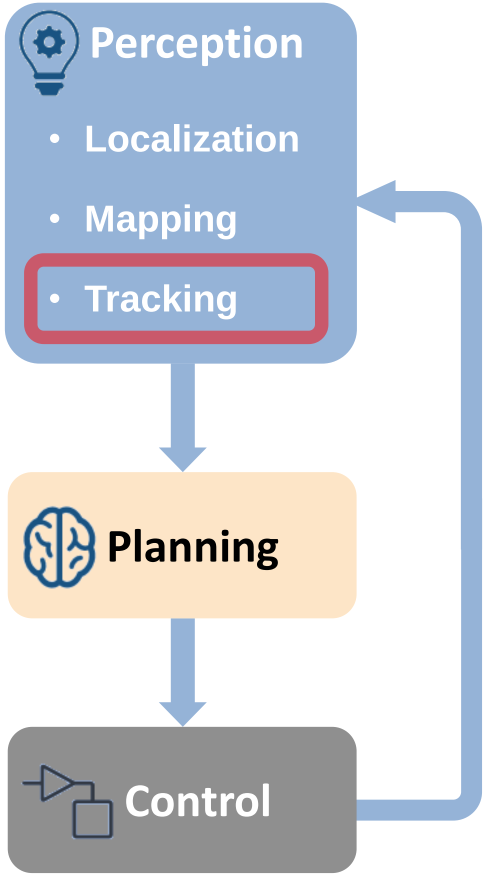


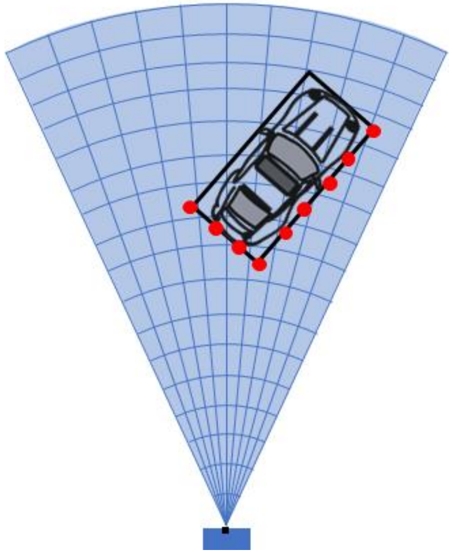
Track Objects Using Lidar: From Point Cloud to Track List

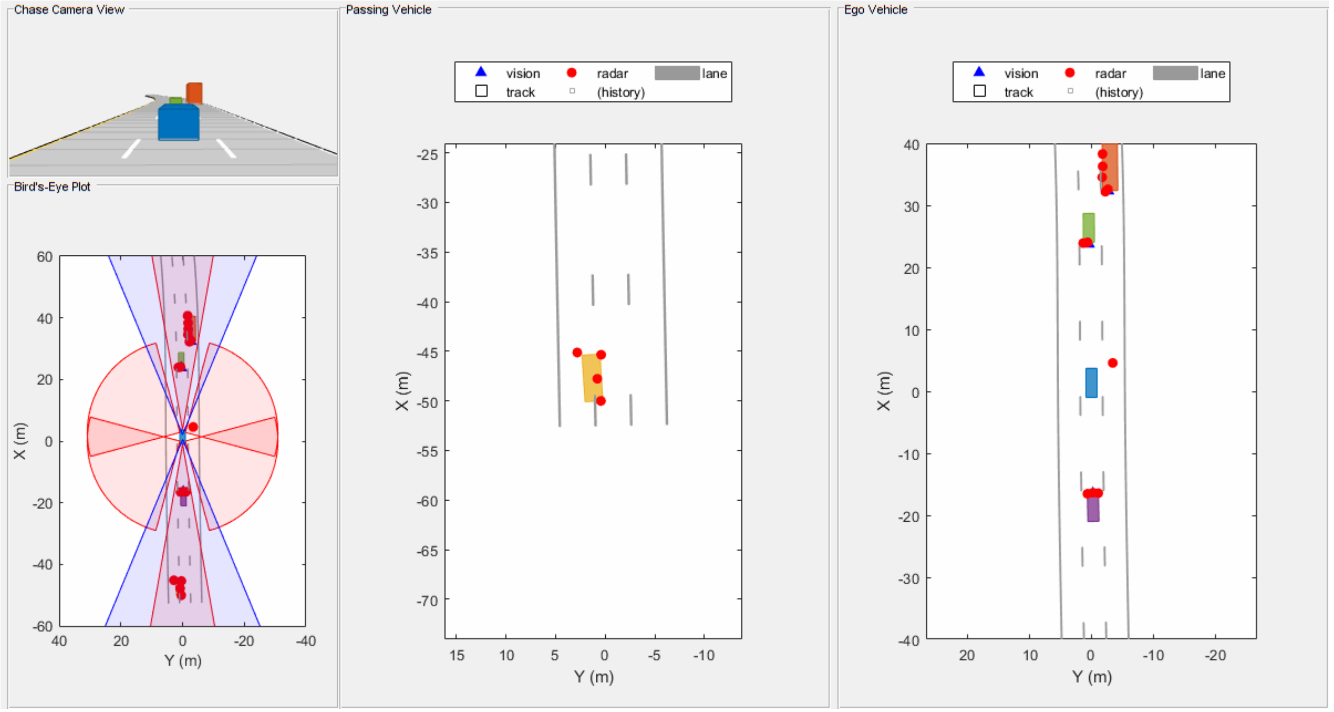


Track surrounding objects during automated lane change

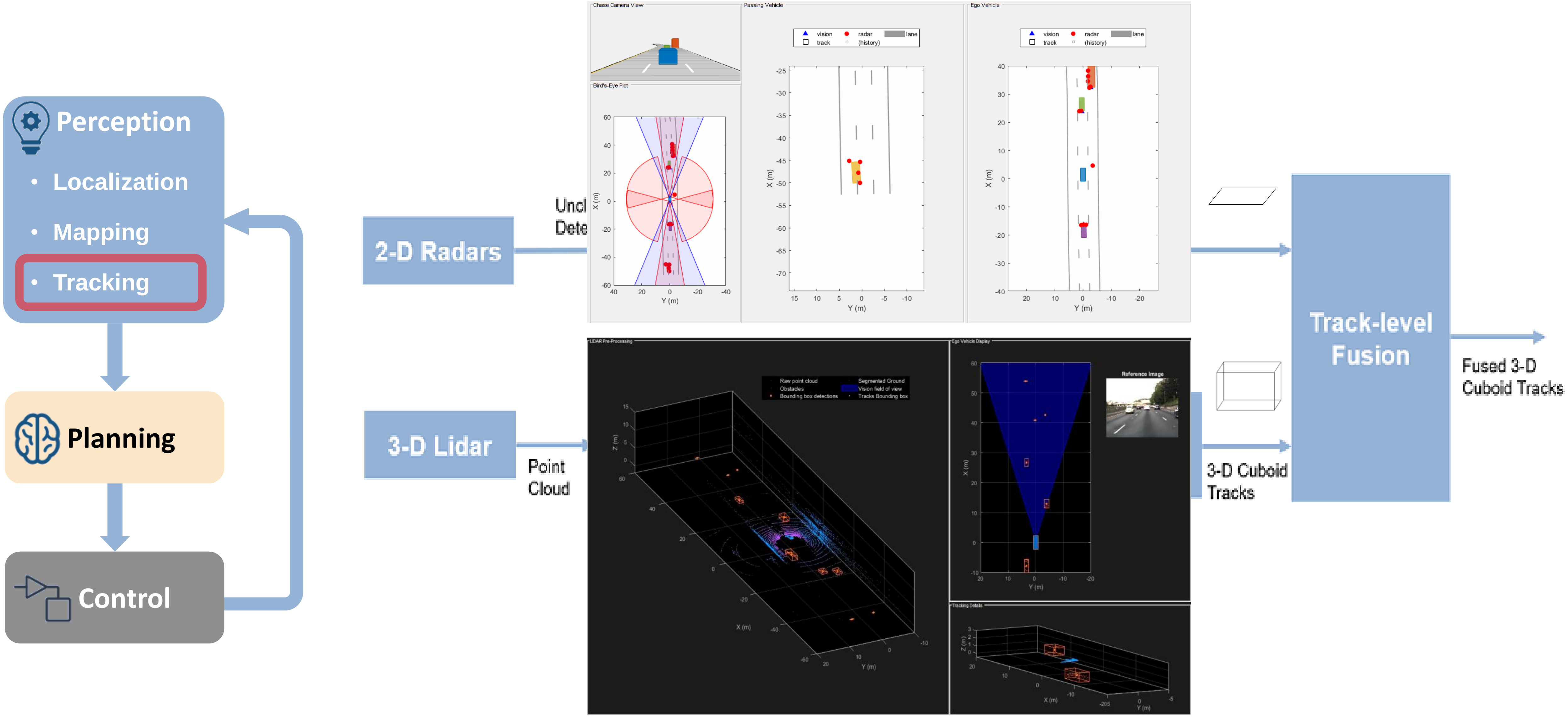
2D radar can be used to track position, size, and orientation



