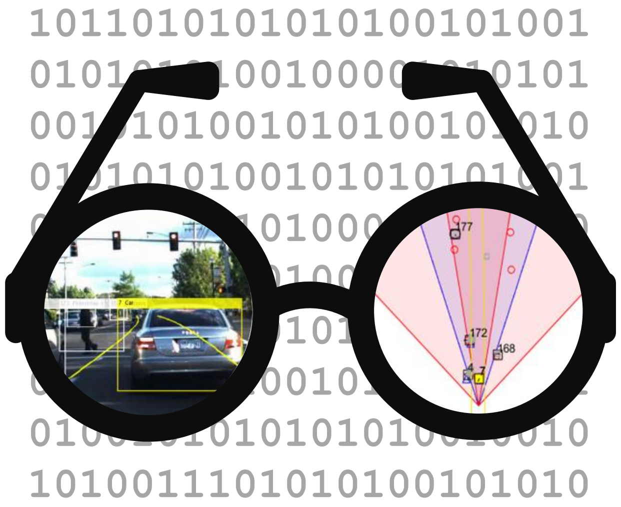
MATLAB EXPO 2017

Automated Driving: Design and Verify Perception Systems

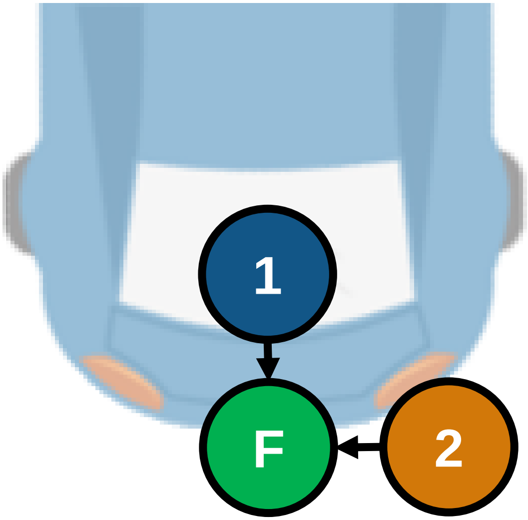
Giuseppe Ridinò

Some common questions from automated driving engineers



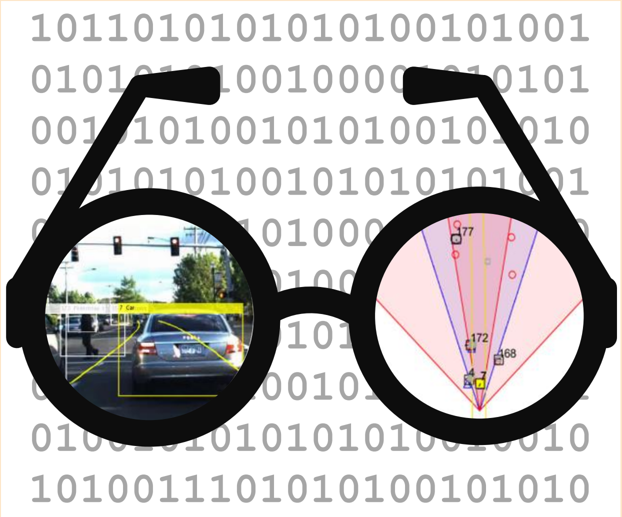
How can I visualize vehicle data?

How can I detect objects in images?



How can I fuse multiple detections?

Some common questions from automated driving engineers



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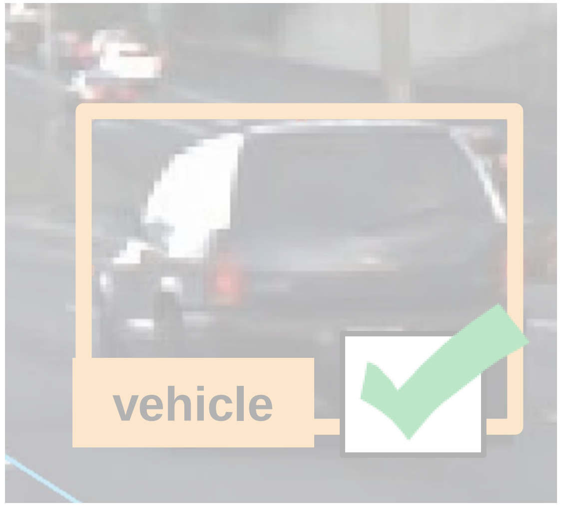

