MATLAB EXPO 2019

Sensor Fusion and Tracking for Autonomous Systems

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Capabilities of an Autonomous System

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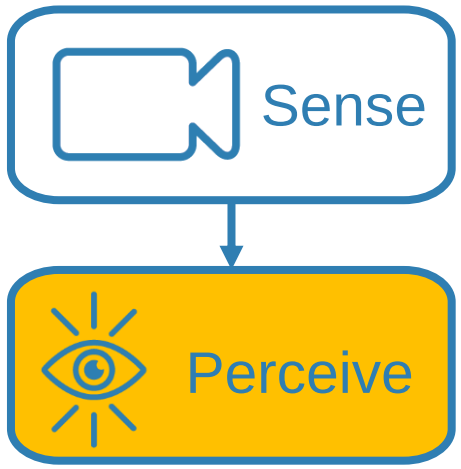
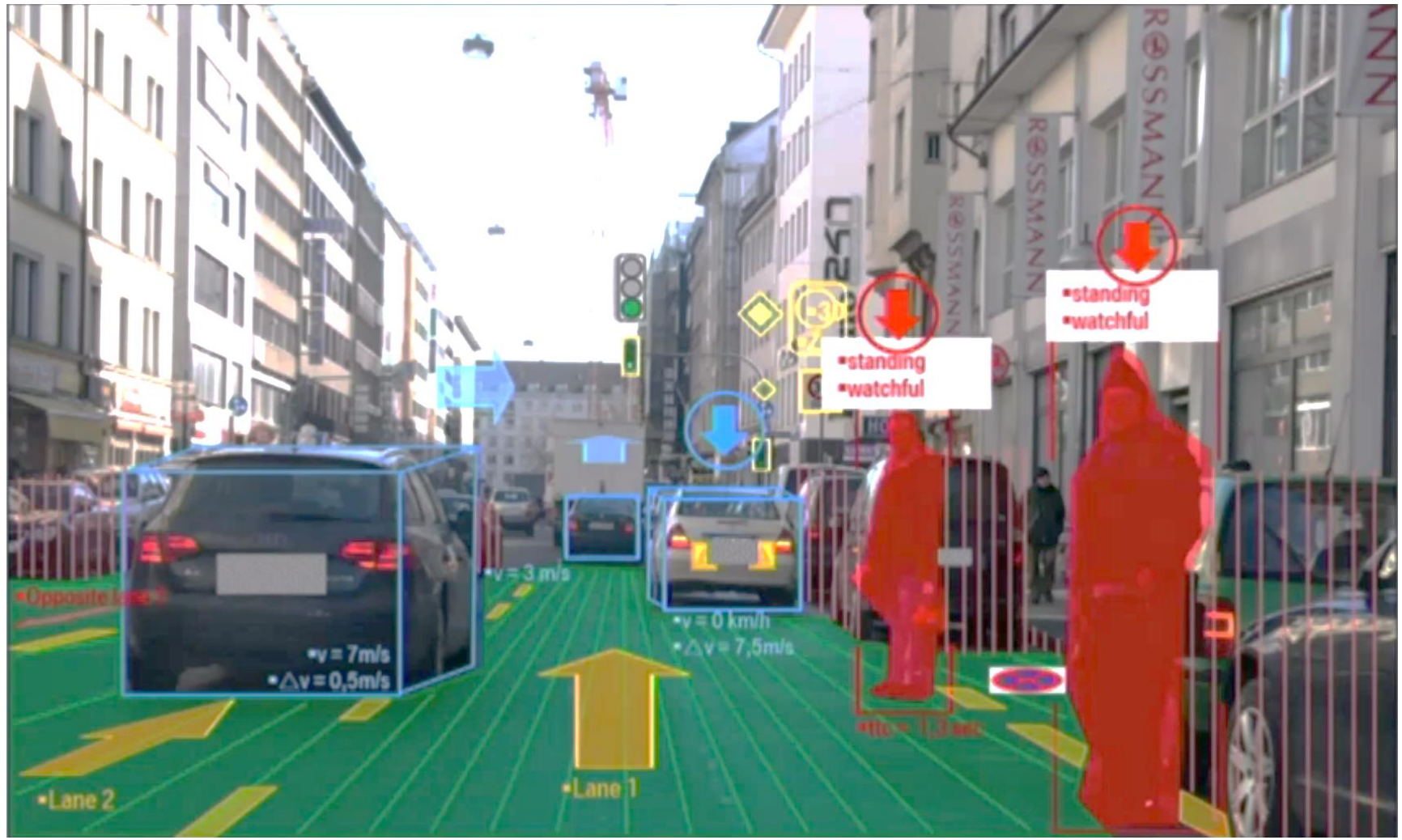
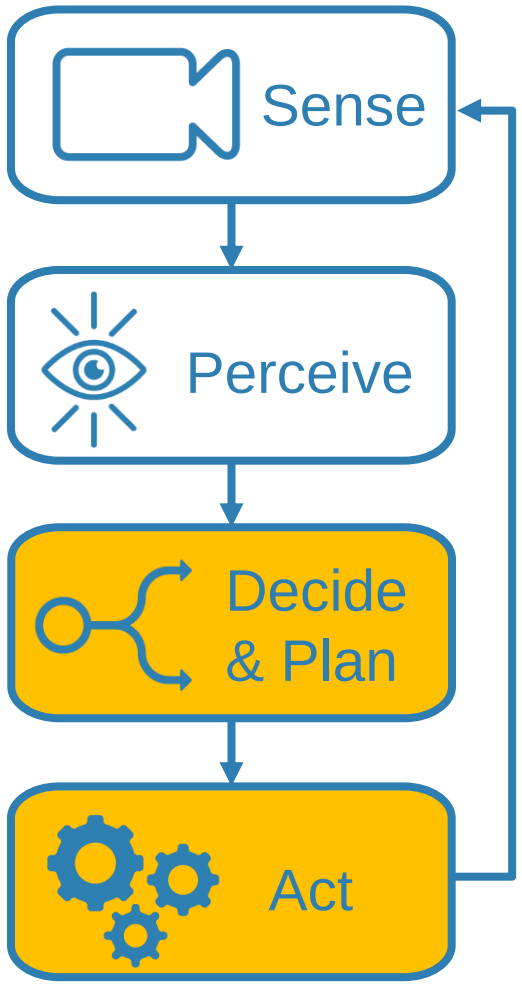
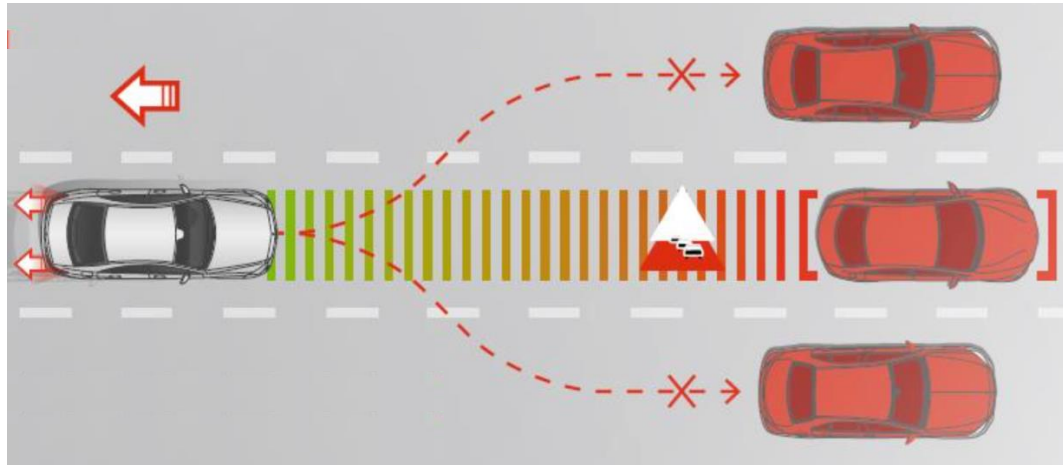




Capabilities of an Autonomous System



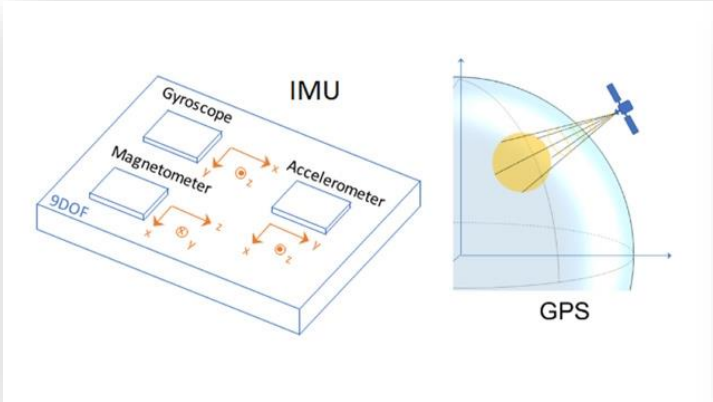


Agenda

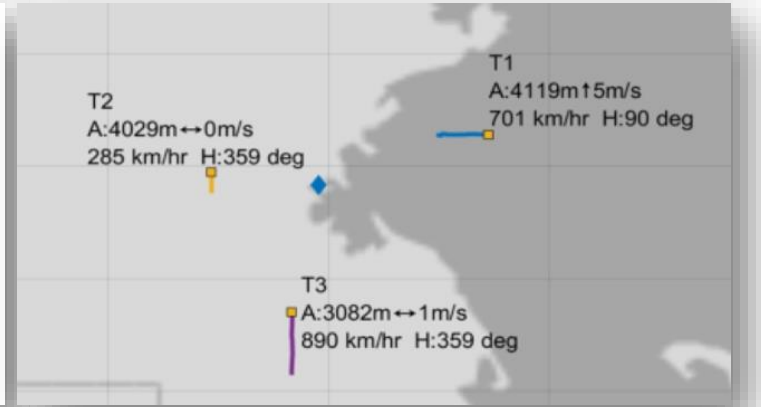
- Introduction
- Technology overview of perception
- Algorithm development for sensor fusion and tracking
- Q&A
- Resources for further exploration