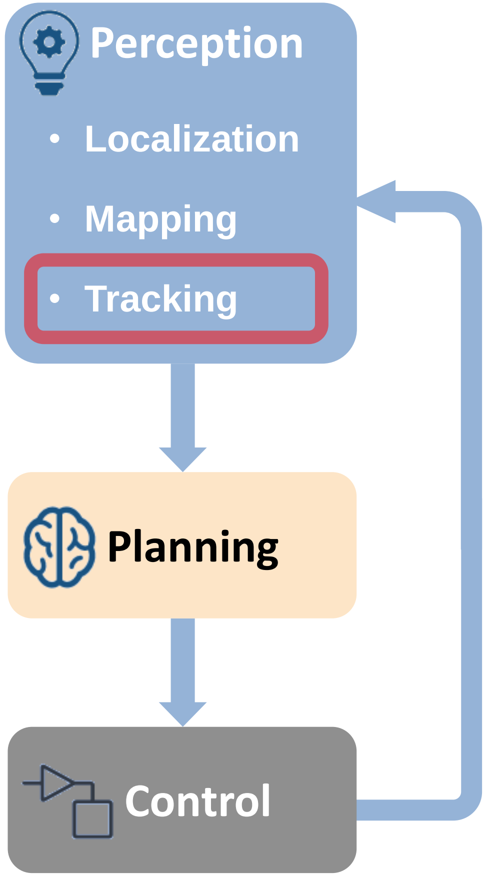


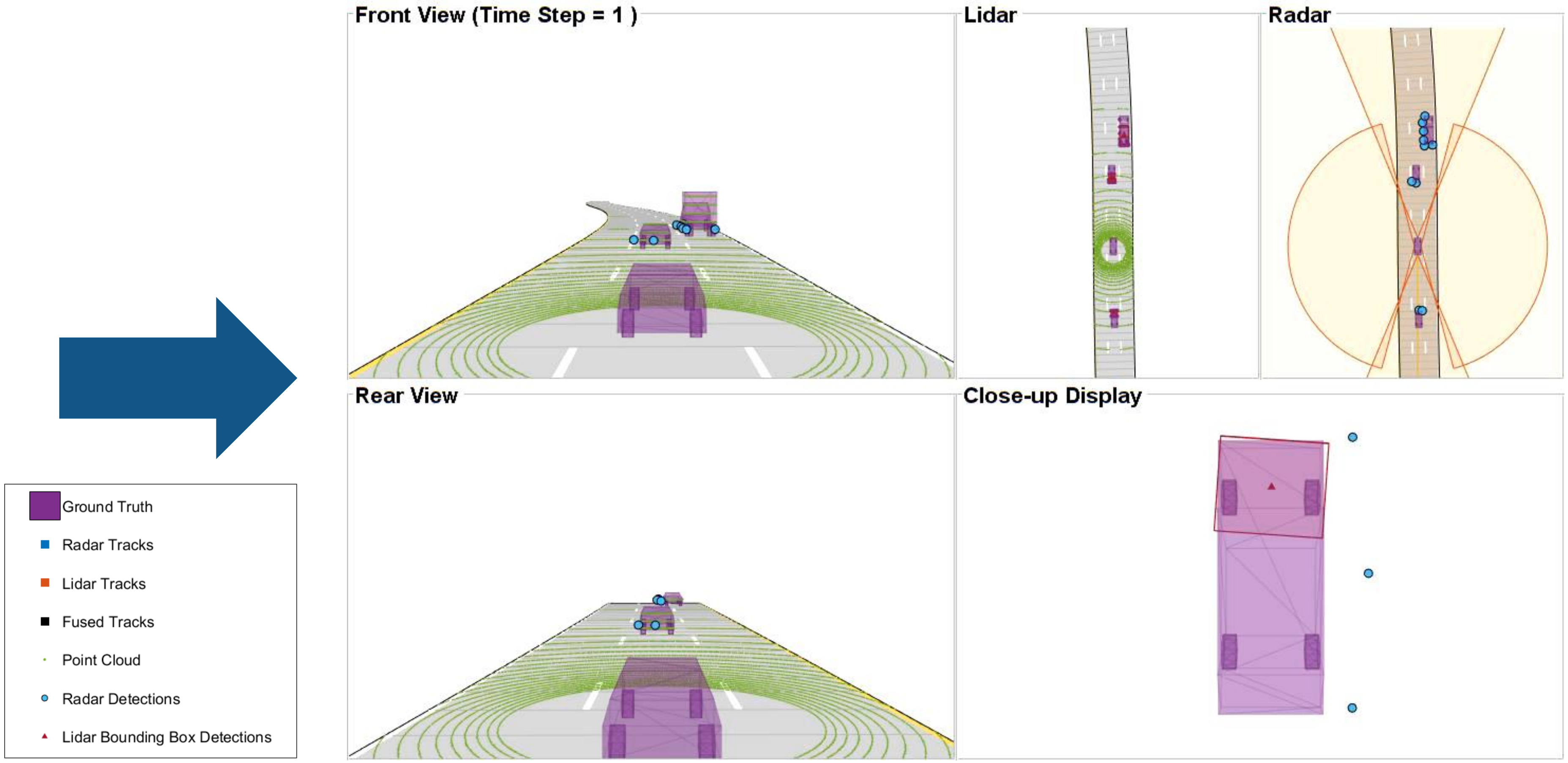


Fusing multiple sensor modalities provides a better result

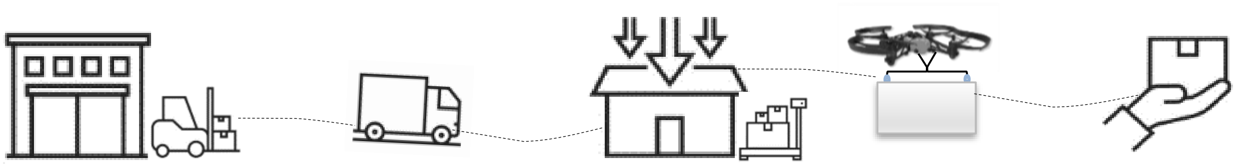


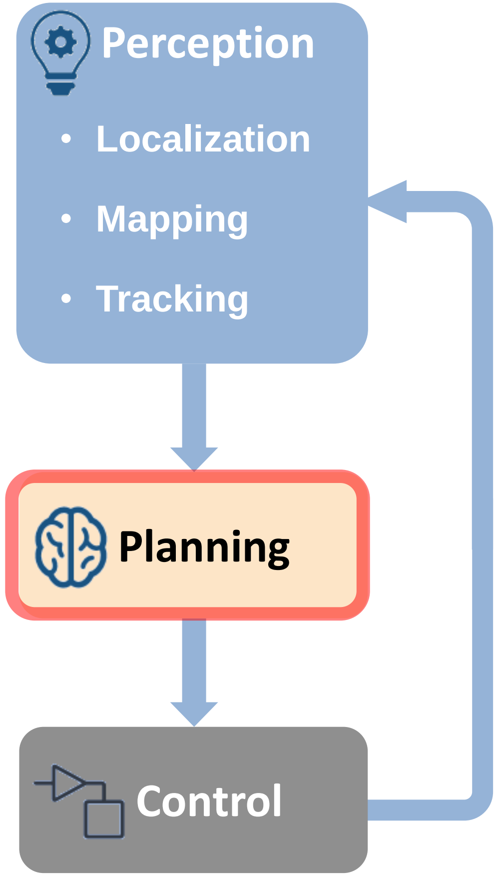
Radar and Lidar fusion can increase tracking performance



