MATLAB EXPO 2019

Sensor Fusion and Tracking for Autonomous Systems

Rick Gentile
Product Manager, Radar and Sensor Fusion
rgentile@mathworks.com
Capabilities of an Autonomous System
Capabilities of an Autonomous System

Sense

Perceive
Capabilities of an Autonomous System

Sense

Perceive

Decide & Plan

Act
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

- Accelerometer, Magnetometer, Gyro, GPS...

Situational awareness

- 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

- Vision measurement at time step k
- Radar measurement at time step k
- Fused estimate at time step k
- Fused estimate at time step k - 1
- Predicted estimate at time step k

Legend:
- Vision Measurement
- Radar measurement
- Track (fused estimate)
- Ellipse represents uncertainty
What is localization?
Fusing sensor data improves localization

Sense

Perceive
Locate
Self

Decide
& Plan

Act

Ground truth vs. Estimate

Sensors

Error Measurements

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Self-awareness is needed to create situational awareness.
Flexible Workflows Ease Adoption: Wholesale or Piecemeal

Scenario Definition and Sensor Simulation

- Ownship Trajectory Generation
- Actors/Platforms
- INS Sensor Simulation
- Radar, IR, & Sonar Sensor Simulation

Algorithms

- INS Filter, Tracker, etc..

Recorded Sensor Data

Documented Interface for detections

Documented Interface for tracks

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

Two targets seen as one by the radar

1° Azimuth Resolution

Did the trajectories cross?
Perform quick what-if analyses between different trackers

>> trackerGNN, CV

>> trackerTOMHT, IMM
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

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

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Tracking with Lidar (with ground truth shown)
Extended Object Tracking: Estimate position, velocity, and size

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Evaluate tracker performance of Extended Objects
Fusing tracks is also easy

- Sense
- Perceive
  - Locate
  - Self
  - Track
  - Obstacles
- Decide & Plan
- Act
Track-to-Track Fusion

Parked vehicles observed by vehicle 1
Pedestrian observed by vehicle 1

Occluded vehicle fused from vehicle 1 pedestrian fused from 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

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ACCWithSensorFusionMdlRef

ACC with Sensor Fusion

Locate  Track
Self  Obstacles

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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 Tech Talks

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 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 maintainance. We cover a few ways to solve these issues and provide a general way to approach all multi-object tracking problems.

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