Sensor fusion and tracking is…

Self- awareness



Situational awareness



Accelerometer, Magnetometer, Gyro, GPS…

Radar, Camera, IR, Sonar, Lidar, …

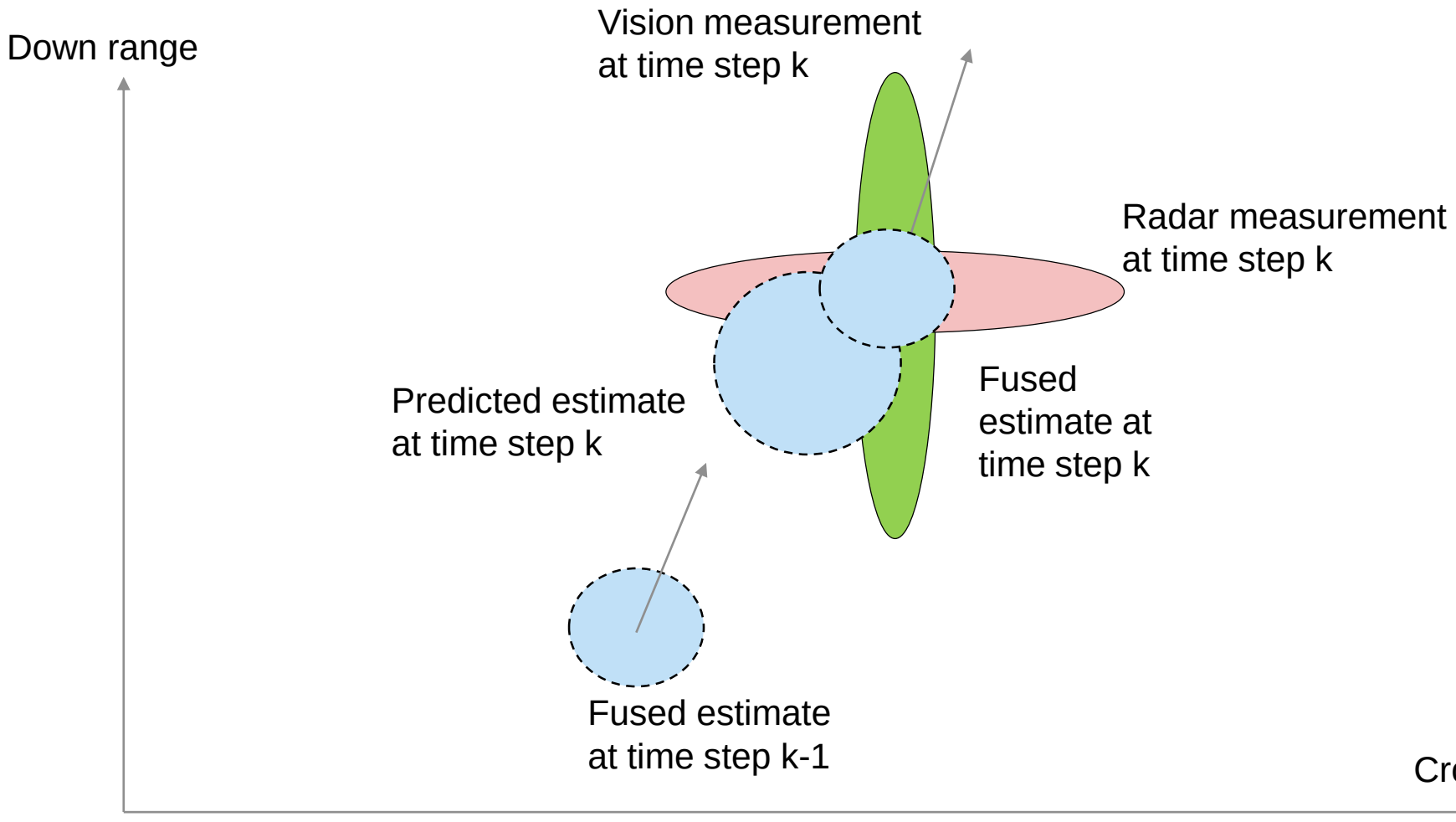
Signal and Image Processing

Sensor Fusion and Tracking

Control

Sensor Fusion and Tracking Toolbox

Fusion combines the strengths of each sensor

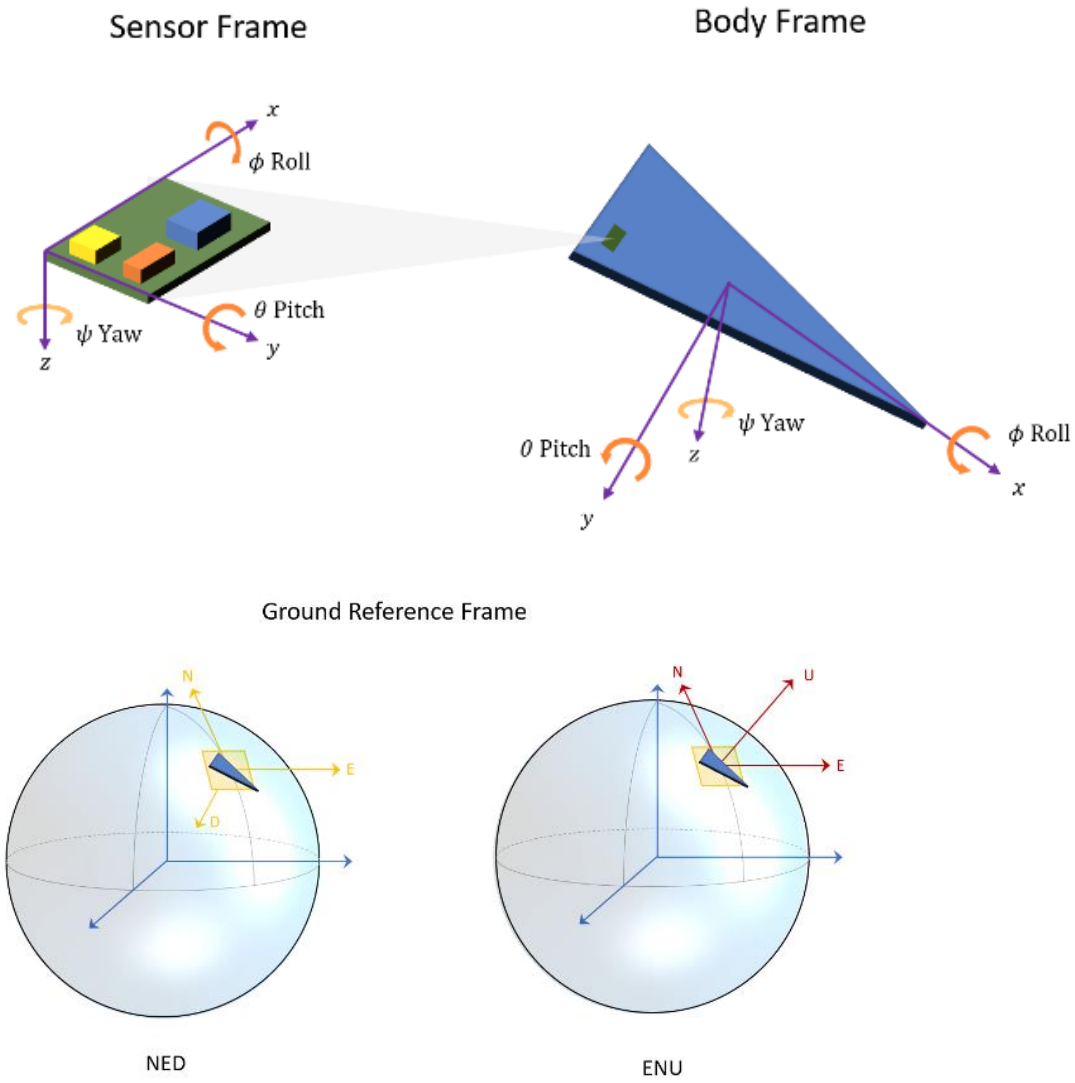


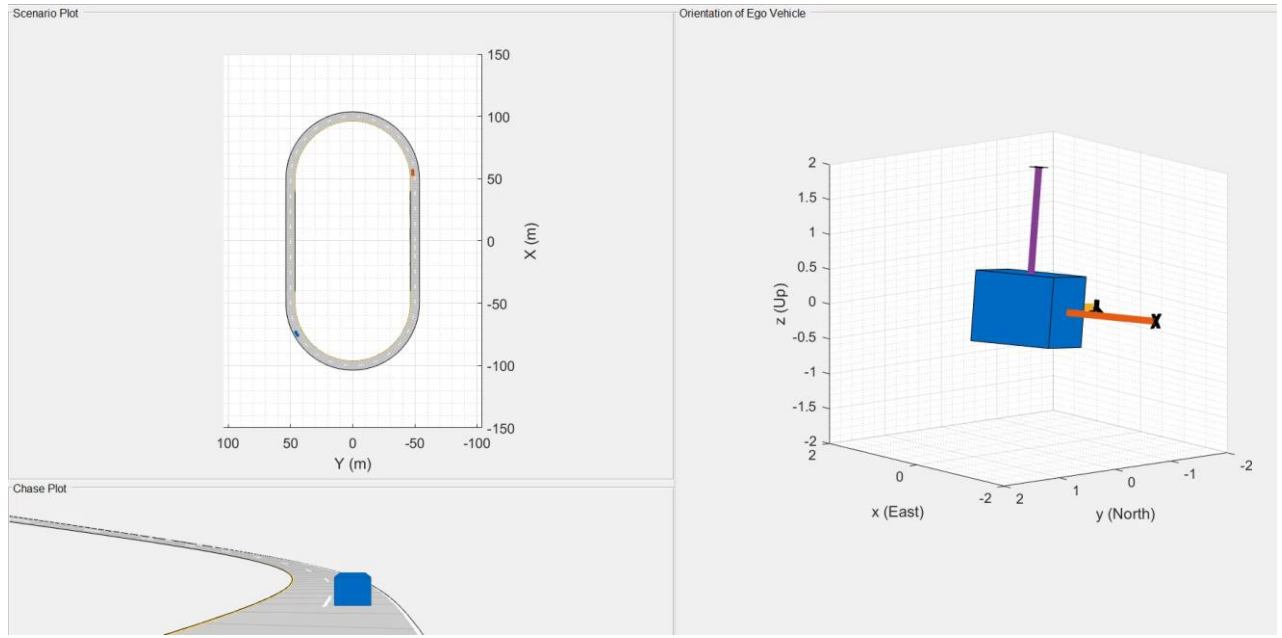
Legend

- Vision Measurement
- Radar measurement
- Track (fused estimate)

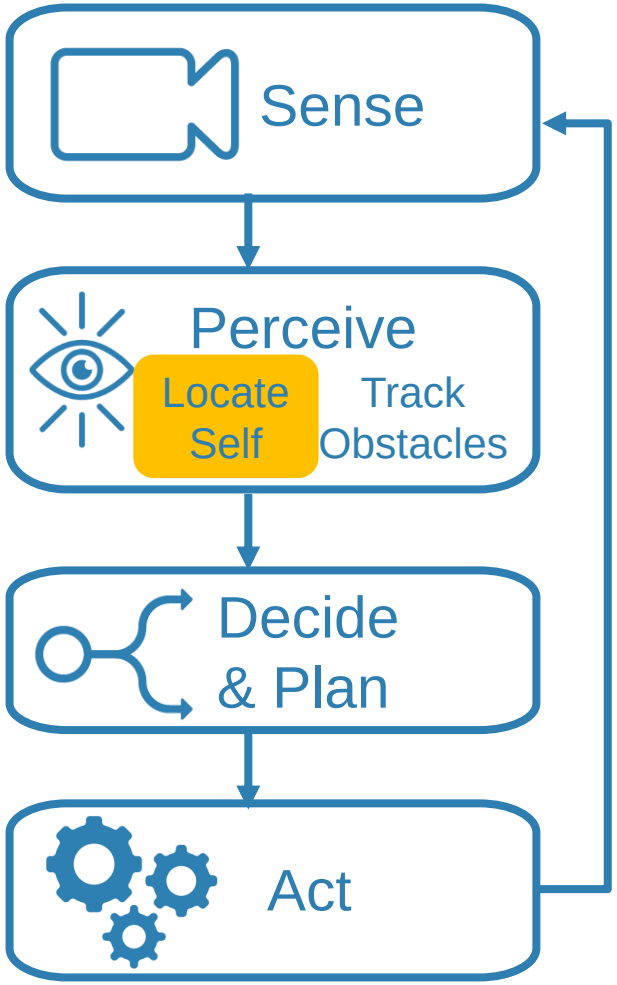
Ellipse represents uncertainty

What is localization?





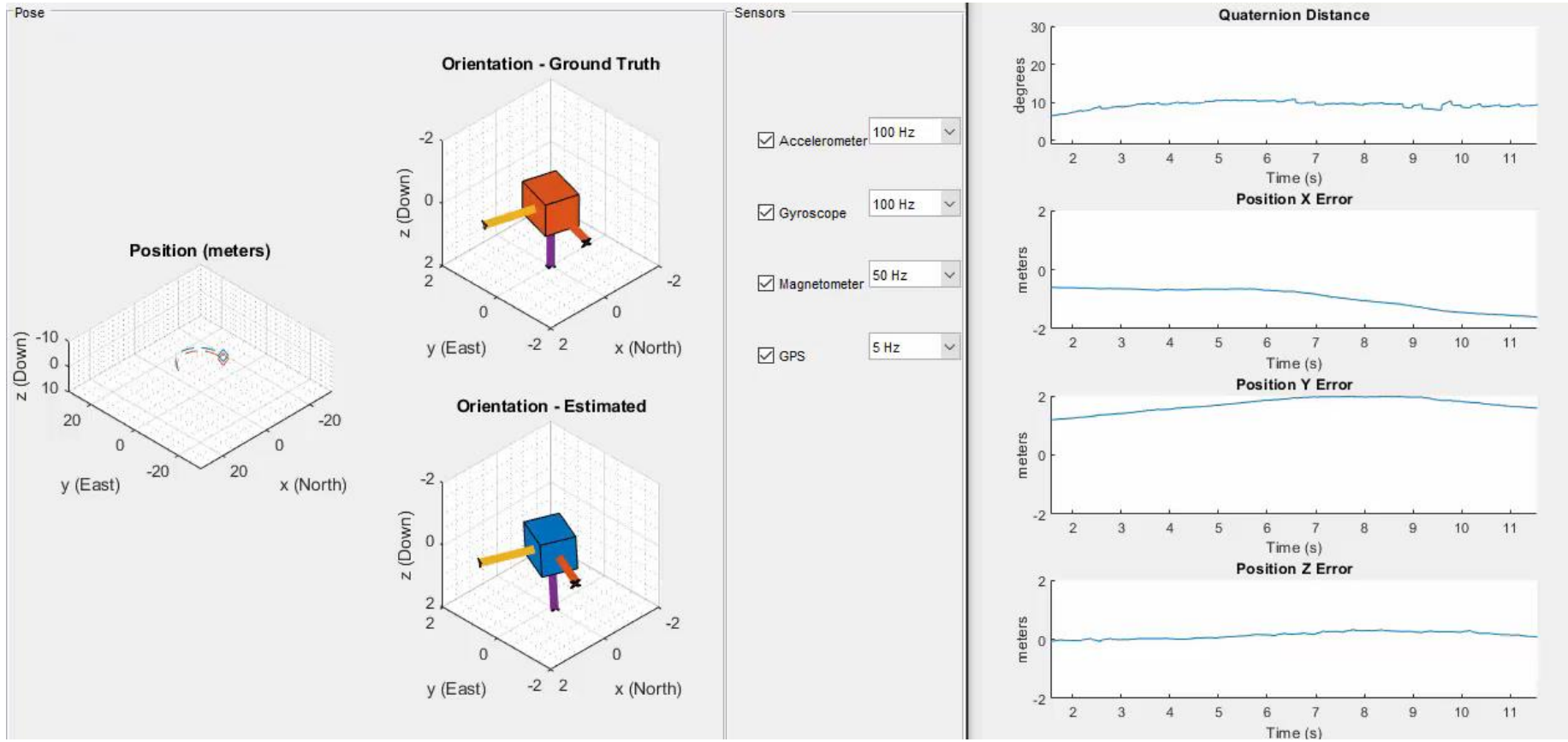
Fusing sensor data improves localization