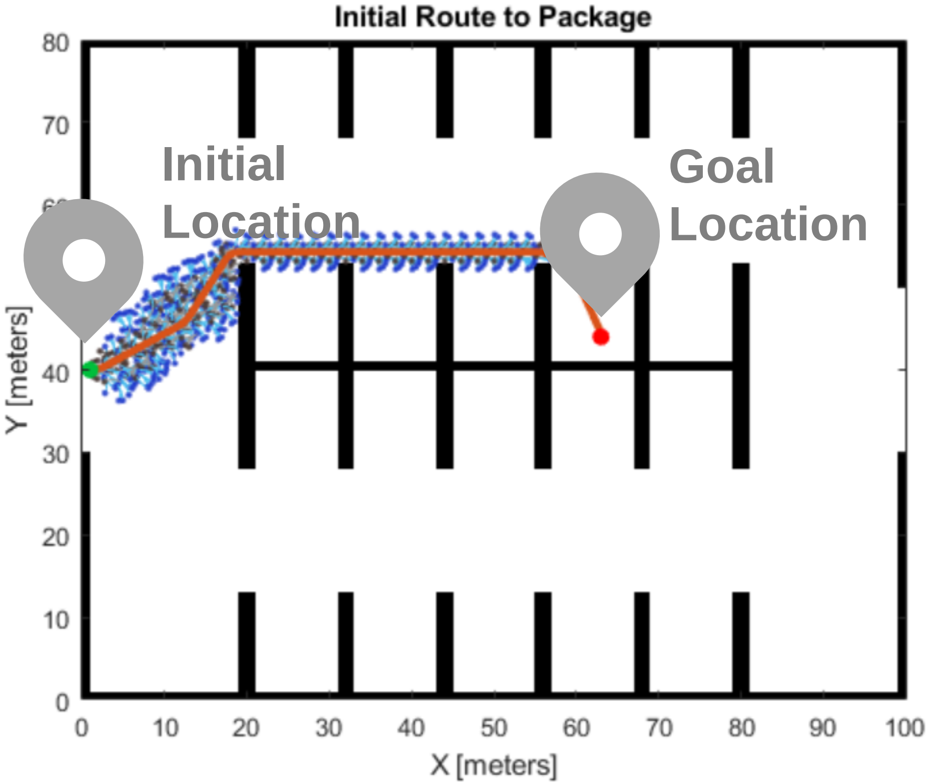


Find shortest path to the destination

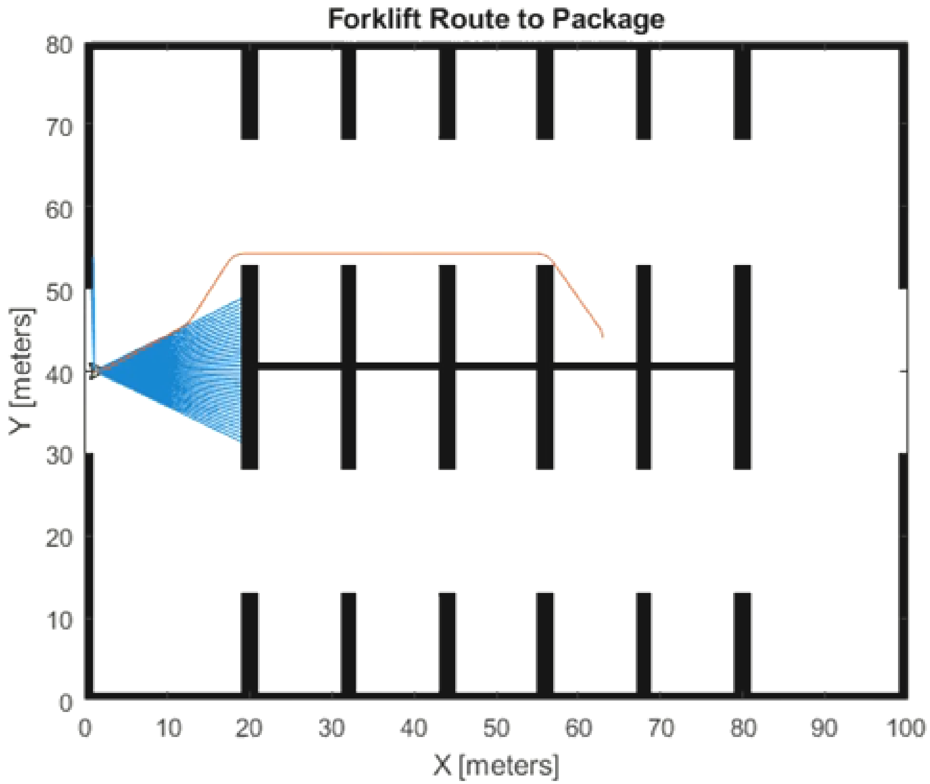




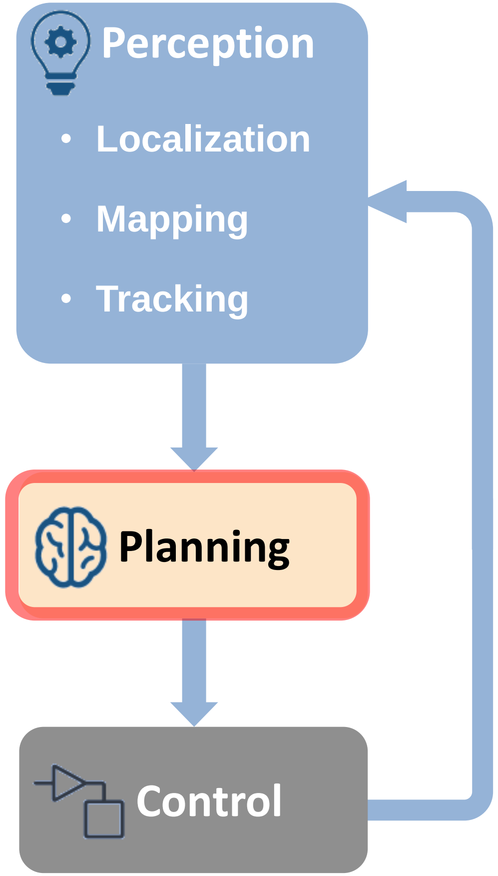
Global Planning



Local Re-planning



Find shortest path to the destination



Motion Planning

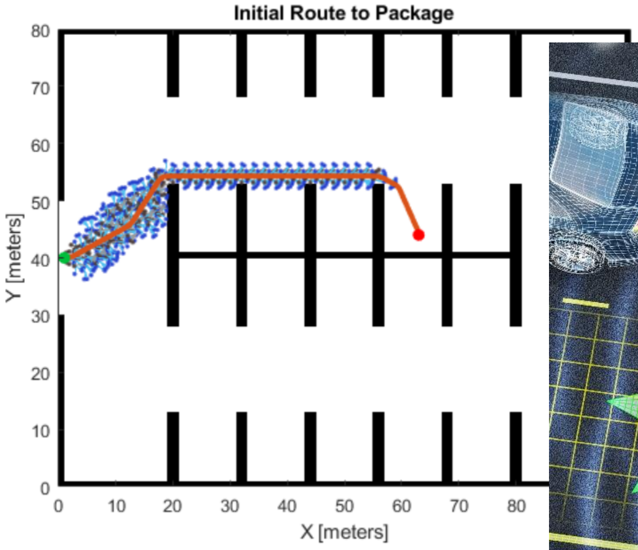
- Path Planning & trajectory generation

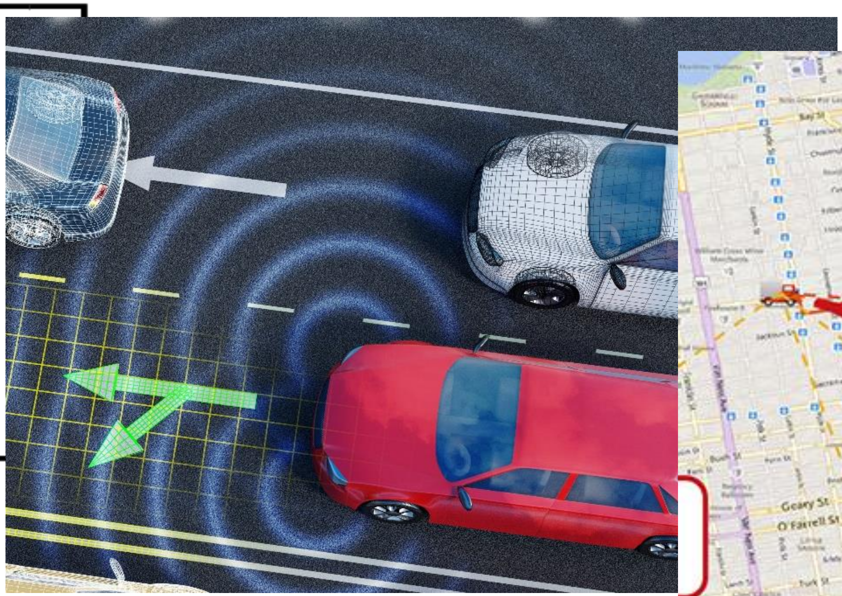
Behavior Planning

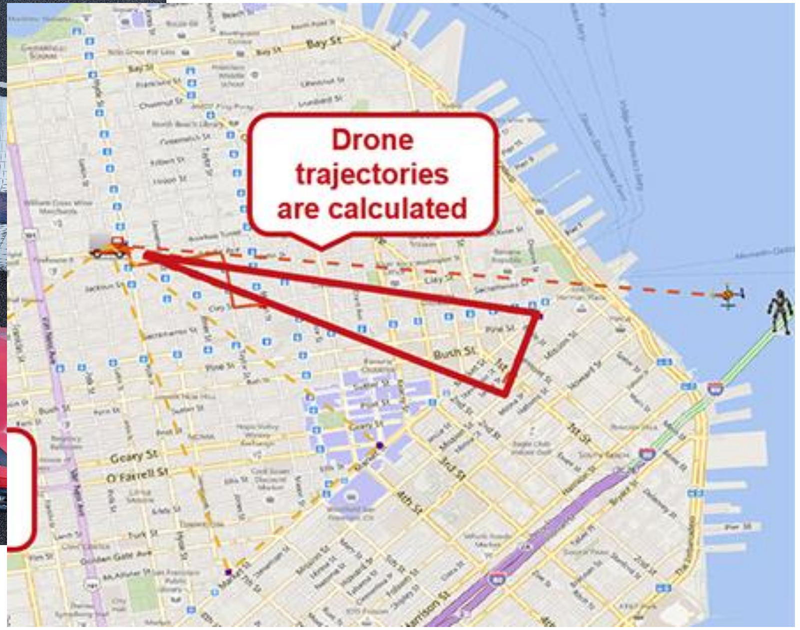
- High-level decision making

Mission Planning

