Sensor Fusion and Navigation for Autonomous Systems Using MATLAB & Simulink
Smart autonomous package delivery

① Autonomous Driving

Manufacturer

② Warehouse Automation

③ Last Mile Delivery

Consumer
Capabilities of an Autonomous System

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

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

Perception ➔ Planning

- 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

- 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

Scenario Definition and Sensor Simulation

- Ownship Trajectory Generation
- Actors/Platforms
- INS (IMU, GPS) Sensor Simulation
- Lidar, Radar, IR, & Sonar Sensor Simulation

Multi-object Trackers
Fusion for orientation and position
SLAM

Visualization & Metrics

Perception
- Localization
- Mapping
- Tracking

Planning

Control
Live data can be augmented for a more robust testbench

Perception
- Localization
- Mapping
- Tracking

Planning

Control

Define scenarios

Simulate sensors
Estimate the pose using Monte Carlo Localization

- Perception
  - Localization
  - Mapping
  - Tracking

- Planning

- Control

Motion Model (Odometry readings)

Particle Filter

Sensor Model (Lidar scan)

Known Map
What is the world around me?

Egocentric occupancy maps

- Support dynamic environment changes
- Synchronization between global and local maps
What is the world around me?

3D Occupancy Map

- Perception
  - Localization
  - Mapping
  - Tracking

- Planning

- Control

3D map for Autonomous Driving

3D map for UAV motion planning
Where am I in the unknown environment?
Simultaneous Localization and Mapping (SLAM)

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

Perception
- SLAM
  - Localization
  - Mapping
  - Tracking

Planning

Control
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

- Perception
  - SLAM
    - Localization
    - Mapping
    - Tracking
- Planning
- Control

SLAM

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

Computer Vision

Navigation

MATLAB EXPO

MathWorks®
Autonomous systems can track objects from Lidar point clouds

Track Objects Using Lidar: From Point Cloud to Track List

- Perception
  - Localization
  - Mapping
  - Tracking

Planning

Control

Track surrounding objects during automated lane change
2D radar can be used to track position, size, and orientation.

Perception
- Localization
- Mapping
- Tracking

Planning

Control
Fusing multiple sensor modalities provides a better result

- Perception
  - Localization
  - Mapping
  - Tracking

- Planning

- Control

- 2-D Radars

- 3-D Lidar
  - Point Cloud

- Track-level Fusion

- Fused 3-D Cuboid Tracks
Radar and Lidar fusion can increase tracking performance
Find shortest path to the destination

Global Planning

Local Re-planning

Perception
- Localization
- Mapping
- Tracking

Planning

Control

Initial Location

Goal Location

Initial Route to Package

Forklift Route to Package
Find shortest path to the destination

- **Motion Planning**
  - Path Planning & trajectory generation

- **Behavior Planning**
  - High-level decision making

- **Mission Planning**
  - High-level route planning

**Perception**
- Localization
- Mapping
- Tracking

**Planning**

**Control**
Urban driving needs planning on two levels, global and local

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

Perception
- Localization
- Mapping
- Tracking

Planning

Control
Simulate shortest path to change lanes on a highway

Perception
- Localization
- Mapping
- Tracking

Planning

Control

Simulate trajectory generation and the lane change maneuver
Mission planning for UAV leads to last mile delivery

Perception
- Localization
- Mapping
- Tracking

Planning

Control
Choose a path planner based on your application

- Perception
  - Localization
  - Mapping
  - Tracking

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

Perception
- Localization
- Mapping
- Tracking

Planning

Control
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

Approximate High-Fidelity Model with Low-Fidelity Model
Generate code and deploy sensor fusion and navigation algorithms.
In this talk, we learnt about:

- Localization
- Mapping
- Tracking
- Perception
- Global/Mission Planning
- Local Re-planning
- Path Following / Tracking
- Control
Full Model Based Design Workflow for Autonomous Systems

**Verification & Validation**

**Connect / Deploy**

**Autonomous Algorithms**

**Platform**

- Sensor Fusion and Tracking Toolbox
- Computer Vision Toolbox
- ROS Toolbox
- AUTOSAR Blockset
- Automated Driving Toolbox
- Robotics System Toolbox
- Control Toolbox
- Reinforcement Learning Toolbox
- Stateflow
- Model Predictive Control Toolbox
- Navigation Toolbox
- Code Generation

**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 details 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.

Please visit our Tech Showcase demos
Thank you!

Questions?