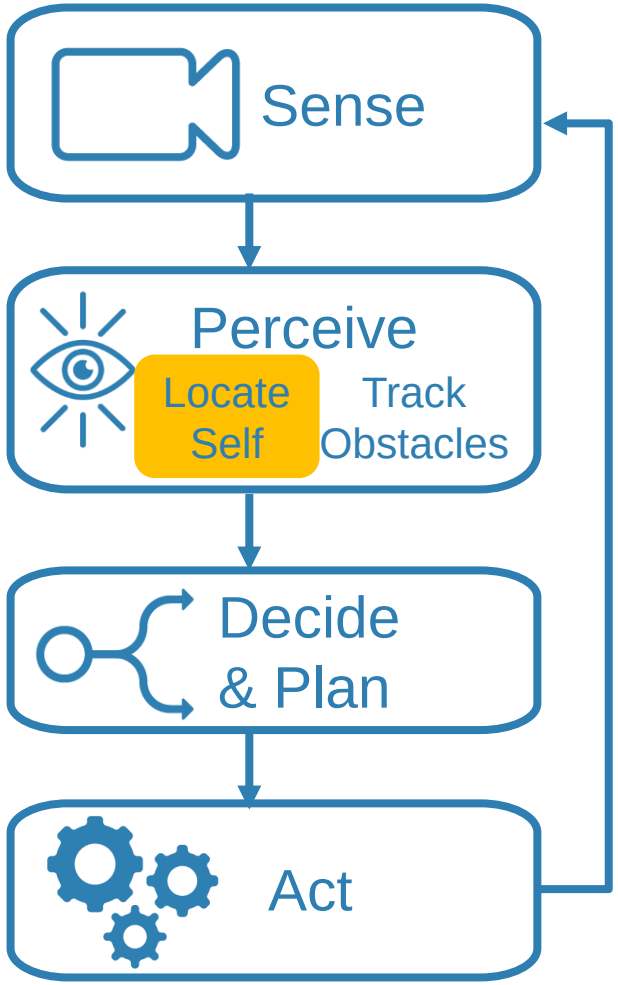
Ground truth vs. Estimate

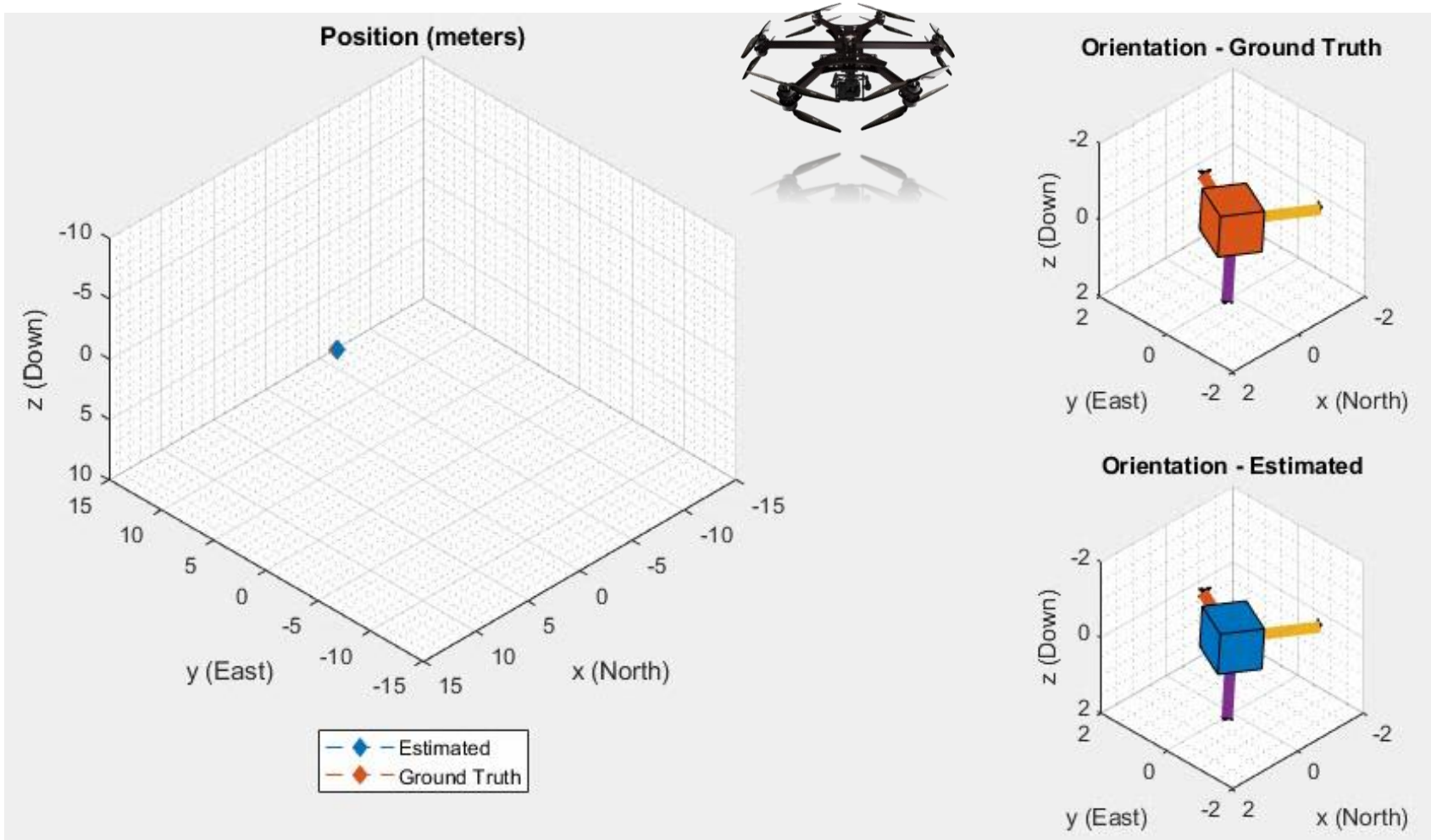
Sensors

Error Measurements

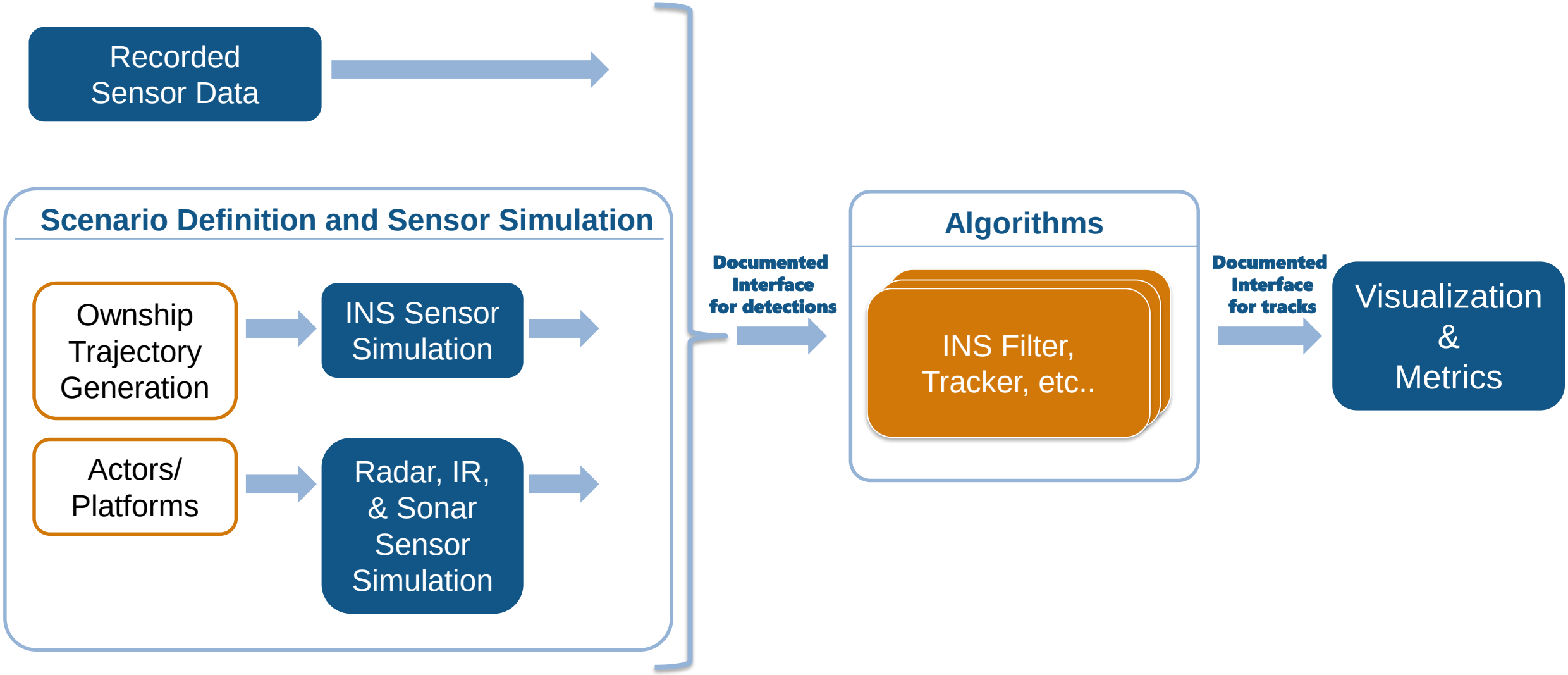


Self-awareness is needed to create situational awareness

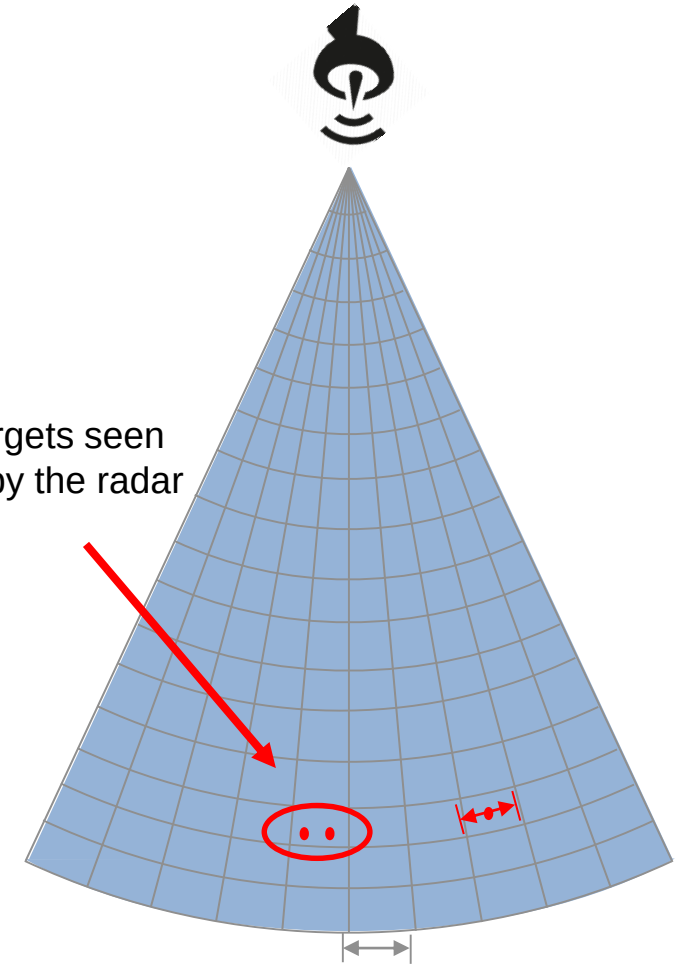




Flexible Workflows Ease Adoption: Wholesale or Piecemeal

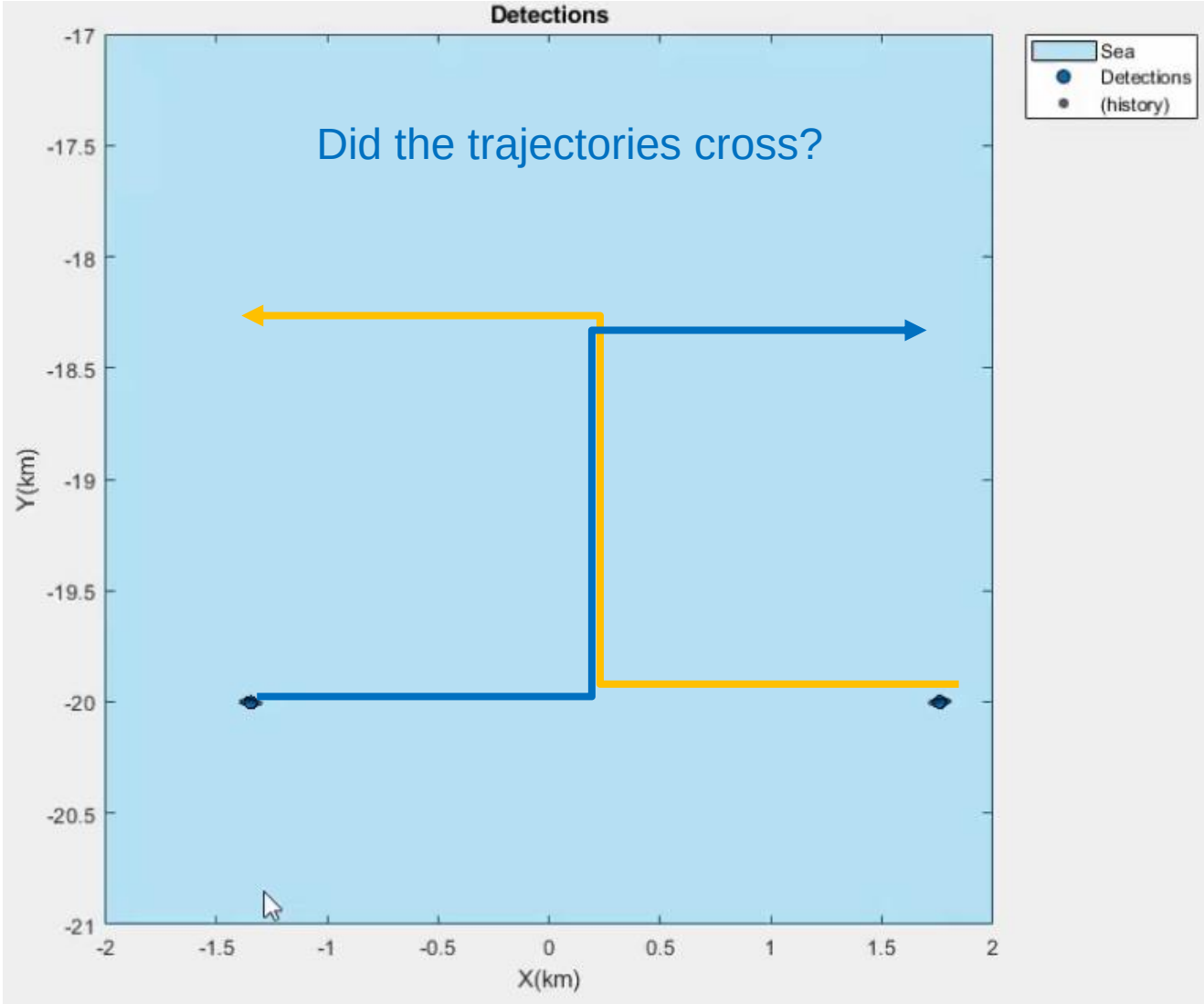


You can synthesize test cases that may be difficult to re-create

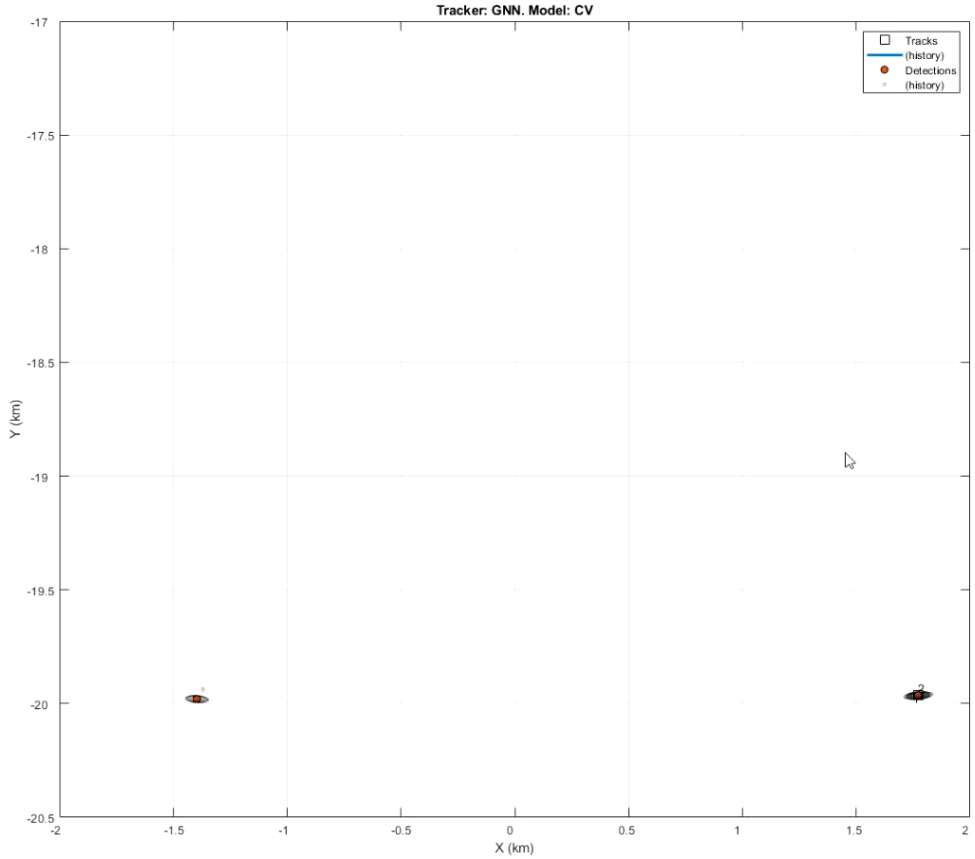


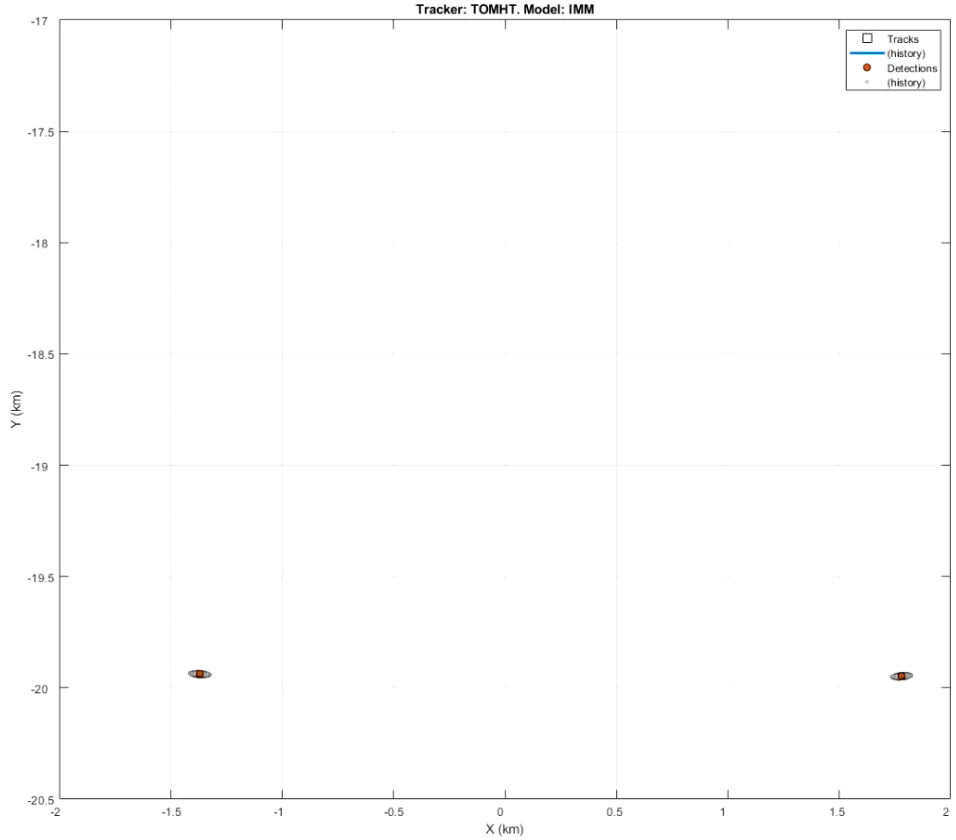