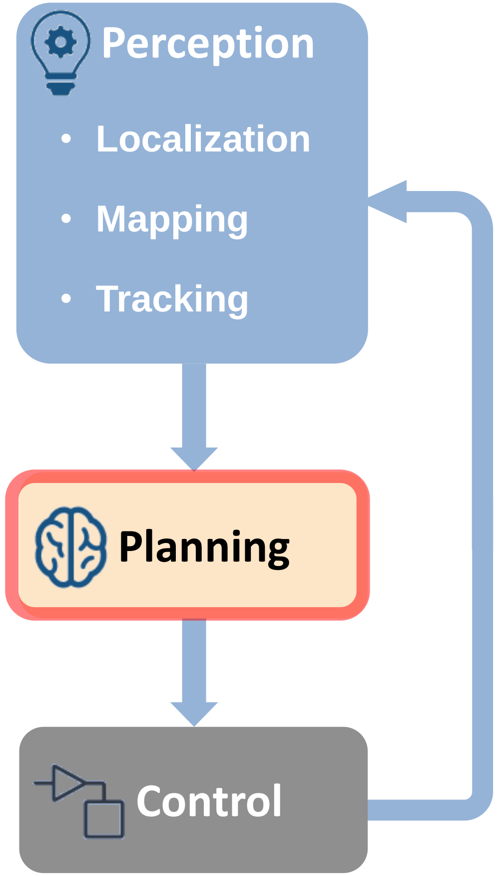
- High-level route planning



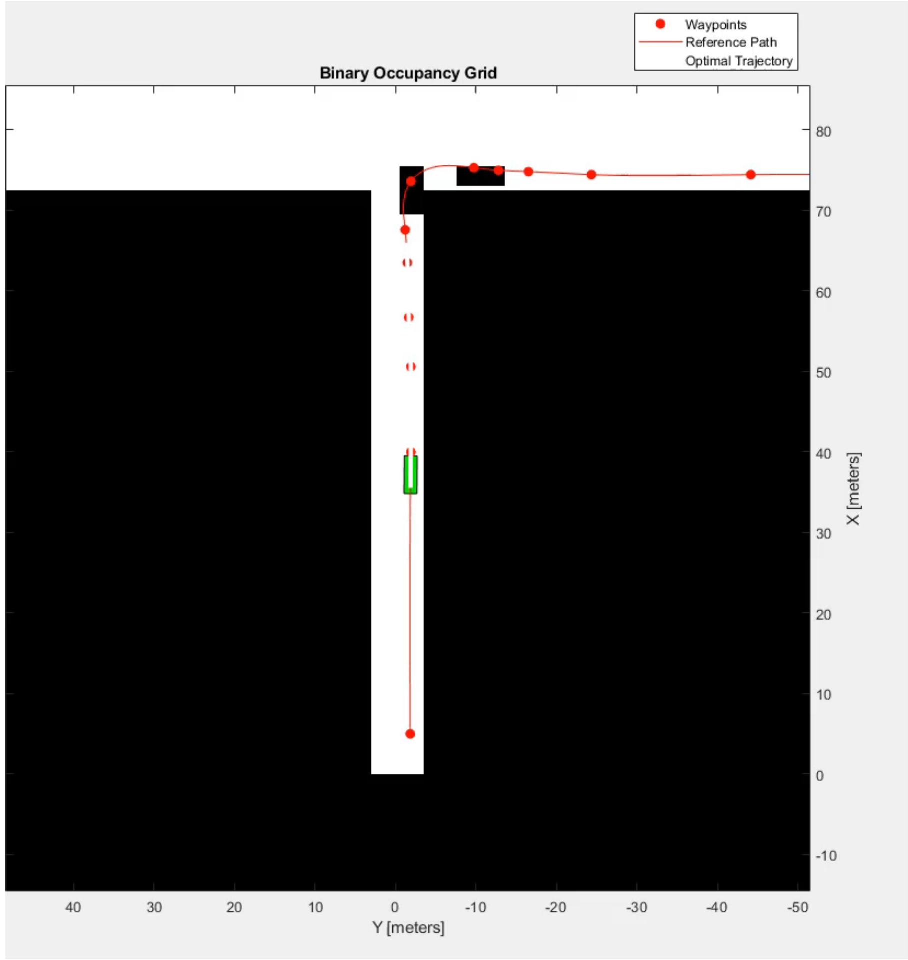


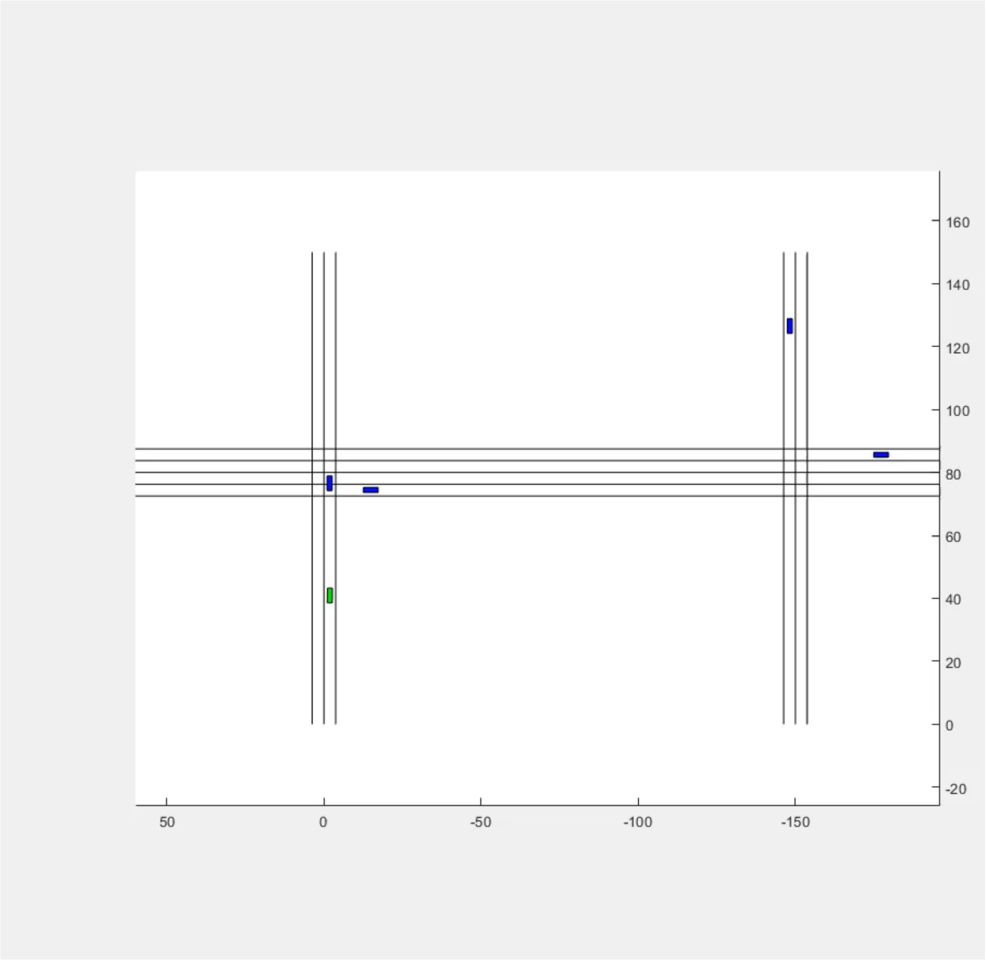


Urban driving needs planning on two levels, global and local

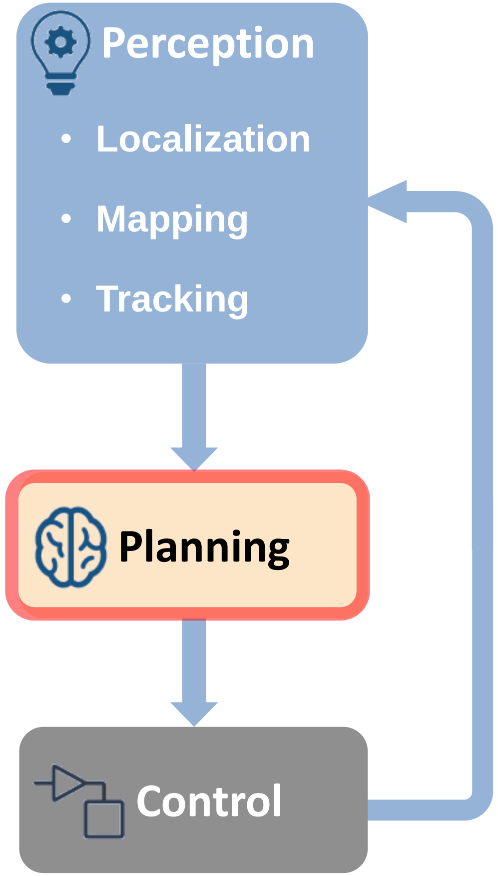


Generate optimal trajectories for local re-planning and merge back with the global plan

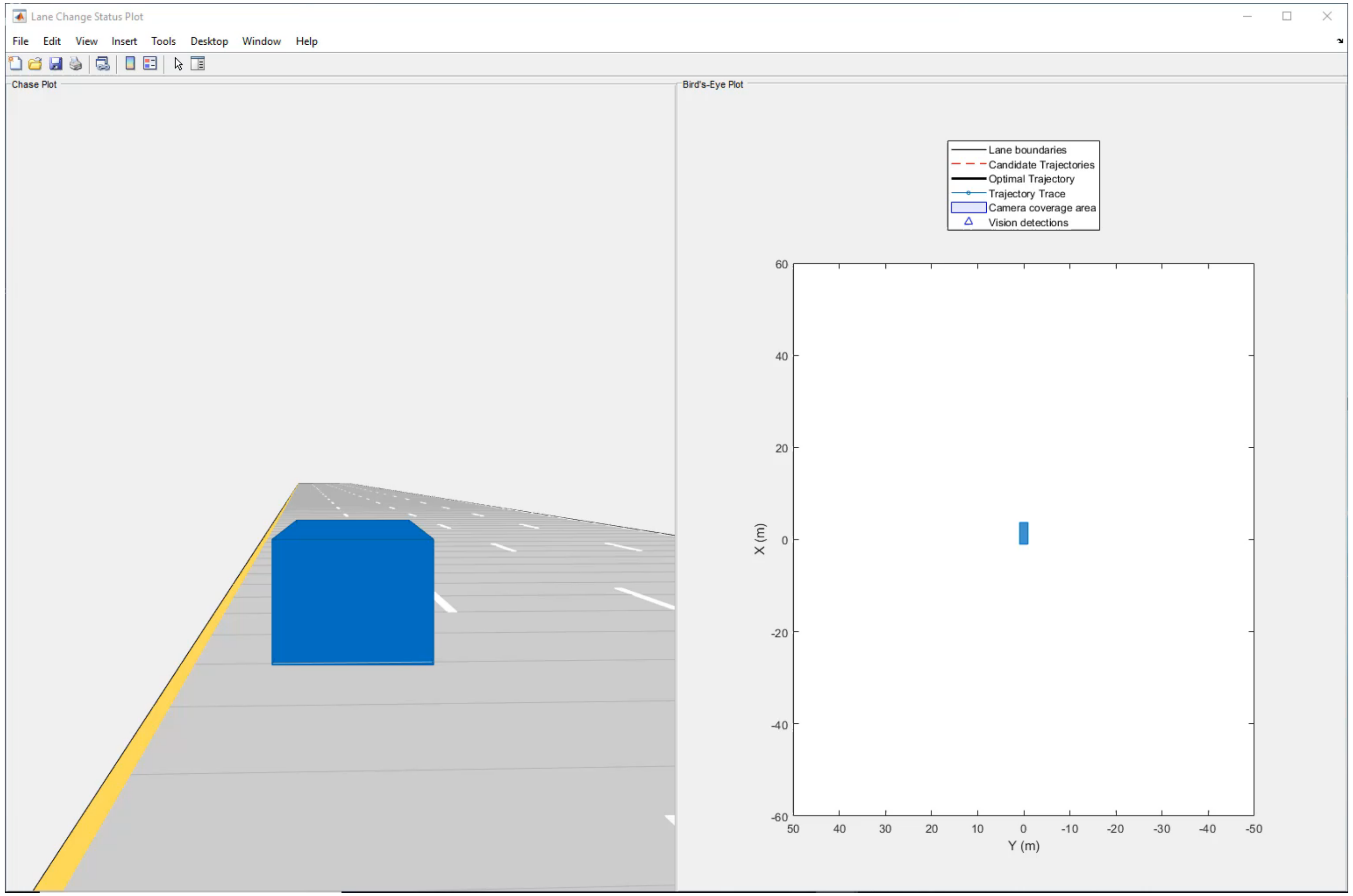




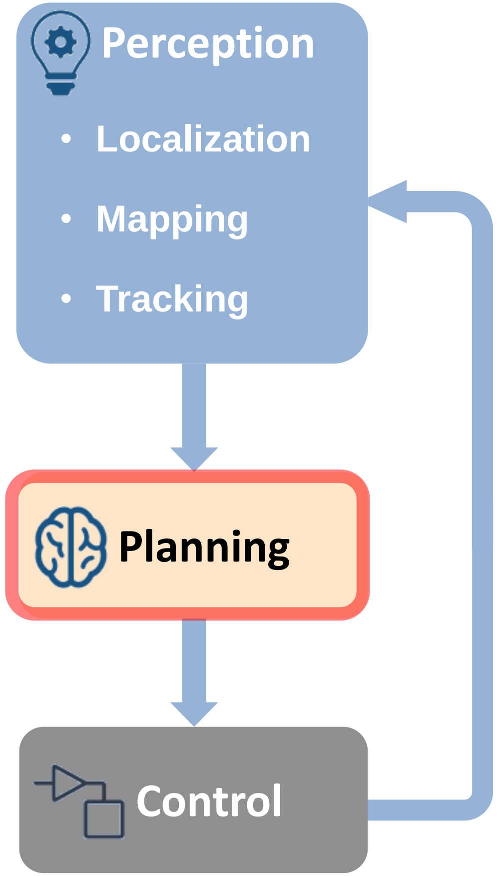
Simulate shortest path to change lanes on a highway

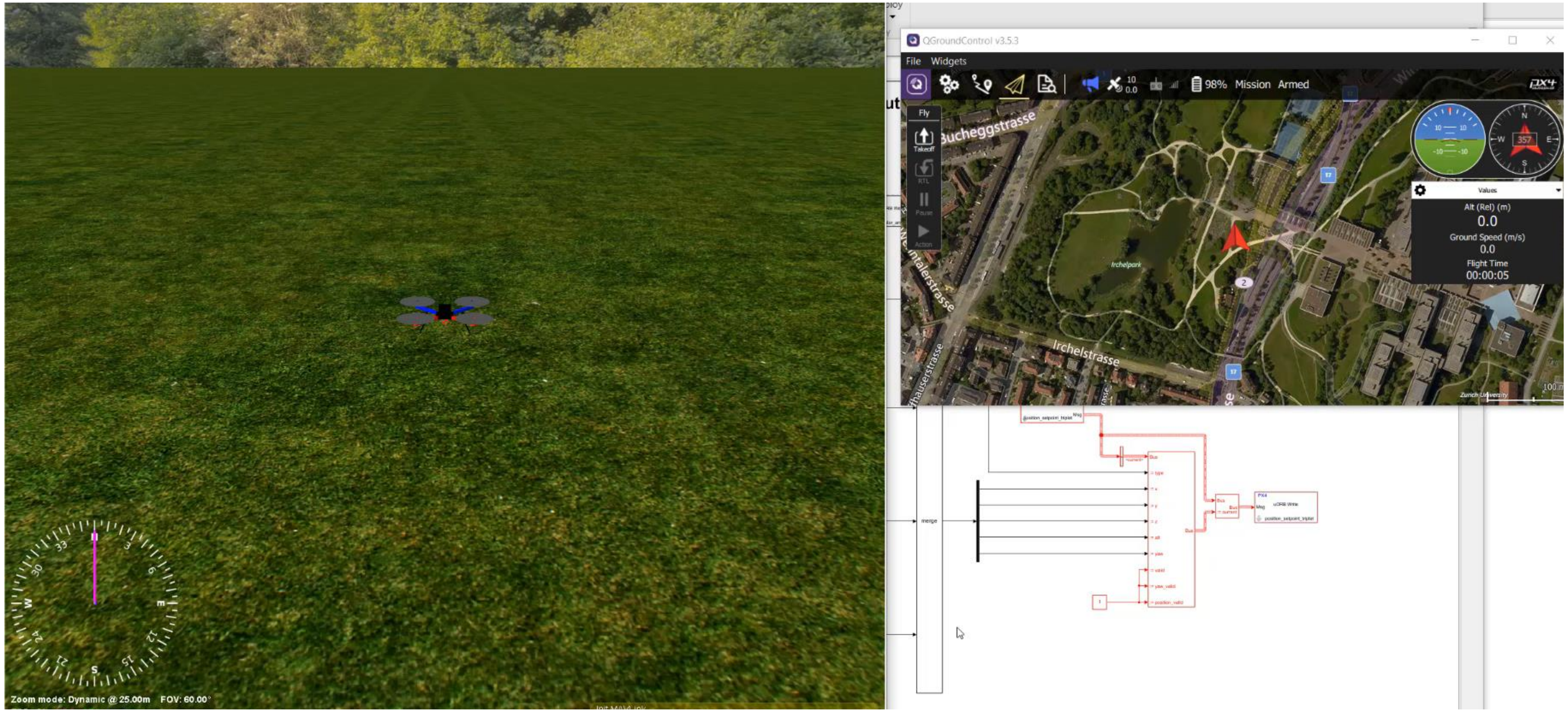


Simulate trajectory generation and the lane change maneuver

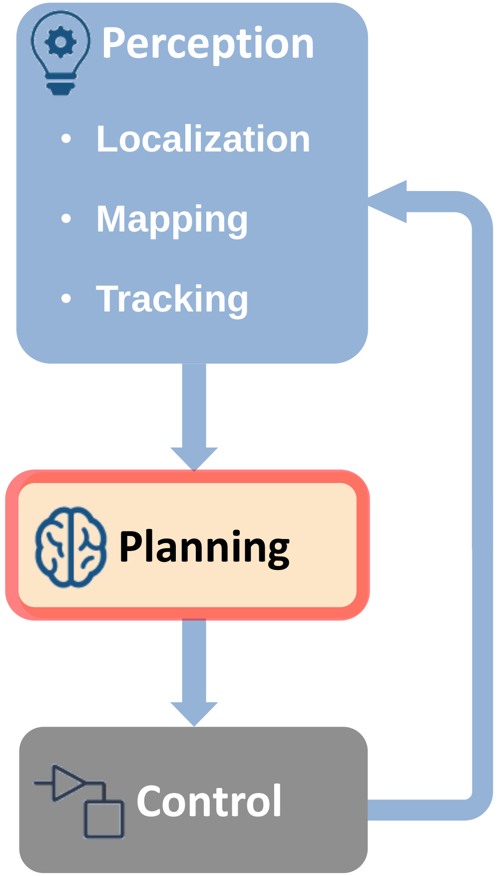


Mission planning for UAV leads to last mile delivery

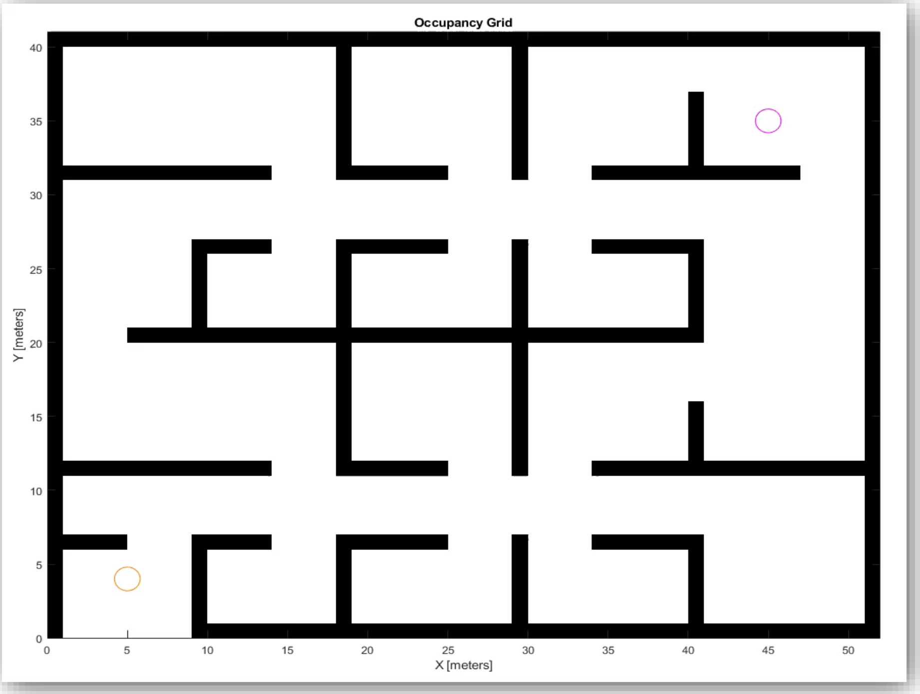




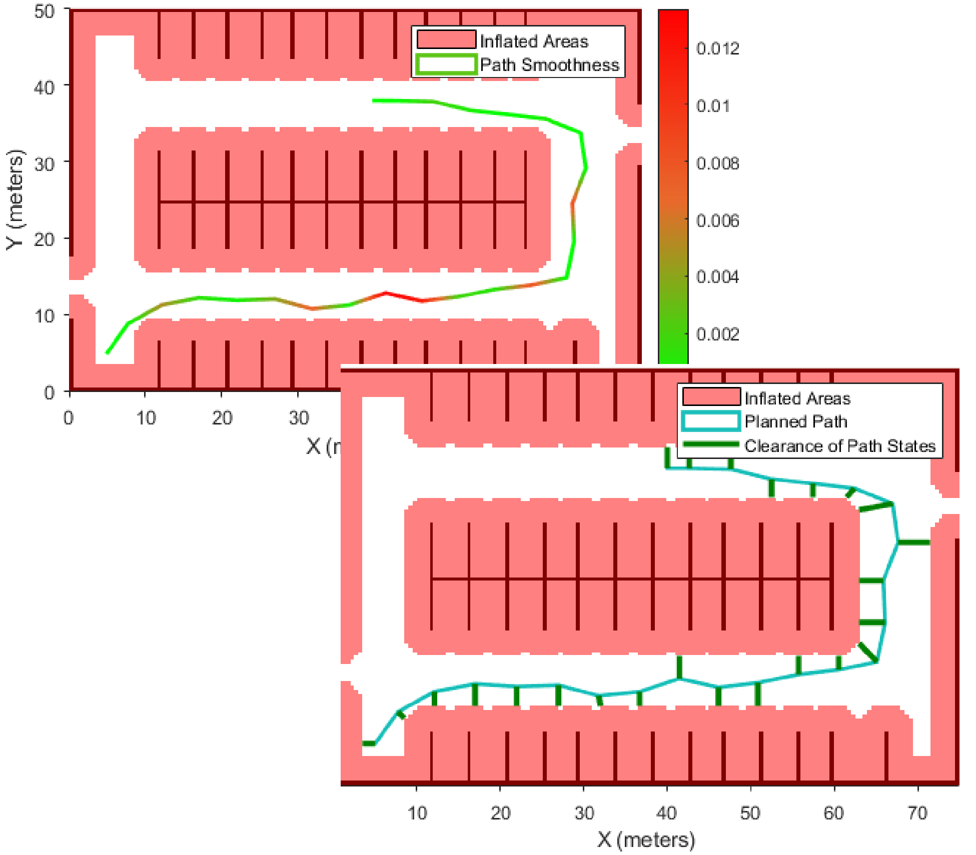
Choose a path planner based on your application