Two targets seen as one by the radar

1° Azimuth Resolution



Perform quick what-if analyses between different trackers



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>> trackerGNN, CV
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>> trackerTOMHT, IMM
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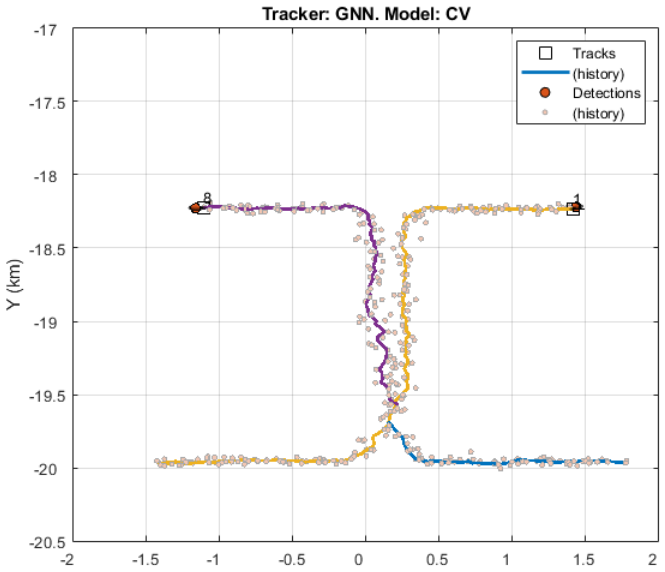
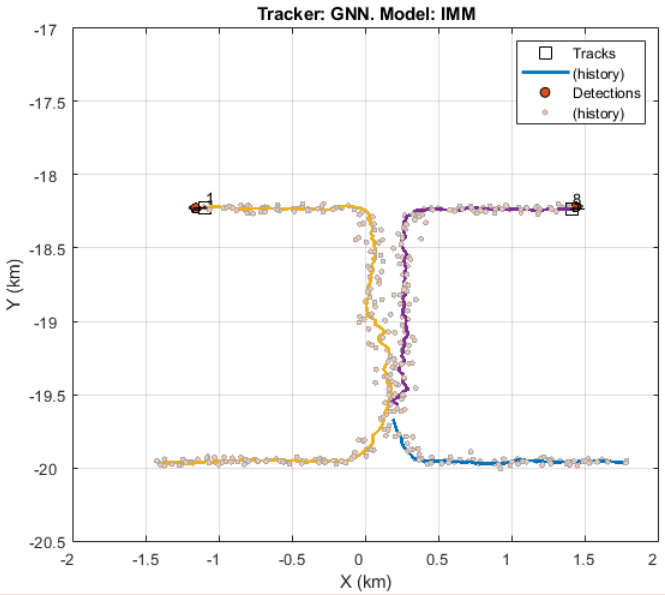
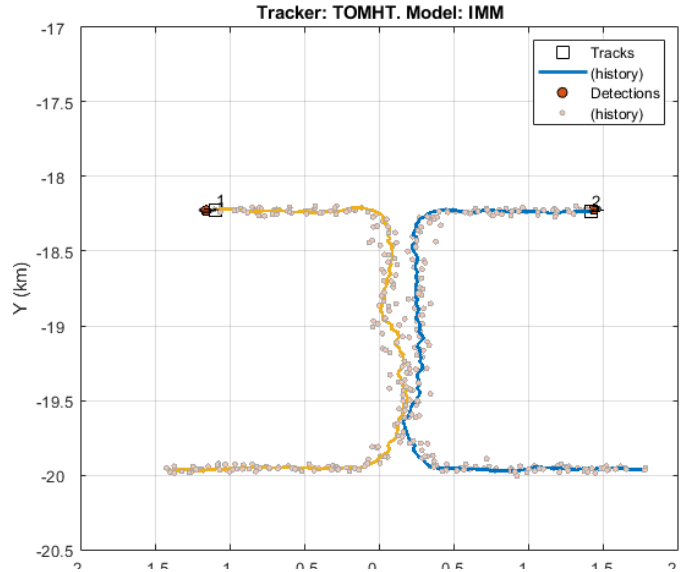
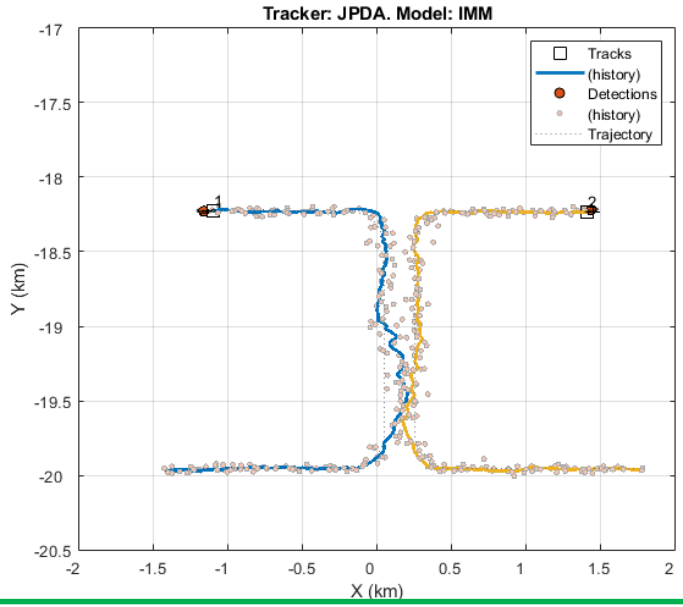
Evaluate results based on performance metrics