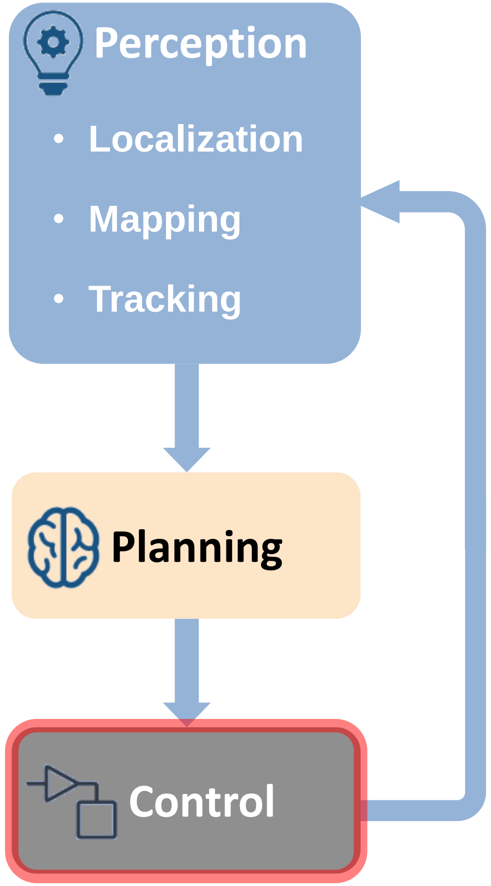
Sampling-based planners such as RRT*



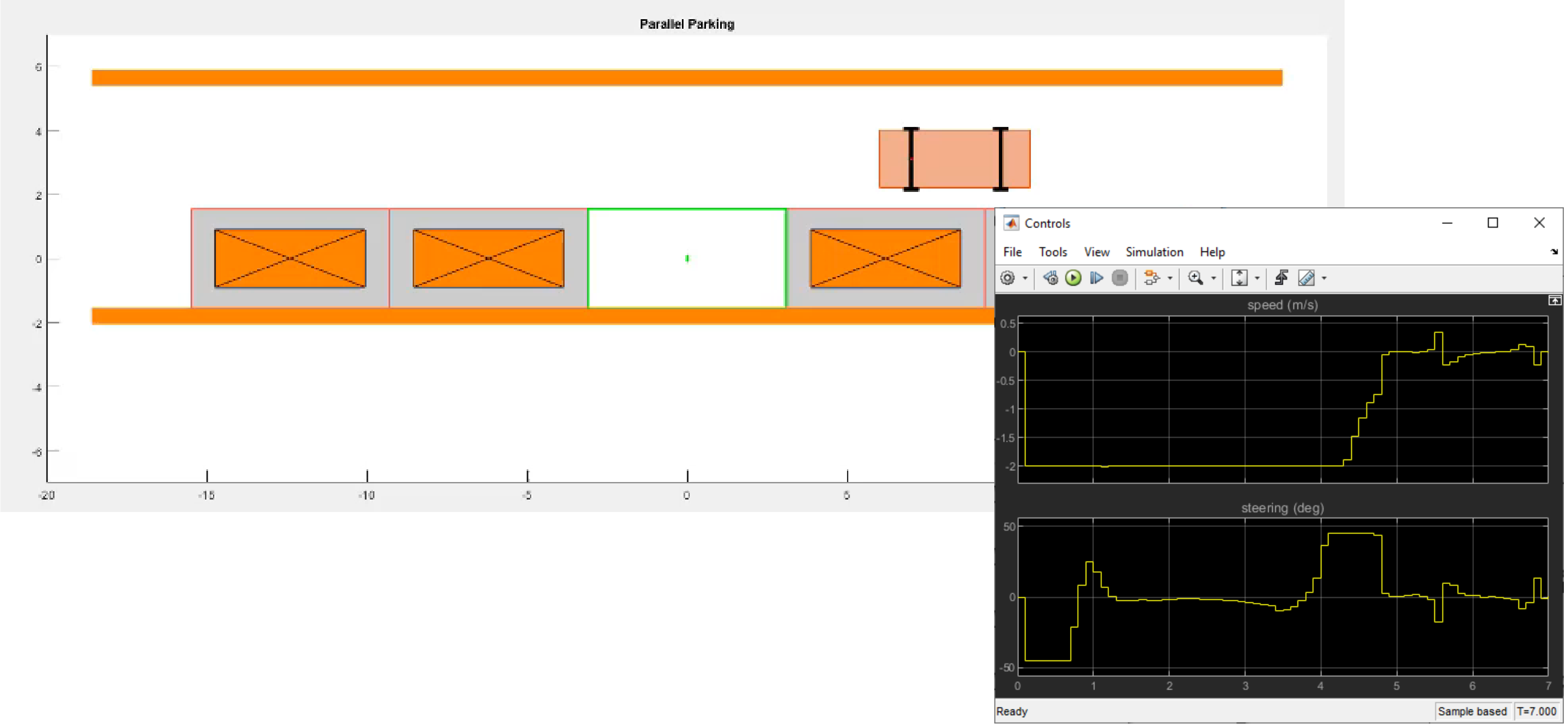
Use path metrics to compare different paths



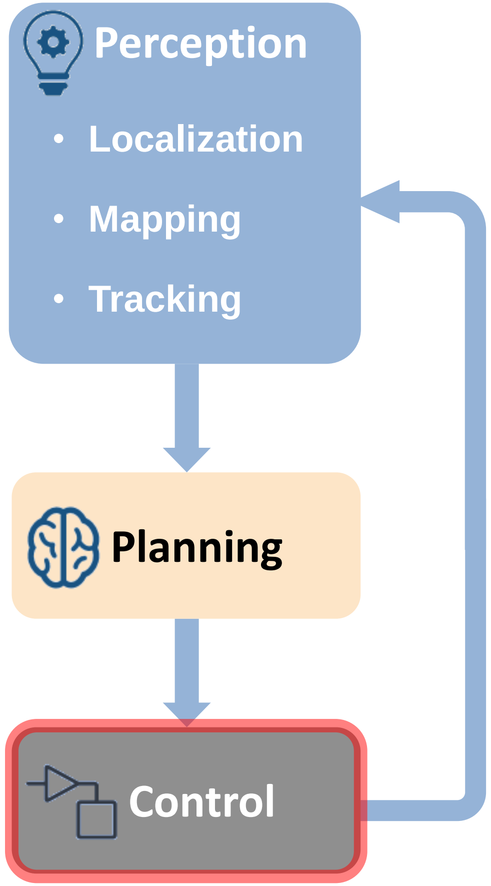
Send control commands to the vehicle to follow the planned path



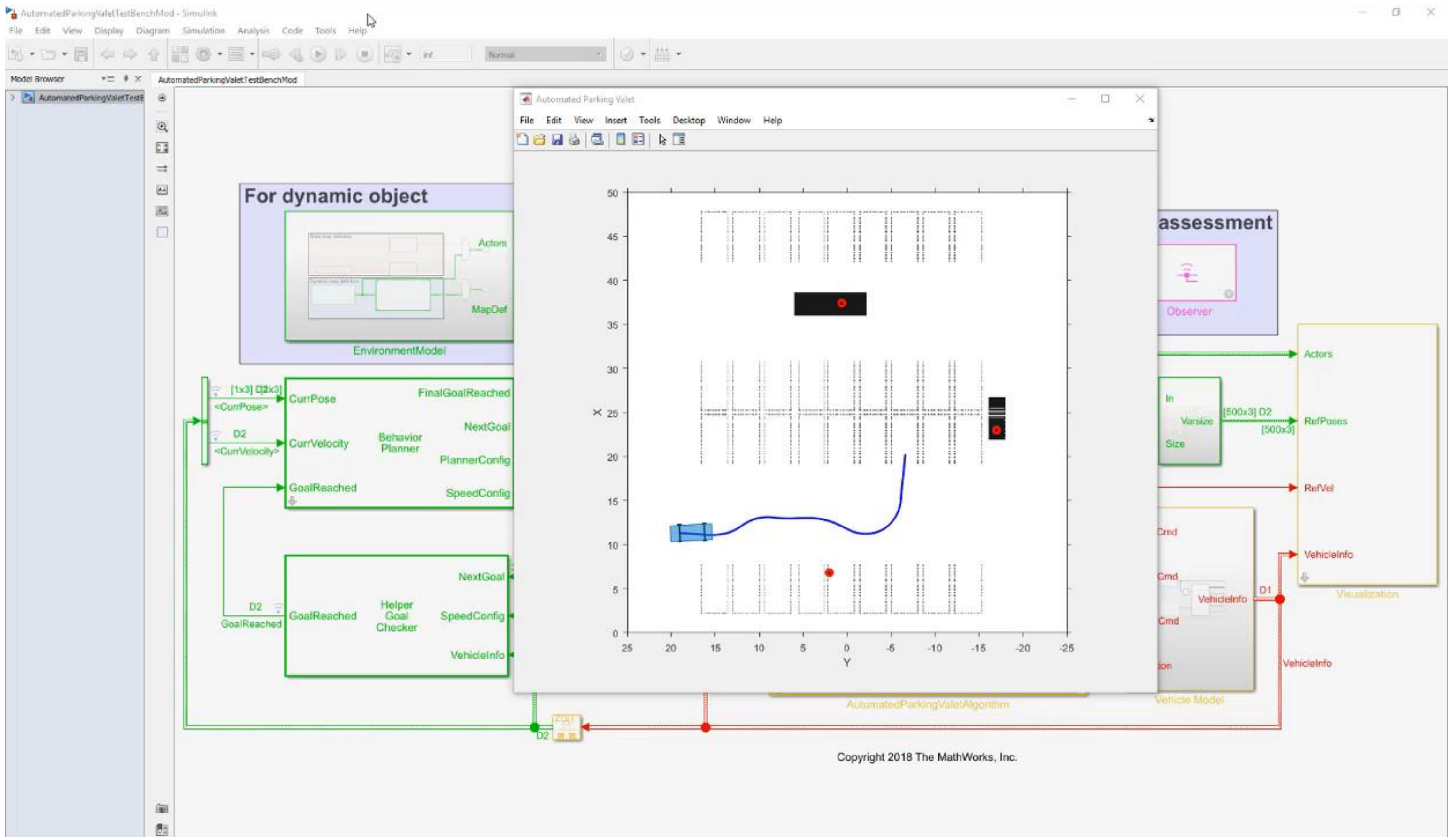
Calculate the steering angle and vehicle velocities to track the trajectories



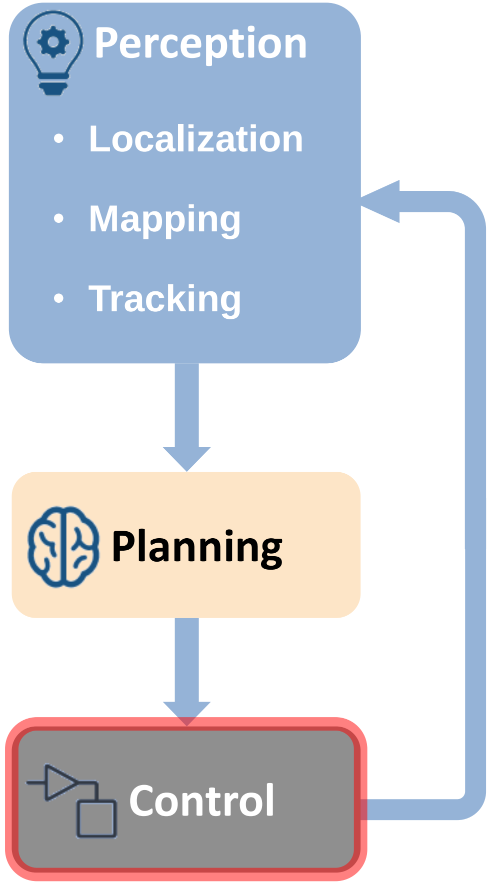
Avoid pedestrian (dynamic obstacles) in a parking lot