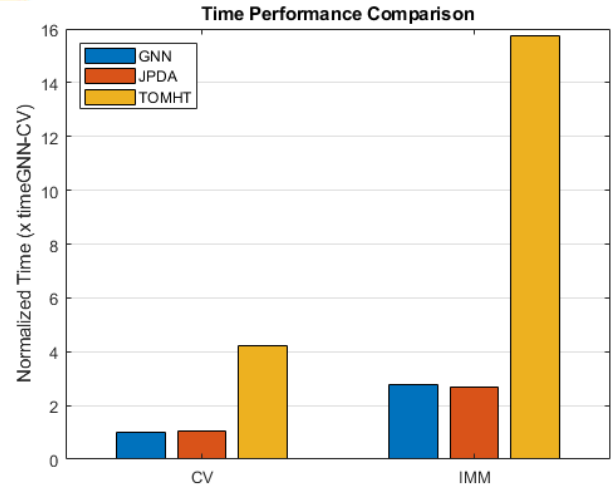


False tracks





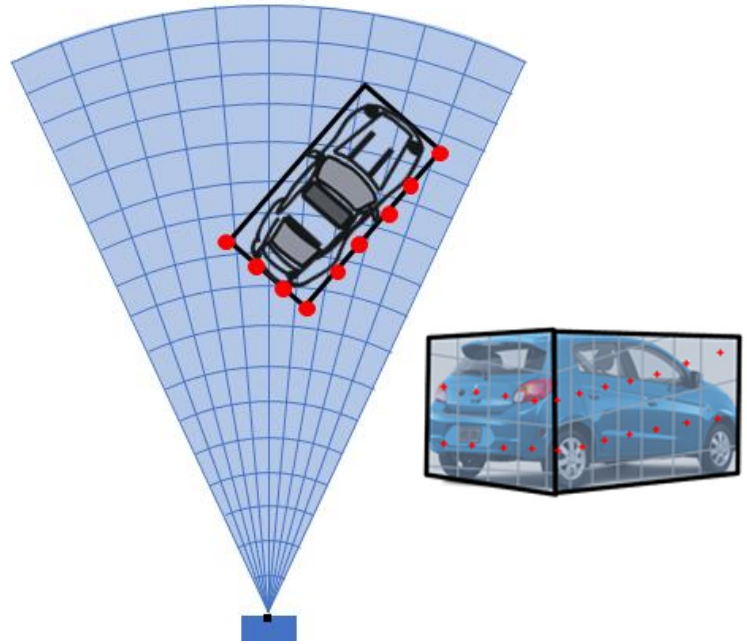
No false tracks



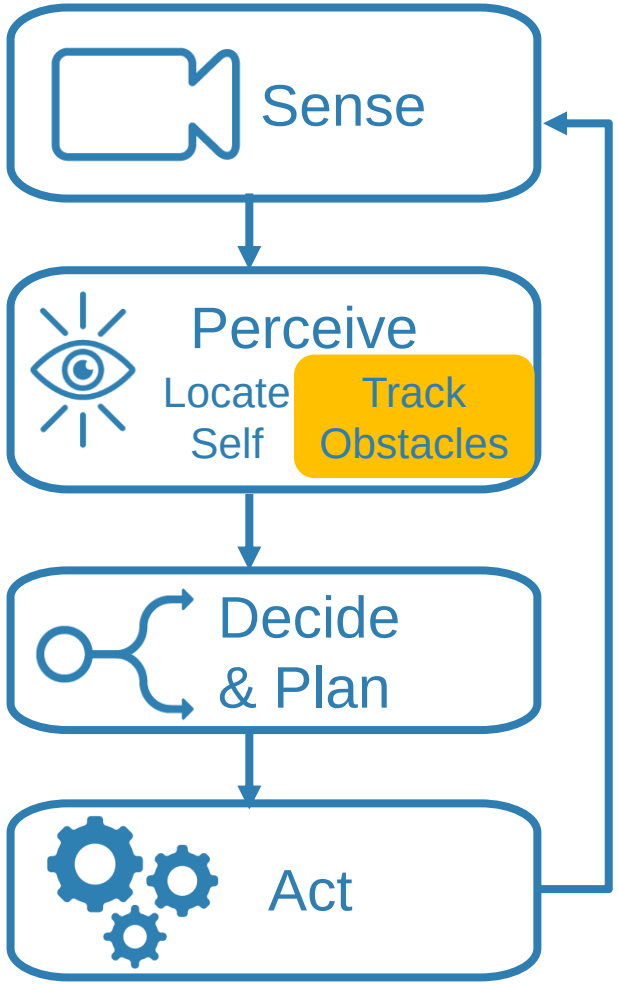
Point object vs. Extended object

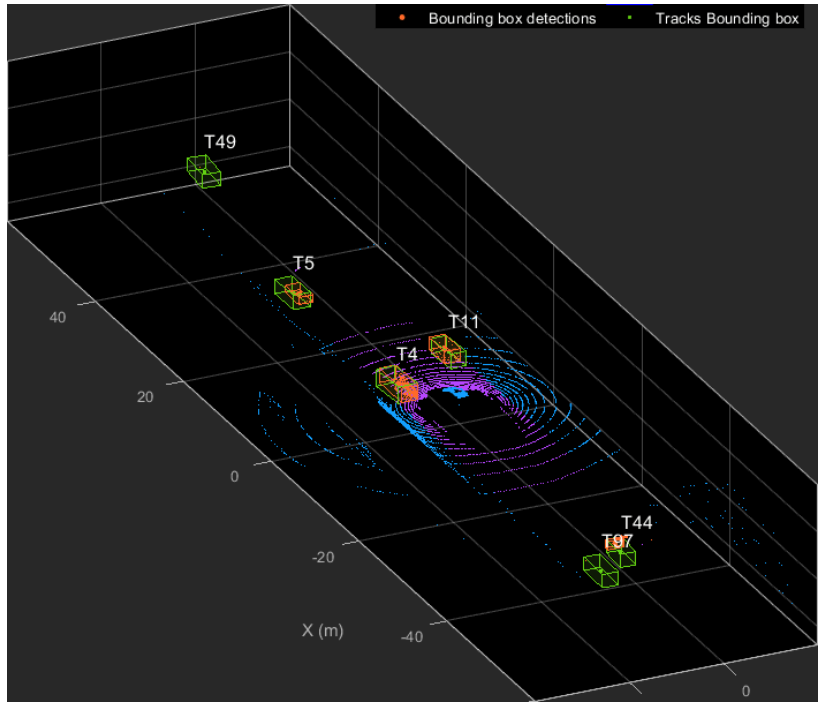
- **Point object**
  - Distant object represented as a single point
  - One detection per object per scan

- **Extended object**
  - High resolution sensors generate multiple detections per object per scan

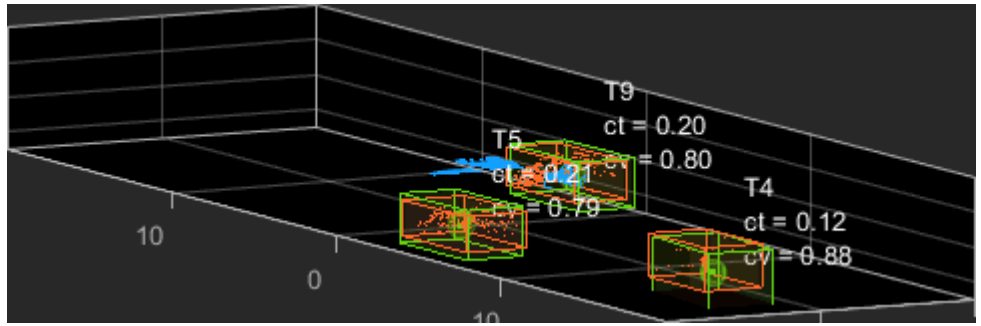


Tracking with Lidar





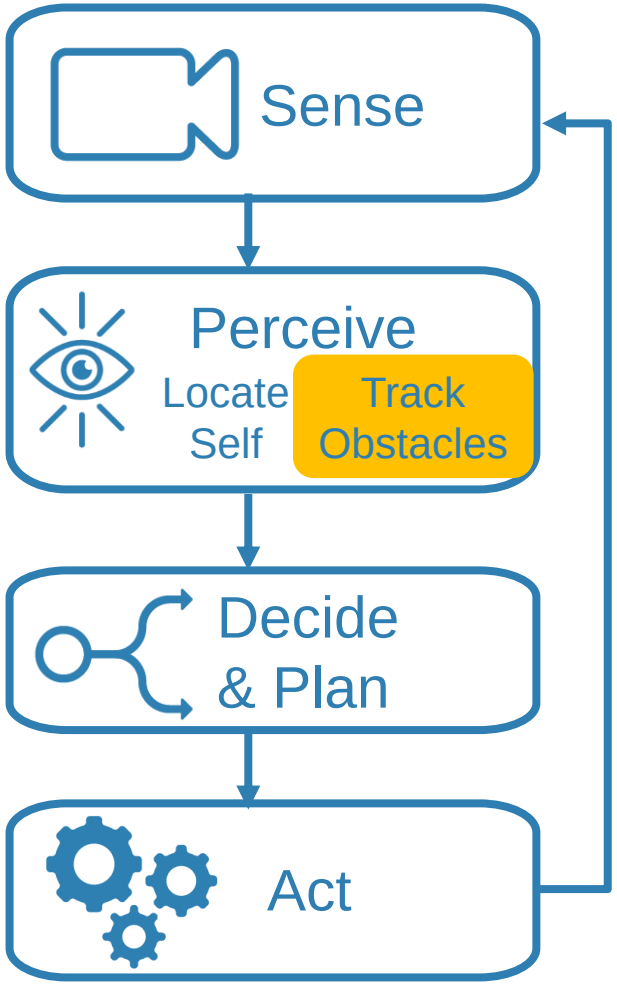
Maintain tracks at edge of coverage

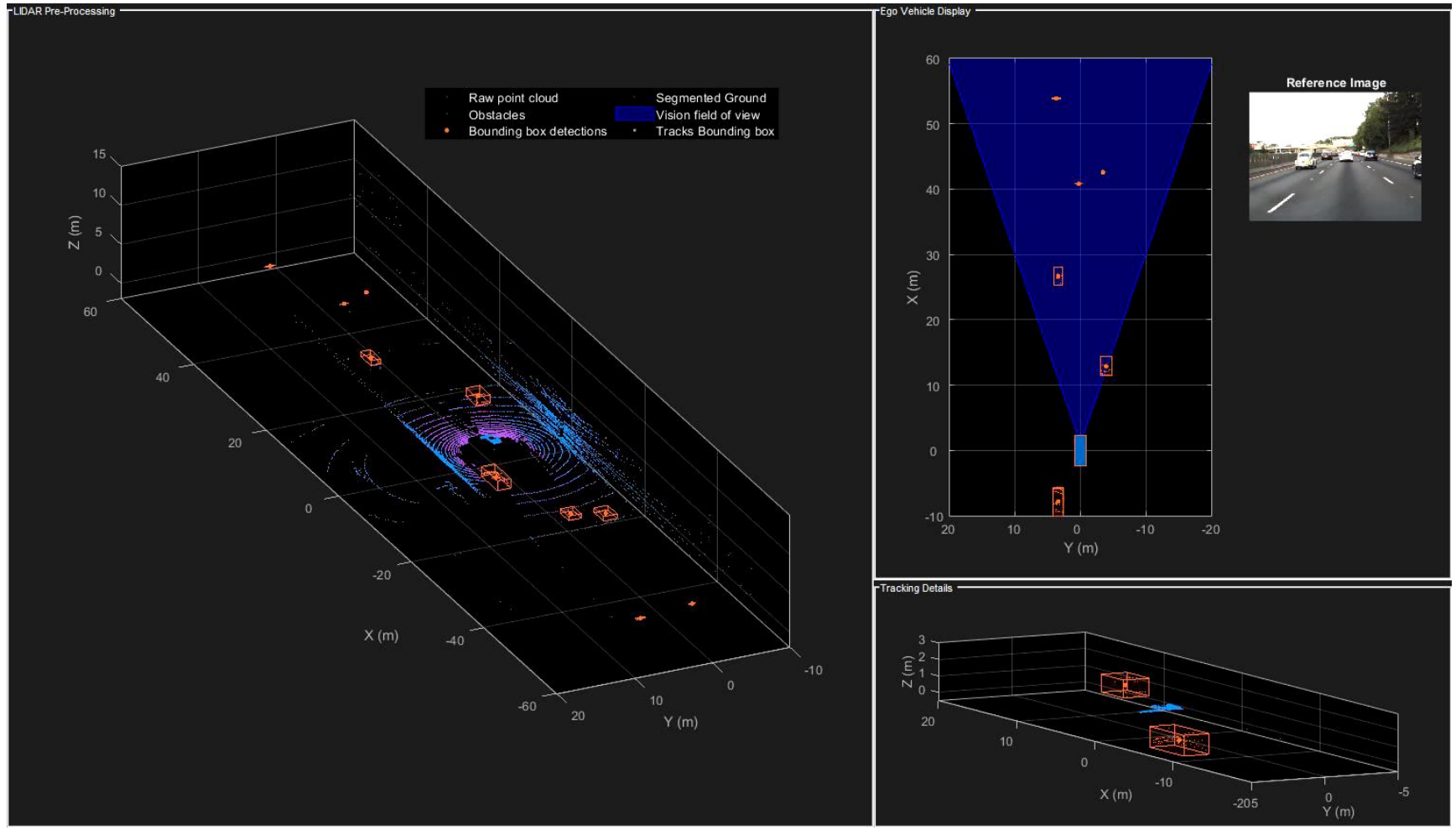


Track maneuvering vehicles (during lane changes)

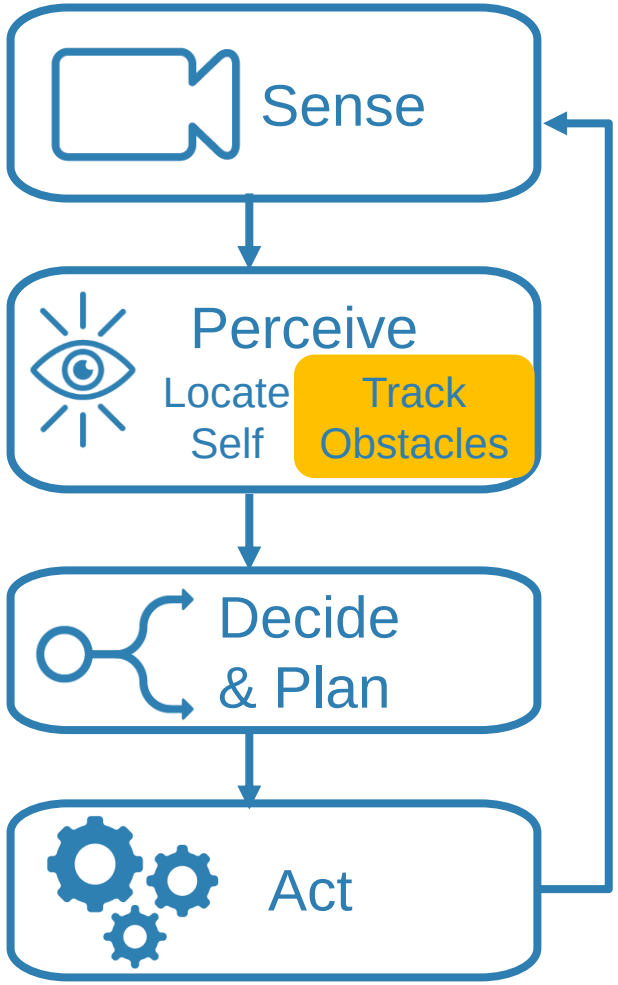
- Design 3-D bounding box detector
- Design IMM-JPDA tracker
- Generate C/C++ code for tracker

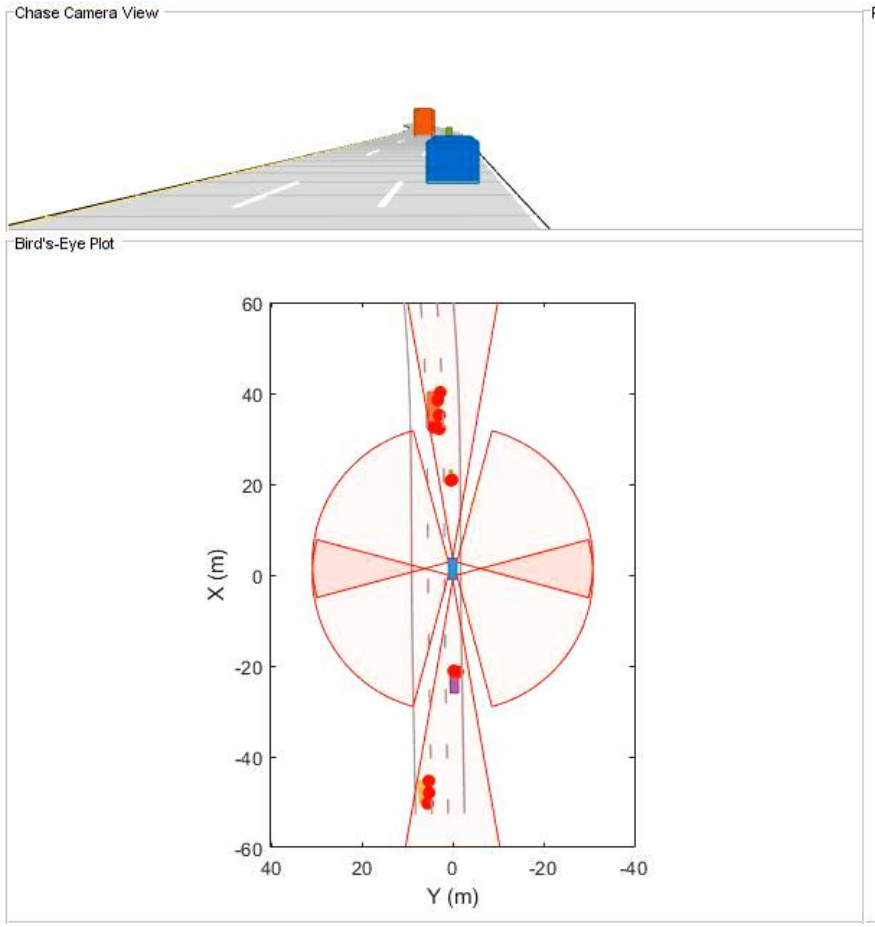
Tracking with Lidar (with ground truth shown)

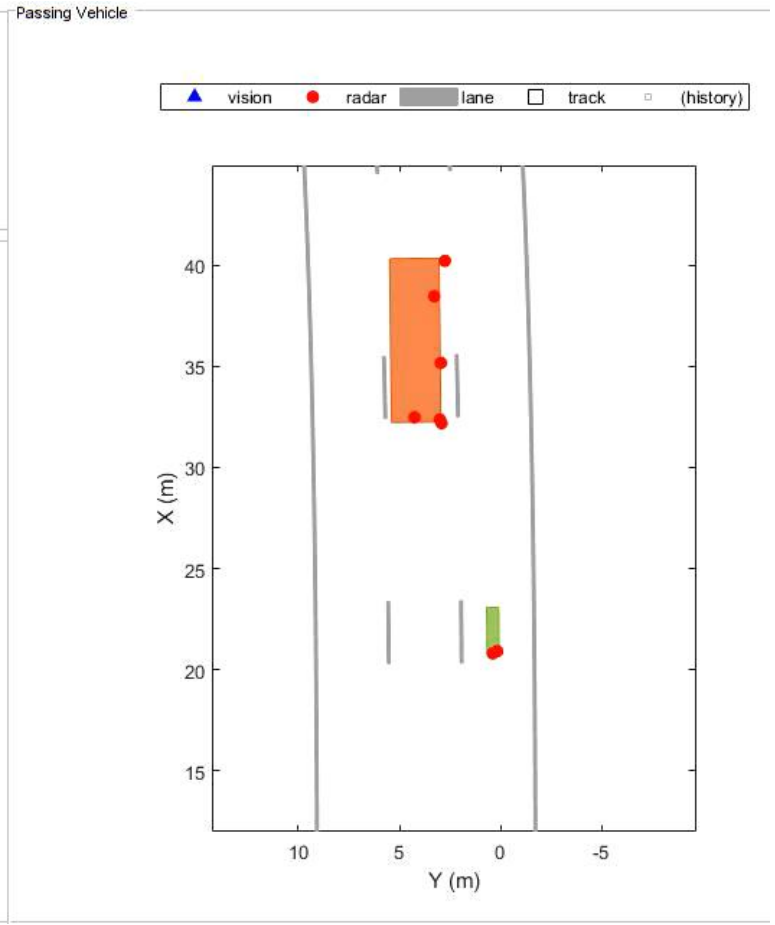




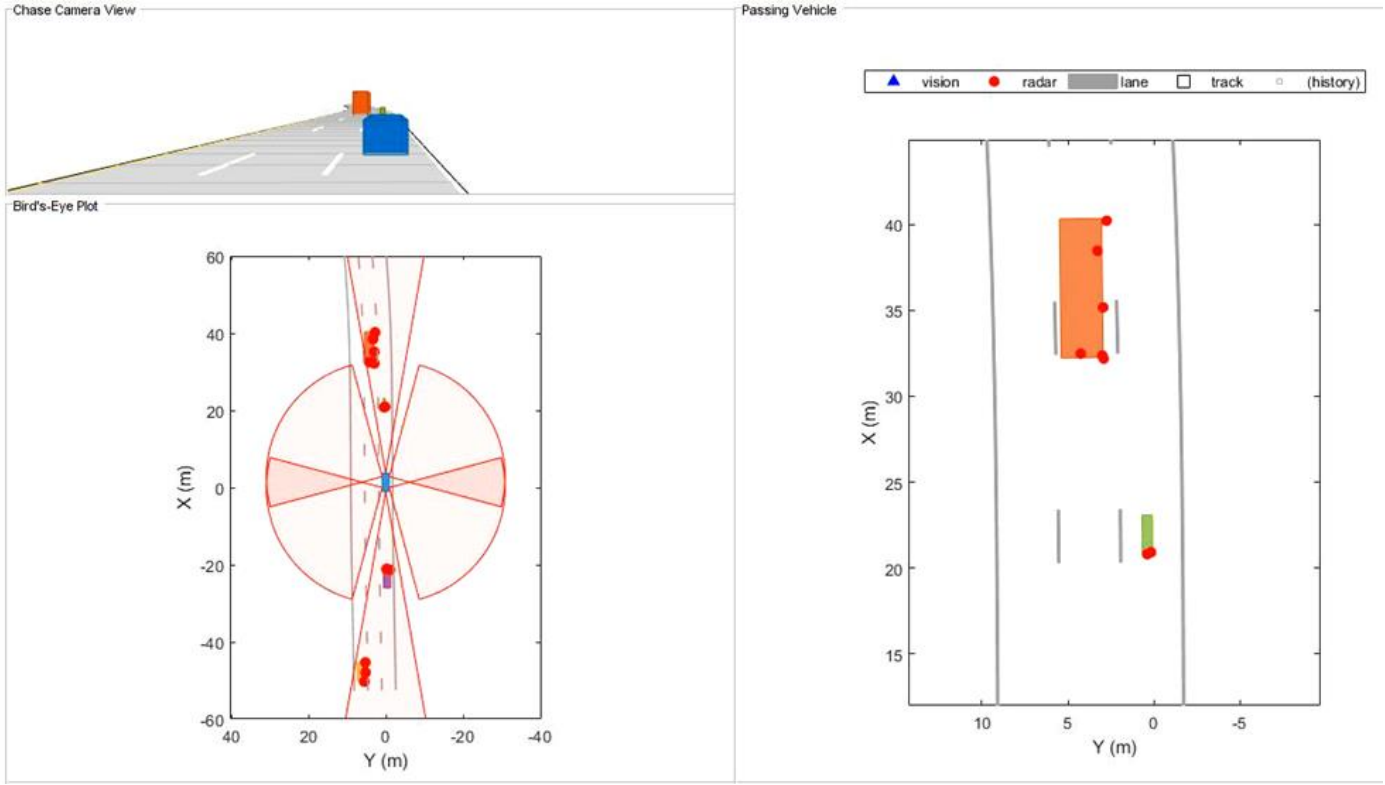
Extended Object Tracking: Estimate position, velocity, and size



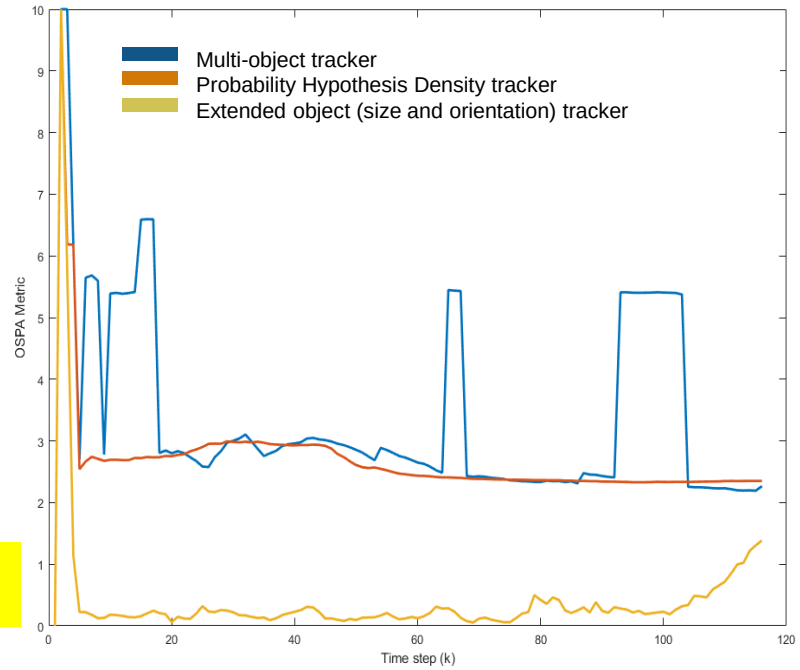




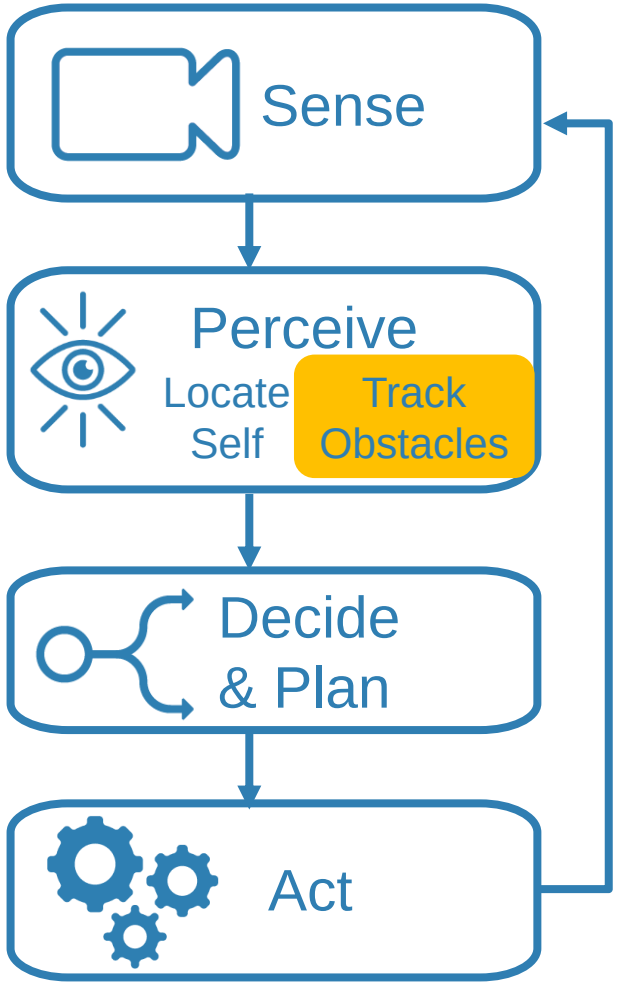
Evaluate tracker performance of Extended Objects