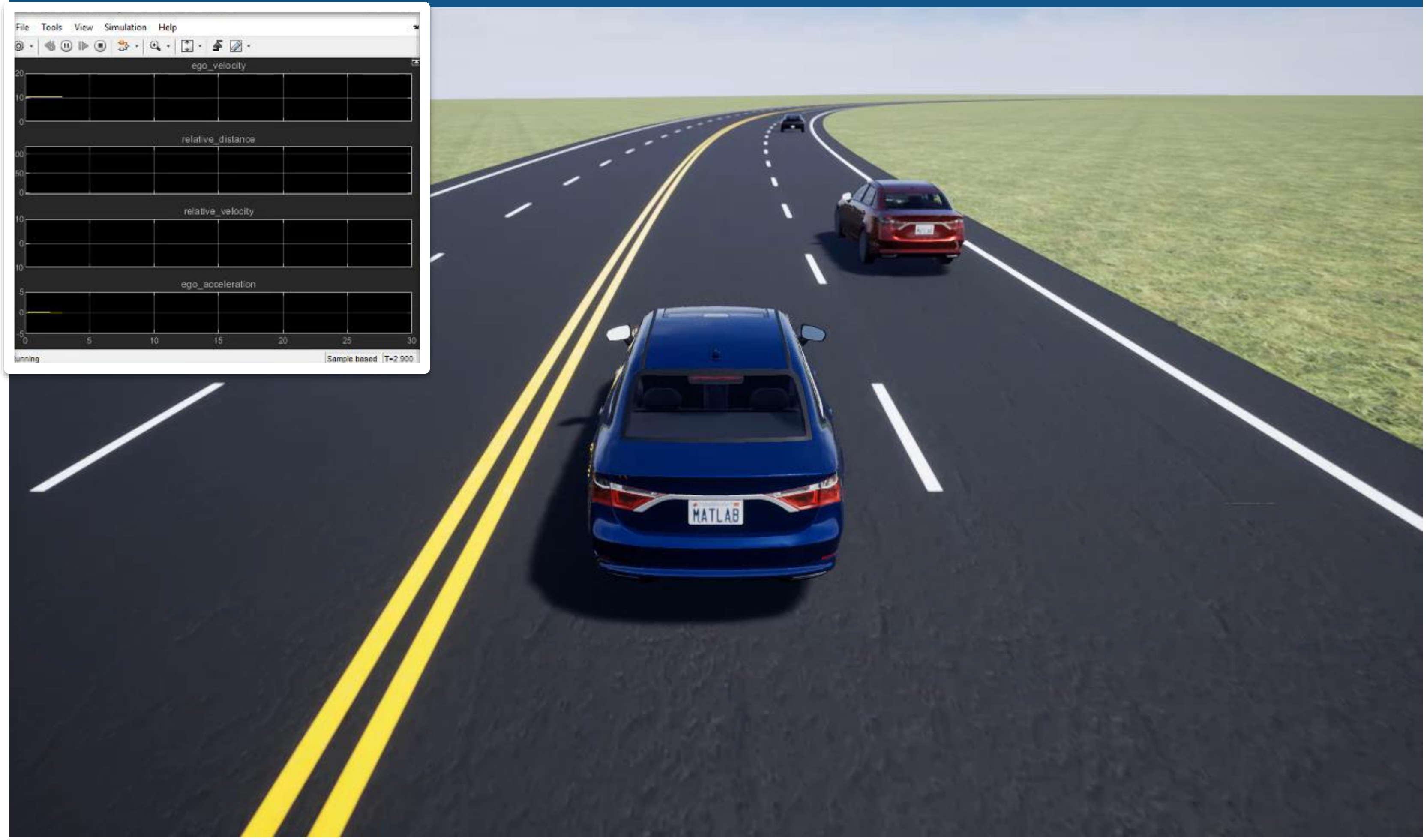
Define control commands to avoid potential collision



Control lane change maneuver for highway driving

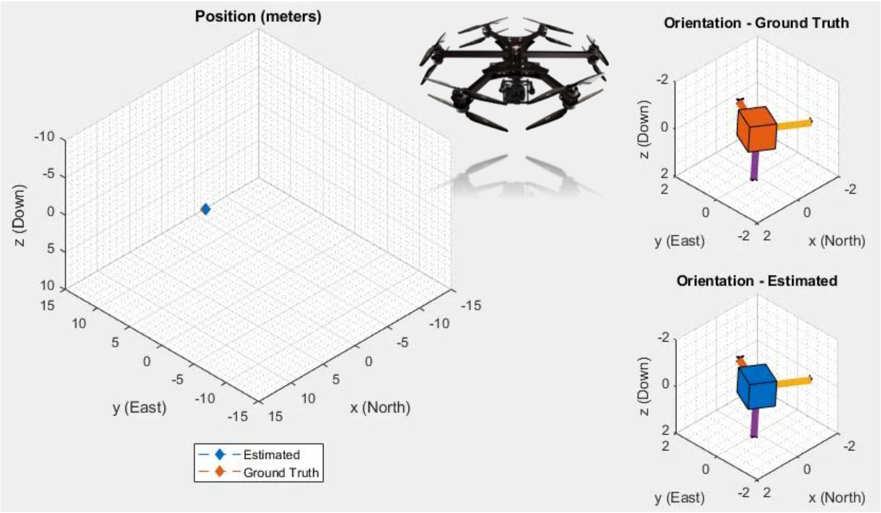


Longitudinal and Lateral Controllers to adjust the acceleration and steering

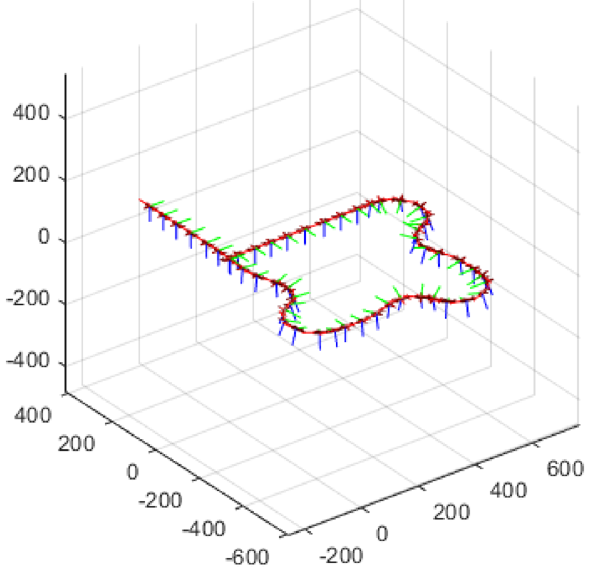


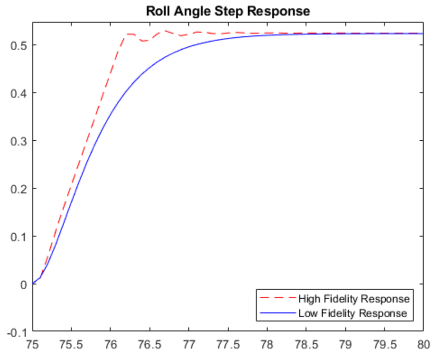
Simulate high-fidelity UAV model with waypoint following

Simulate GPS and IMU sensor models

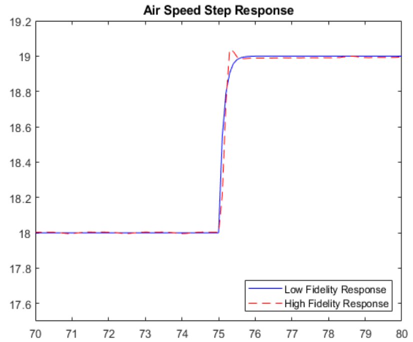


Waypoint following controller

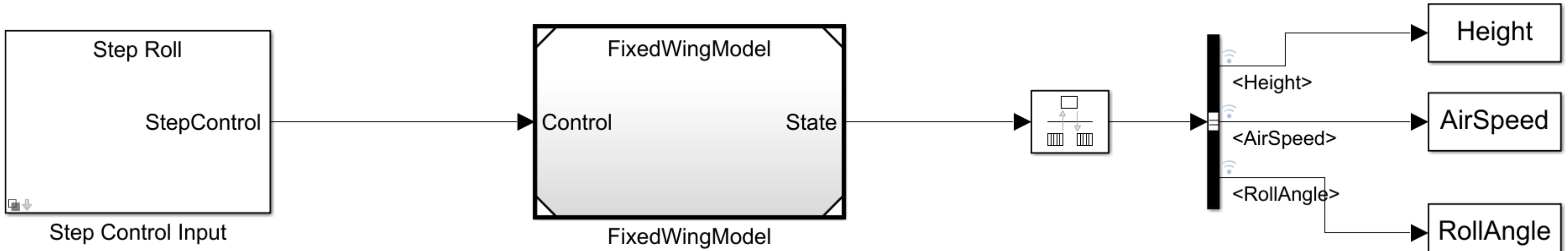


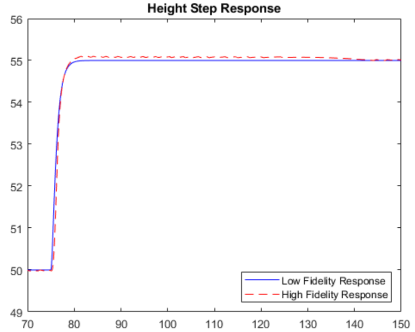


Roll Angle



Air Speed





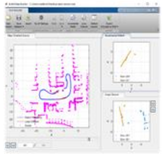
Height

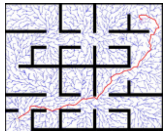
Approximate High-Fidelity Model with Low-Fidelity Model

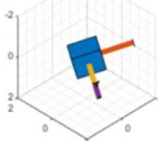
Generate code and deploy sensor fusion and navigation algorithms

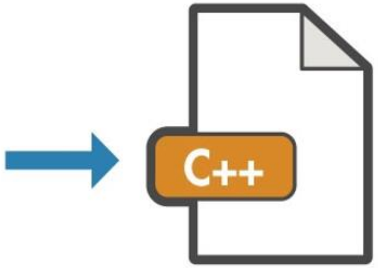
MATLAB Coder™

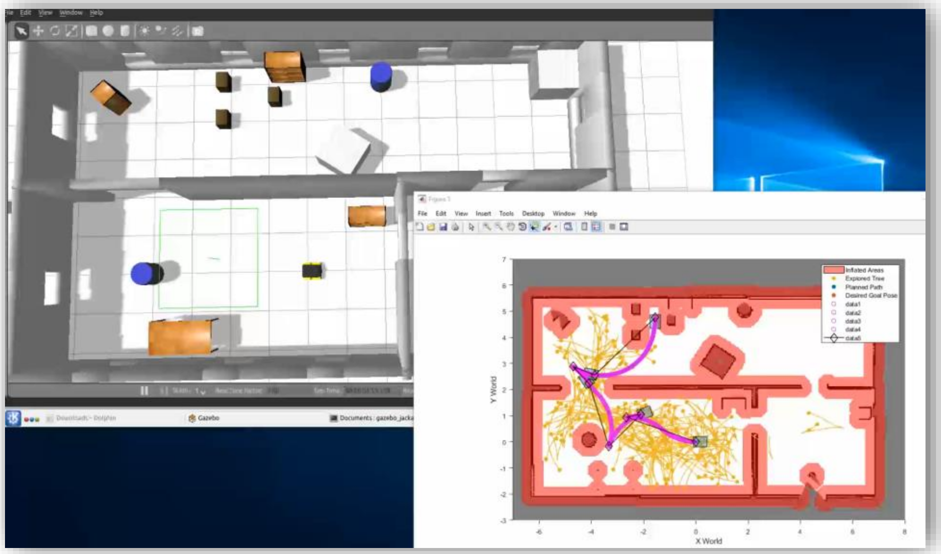
Simulink Coder™

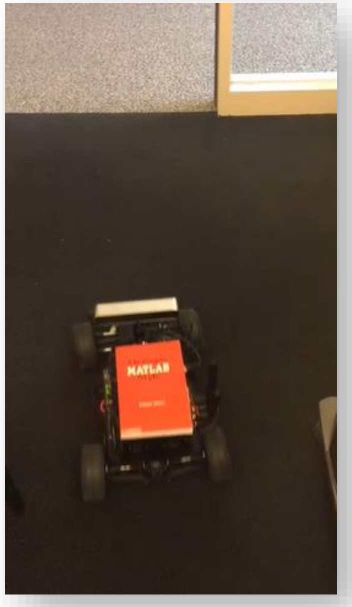


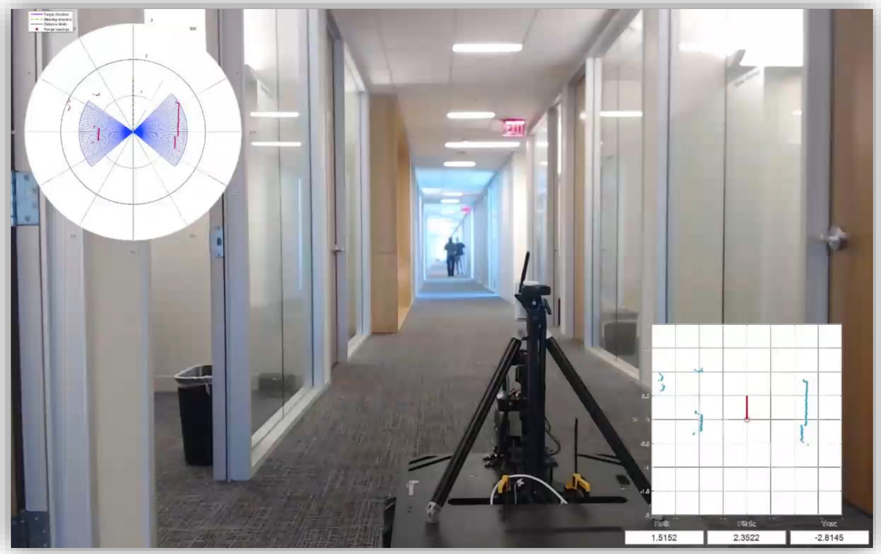




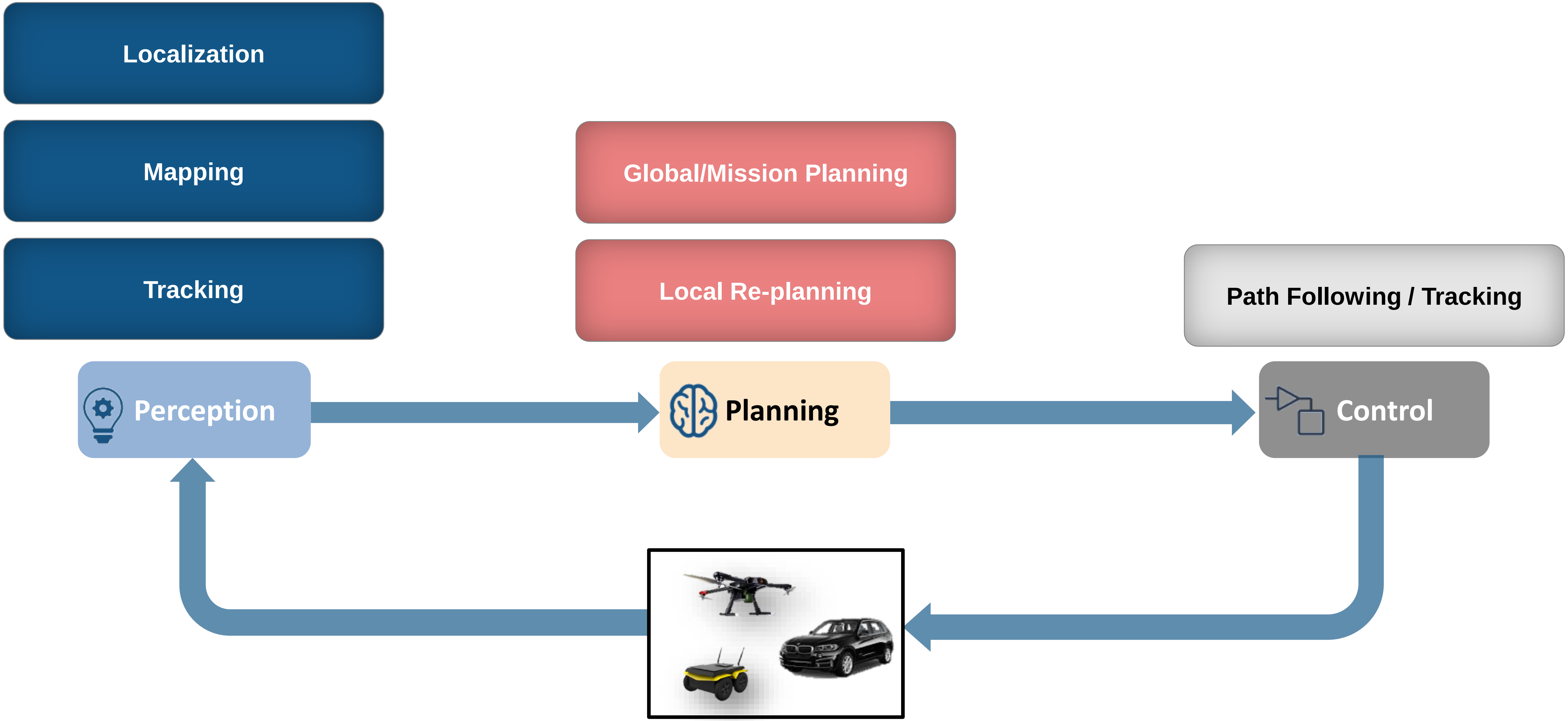








In this talk, we learnt about..



Full Model Based Design Workflow for Autonomous Systems

Verification & Validation

Connect / Deploy

- Code Generation
- ROS Toolbox
- AUTOSAR Blockset

Autonomous Algorithms

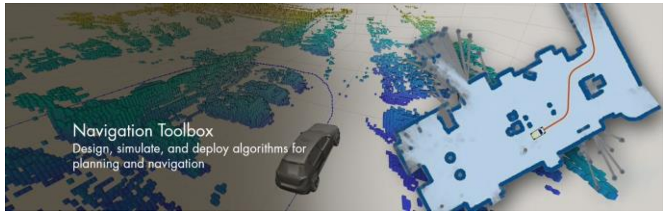
- Sensor Fusion and Tracking Toolbox
- Perceive
- Plan & Decide
- Navigation Toolbox
- Robotics System Toolbox
- Automated Driving Toolbox

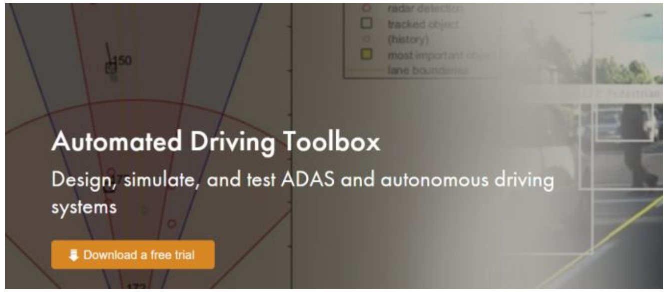
- Stateflow
- Computer Vision Toolbox
- Sense
- Control
- Reinforcement Learning Toolbox
- Model Predictive Control Toolbox

Platform

- MATLAB
- Simulink

There are many resources to get started with



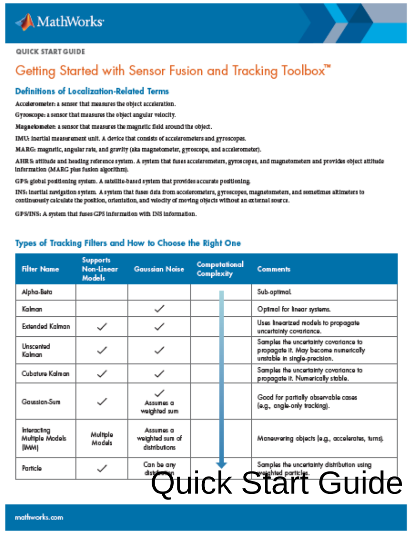


Tech Talks

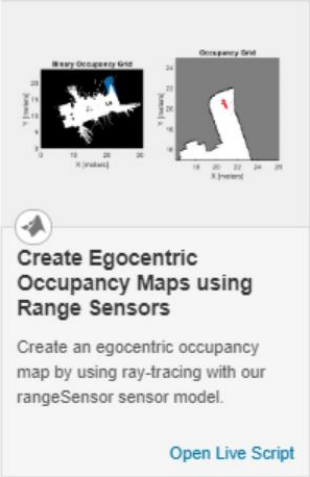
Series: Understanding Sensor Fusion and Tracking

Part 1: What is Sensor Fusion?
This video provides an overview of what sensor fusion is and how it helps in the design of autonomous systems. It also covers a few scenarios that illustrate the various ways in which sensor fusion can be implemented.

Part 2: Fusing a Mag, Accel, and Gyro to Estimate Orientation
This video describes how we can use a magnetometer, accelerometer, and a gyro to estimate an object's orientation. The goal is to show how these sensors contribute to the solution, and to explain a few things to watch out for along the way.



Quick Start Guide



Please visit our Tech Showcase demos

Thank you!

Questions?