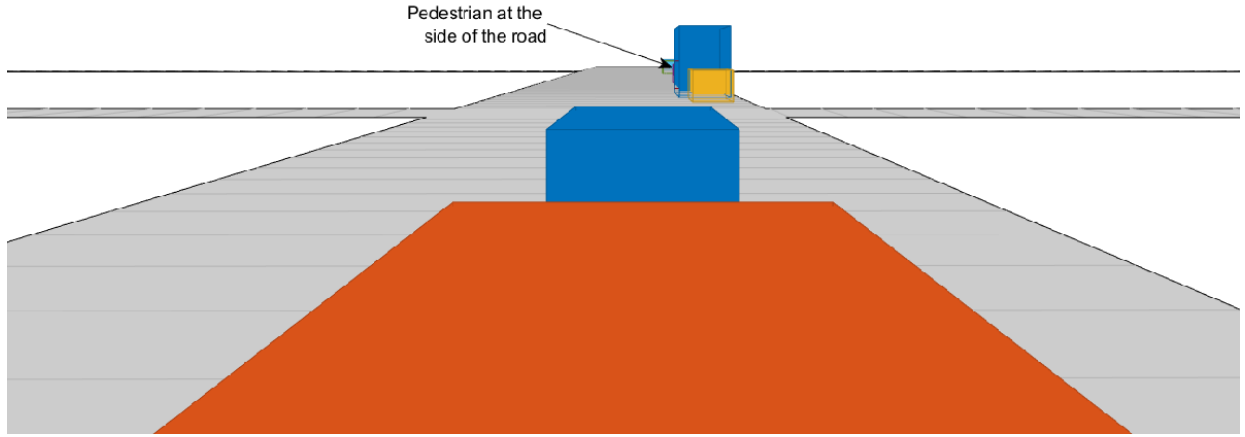


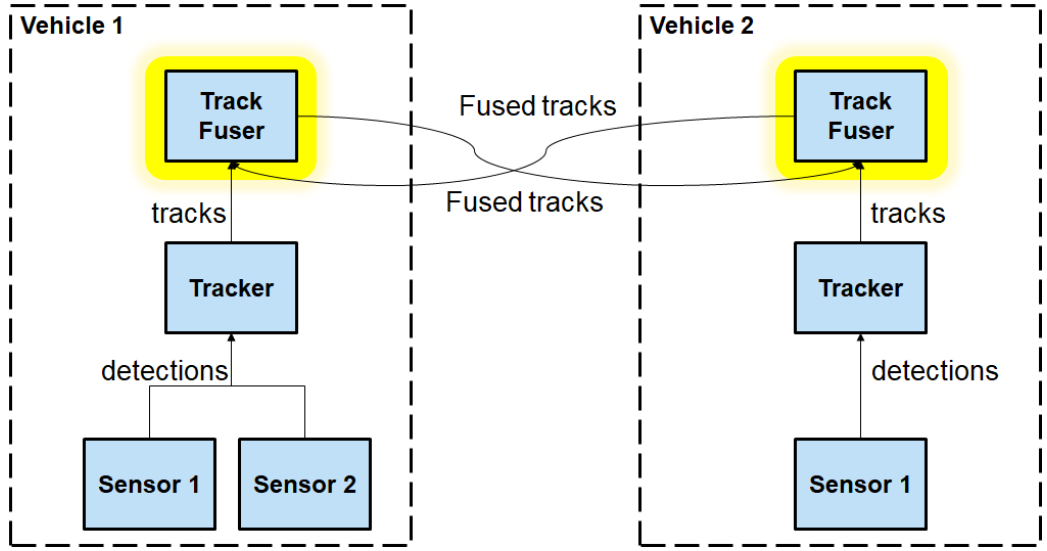
Lower is better



Fusing tracks is also easy



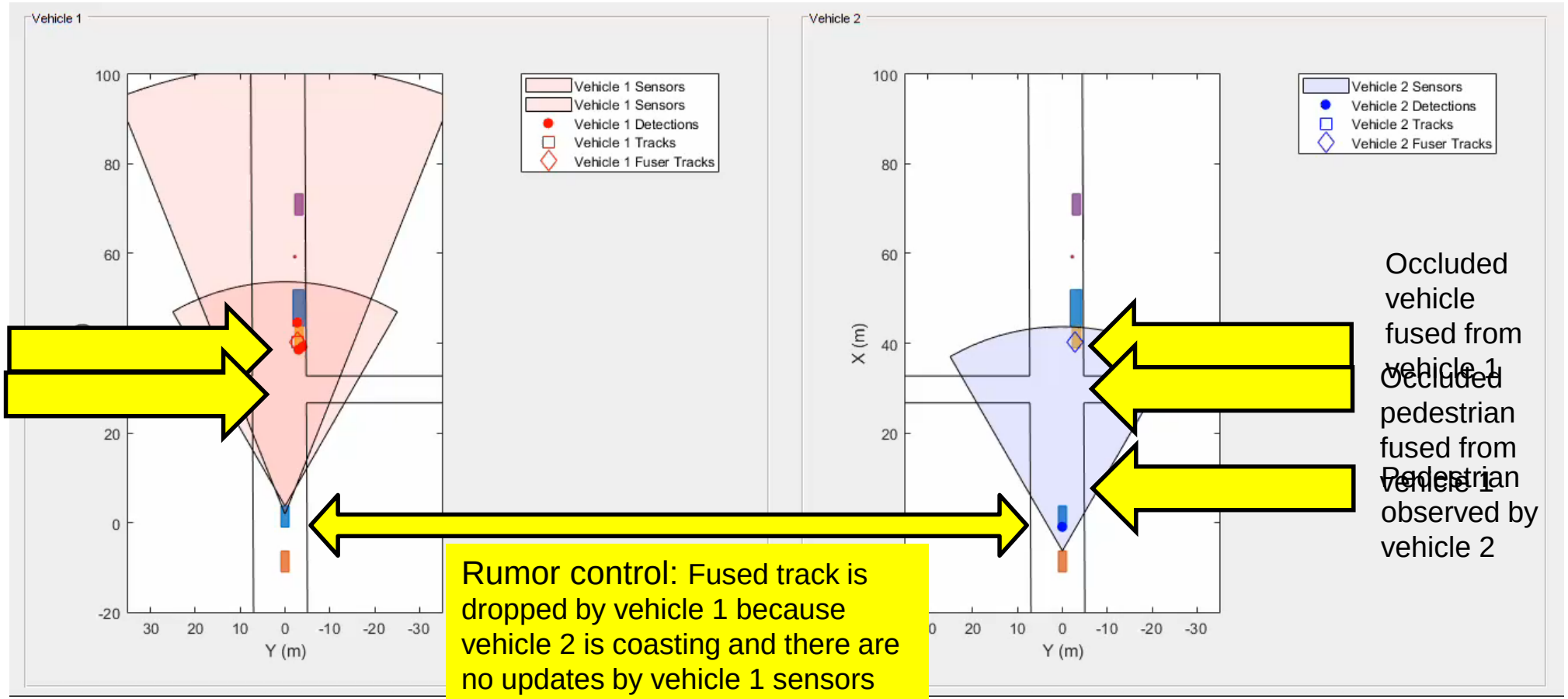




Track-to-Track Fusion

Parked vehicles observed by vehicle 1

Pedestrian observed by vehicle 1



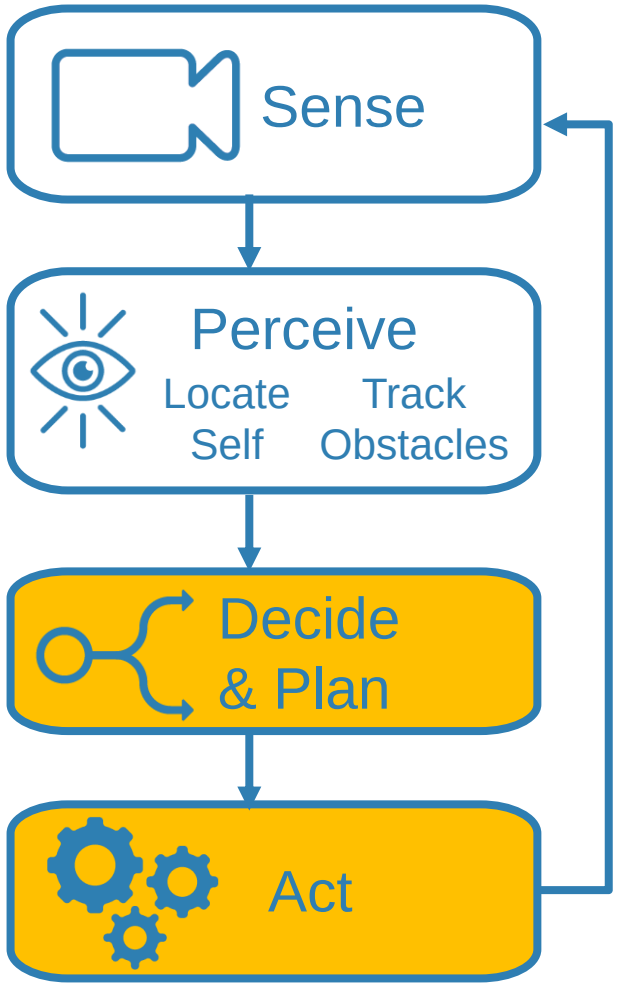
Occluded vehicle fused from vehicle 1

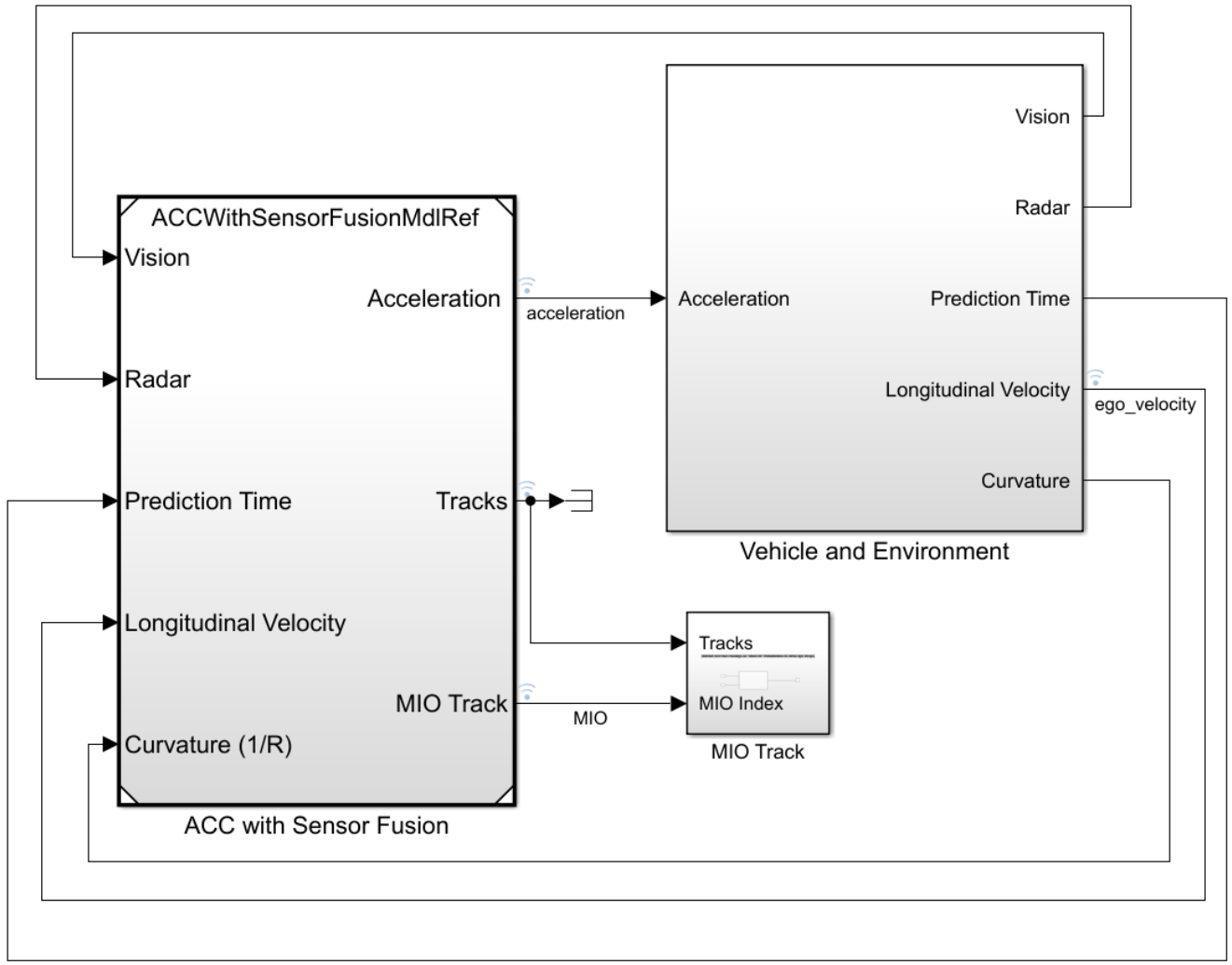
Occluded pedestrian fused from vehicle 1

Pedestrian observed by vehicle 2

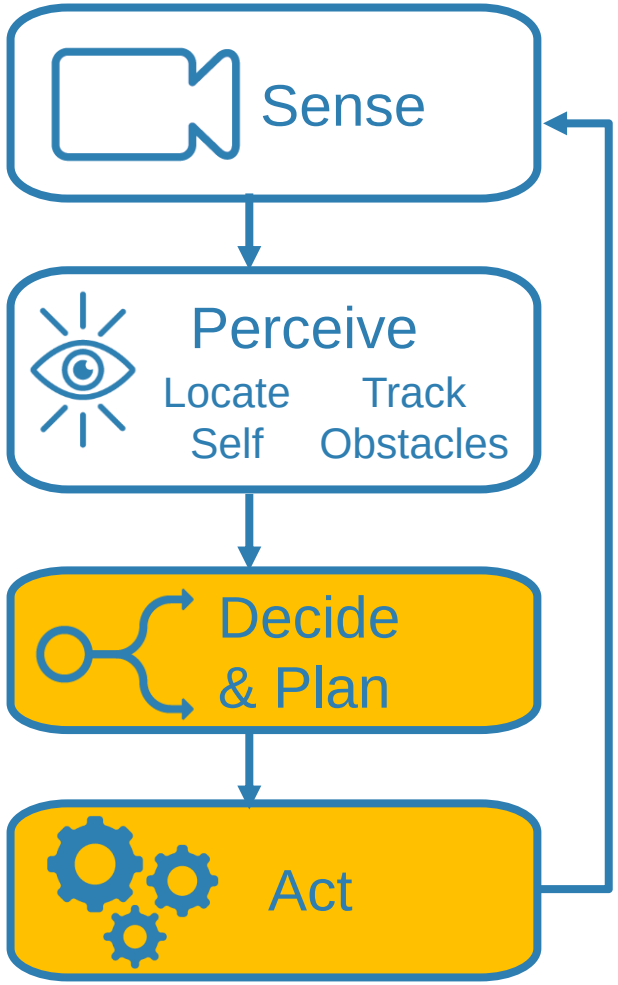
Rumor control: Fused track is dropped by vehicle 1 because vehicle 2 is coasting and there are no updates by vehicle 1 sensors

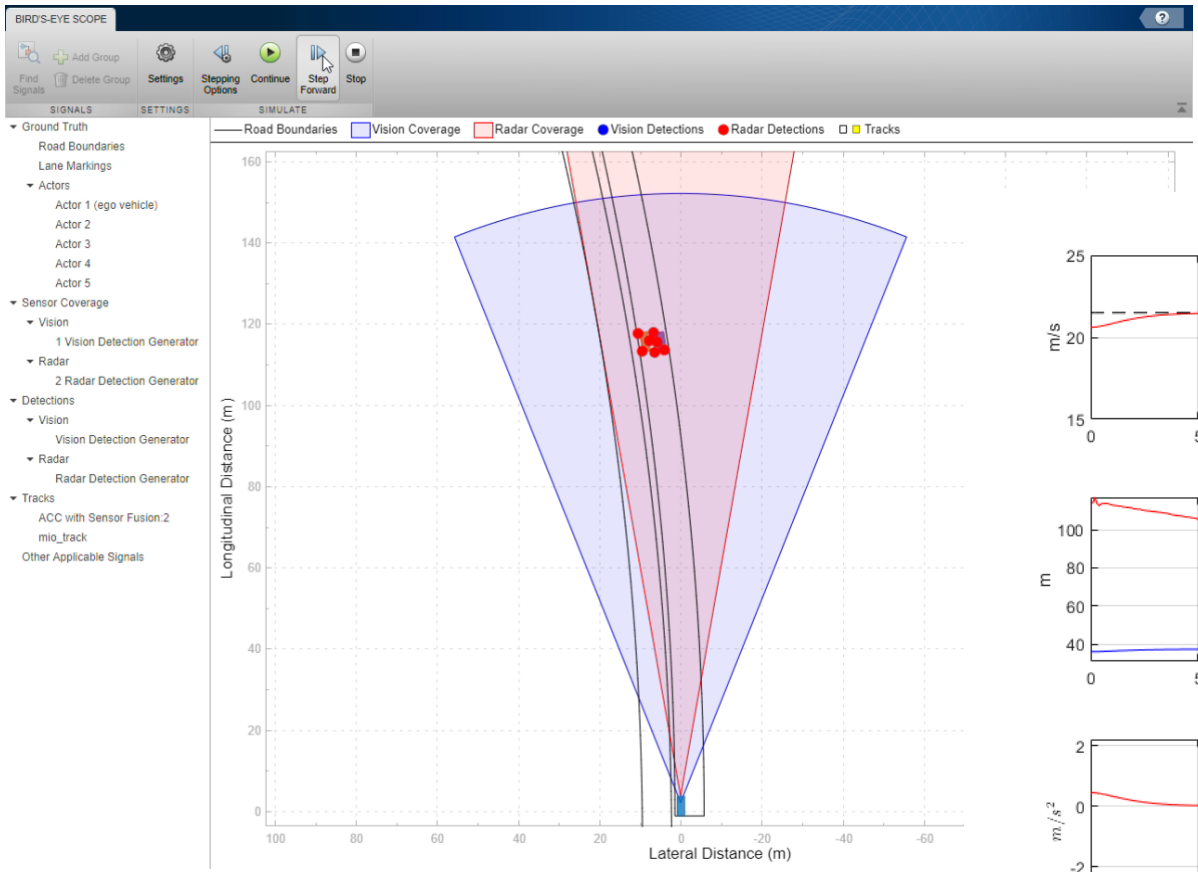
Connect to Decision Making / Control: Adaptive Cruise Control

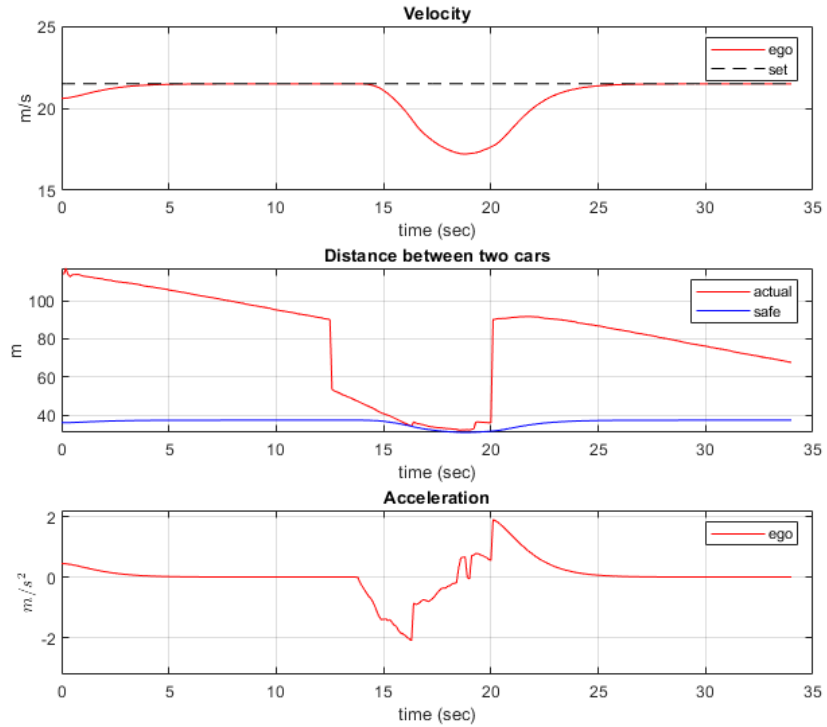




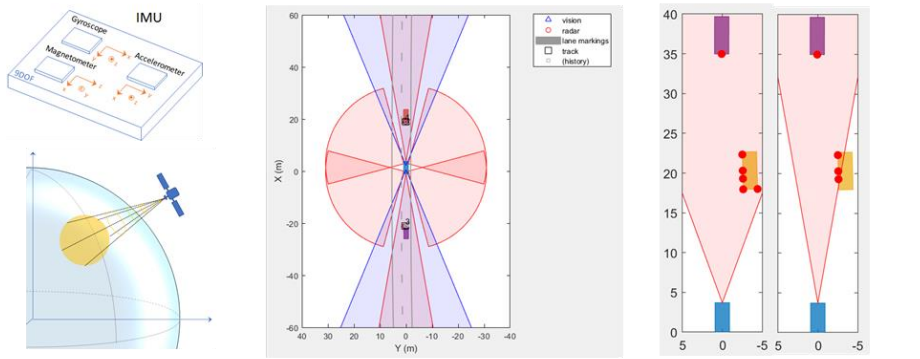
Connect to Decision Making / Control: Adaptive Cruise Control



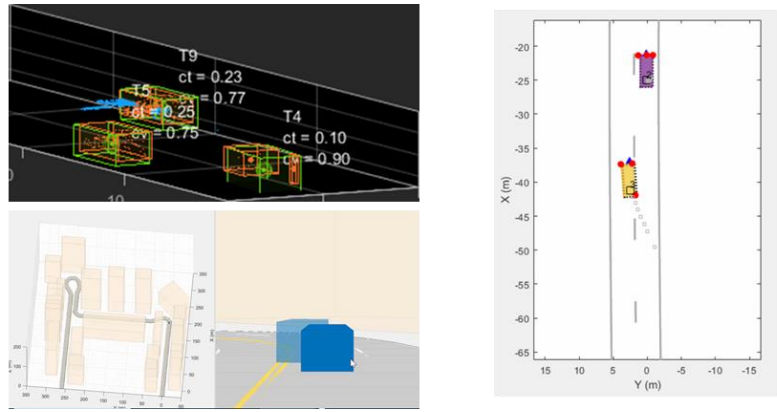




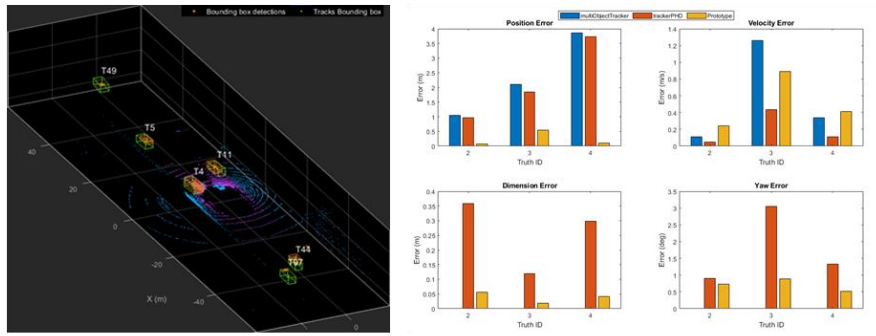
Sensor Fusion and Tracking Toolbox Summary



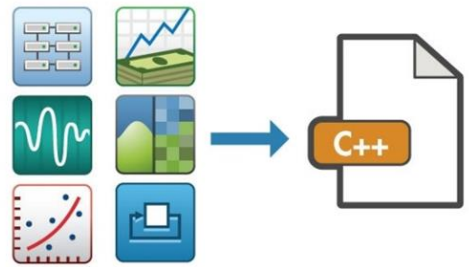
Scenarios and Sensors Simulation



Tracking and Localization Algorithms



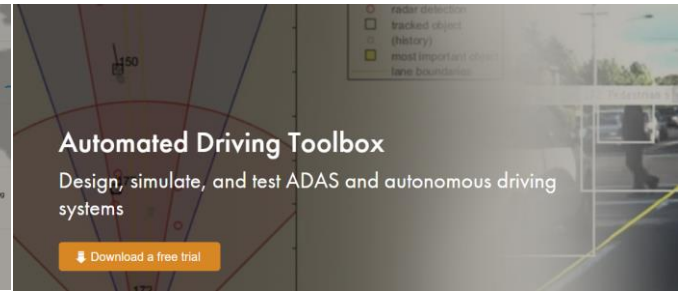
Visualization and Metrics

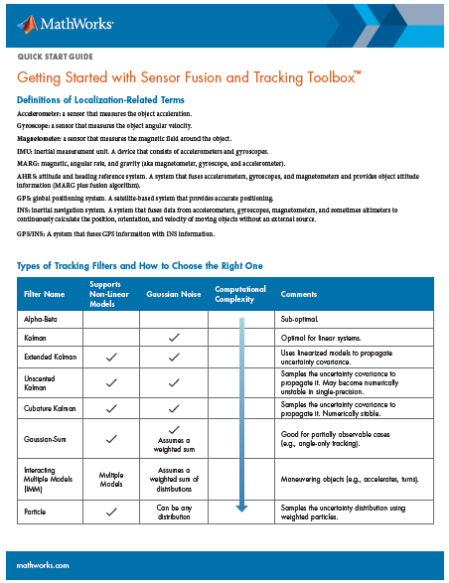


Code Generation

Signal and Image Processing | Sensor Fusion and Tracking | Control

There are many resources to get started with

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QUICK START GUIDE

Getting Started with Sensor Fusion and Tracking Toolbox™

Definitions of Localization-Related Terms

Accelerometer: a sensor that measures the object acceleration.

Gyroscope: a sensor that measures the object angular velocity.

Magnetometer: a sensor that measures the magnetic field around the object.

IMU: inertial measurement unit. A device that consists of accelerometers and gyroscopes.

MARG: magnetic, angular rate, and gravity (aka magnetometer, gyroscope, and accelerometer).

AHRS: attitude and heading reference system. A system that fuses accelerometers, gyroscopes, and magnetometers and provides object attitude information (MARG plus fusion algorithm).

GPS: global positioning system. A satellite-based system that provides accurate positioning.

INS: inertial navigation system. A system that fuses data from accelerometers, gyroscopes, magnetometers, and sometimes altimeters to continuously calculate the position, orientation, and velocity of moving objects without an external source.

GPS/INS: A system that fuses GPS information with INS information.

Types of Tracking Filters and How to Choose the Right One

Filter Name	Supports Non-Linear Models	Gaussian Noise	Computational Complexity	Comments
Alpha-Beta				Sub-optimal
Kalman		✓		Optimal for linear systems.
Extended Kalman	✓	✓		Uses linearized models to propagate uncertainty covariance.
Unscented Kalman	✓	✓		Samples the uncertainty covariance to propagate it. May become numerically unstable in single-precision.
Cubature Kalman	✓	✓		Samples the uncertainty covariance to propagate it. Numerically stable.
Gaussian-Sum	✓	✓ Assumes a weighted sum		Good for partially observable cases (e.g., angle-only tracking).
Interacting Multiple Models (IMM)	Multiple Models	Assumes a weighted sum of distributions		Maneuvering objects (e.g., accelerates, turns).
Particle	✓	Can be any distribution		Samples the uncertainty distribution using weighted particles.

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Quick Start Guide

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.

Part 3: Fusing a GPS and IMU to Estimate Pose
This video describes how we can use a GPS and an IMU to estimate an object's orientation and position. We'll go over the structure of the algorithm and show you how the GPS and IMU both contribute to the final solution.

Part 4: Tracking a Single Object With an IMM Filter
This video describes how we can track a single object by estimating state with an interacting multiple model filter. We build up some intuition about the IMM filter and show how it is a better tracking algorithm than a single model Kalman filter.

Part 5: How to Track Multiple Objects at Once
This video describes two common problems that arise when tracking multiple objects: data association and track maintenance. We cover a few ways to solve these issues and provide a general way to approach all multi-object tracking problems.

Please visit to see our Tech Showcase demos