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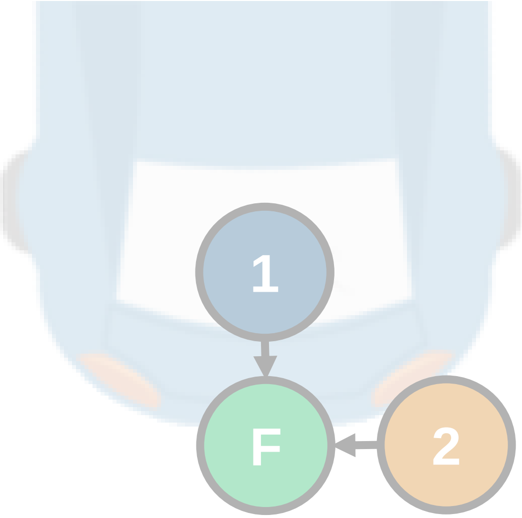


How can I fuse multiple detections?

Examples of automated driving sensors

Camera

Radar-based object detector

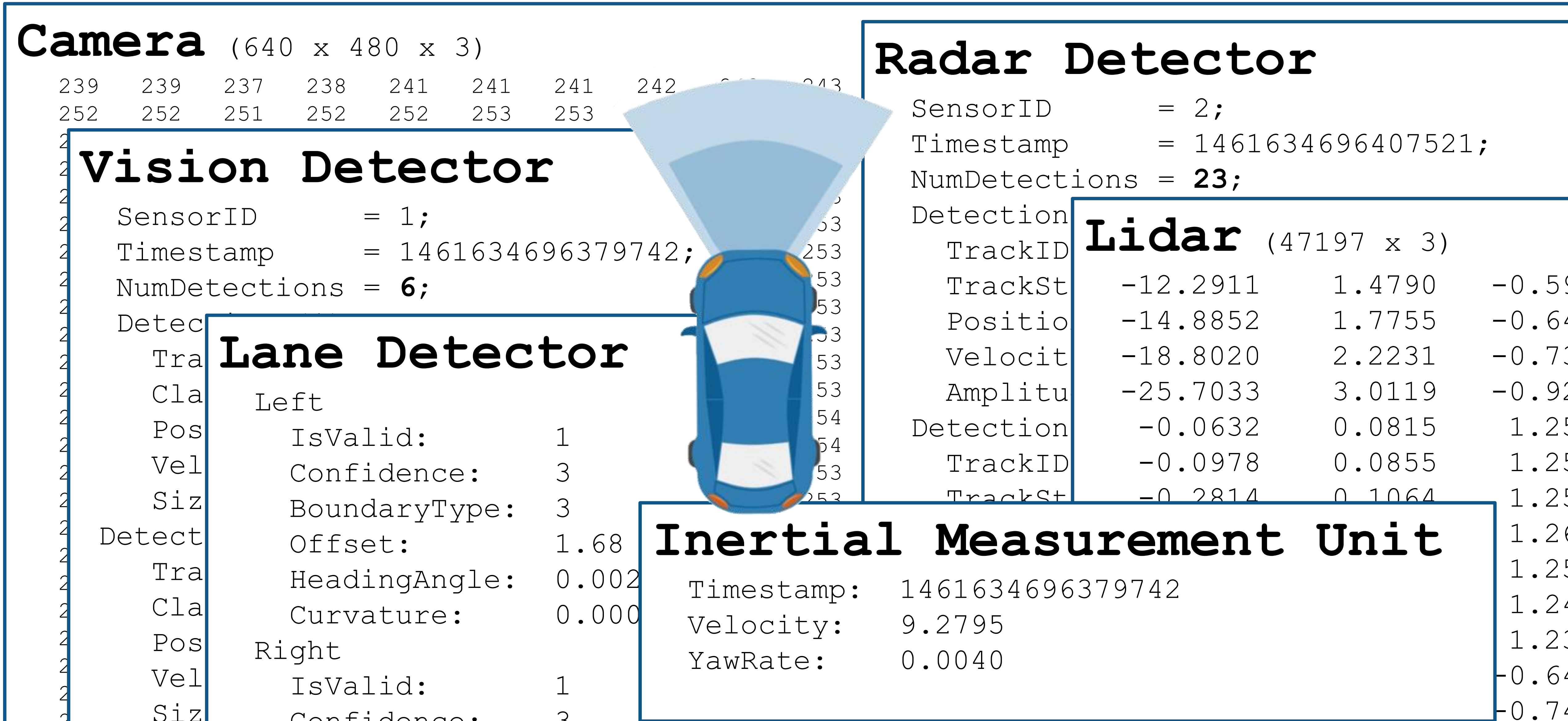
Vision-based object detector

Lidar

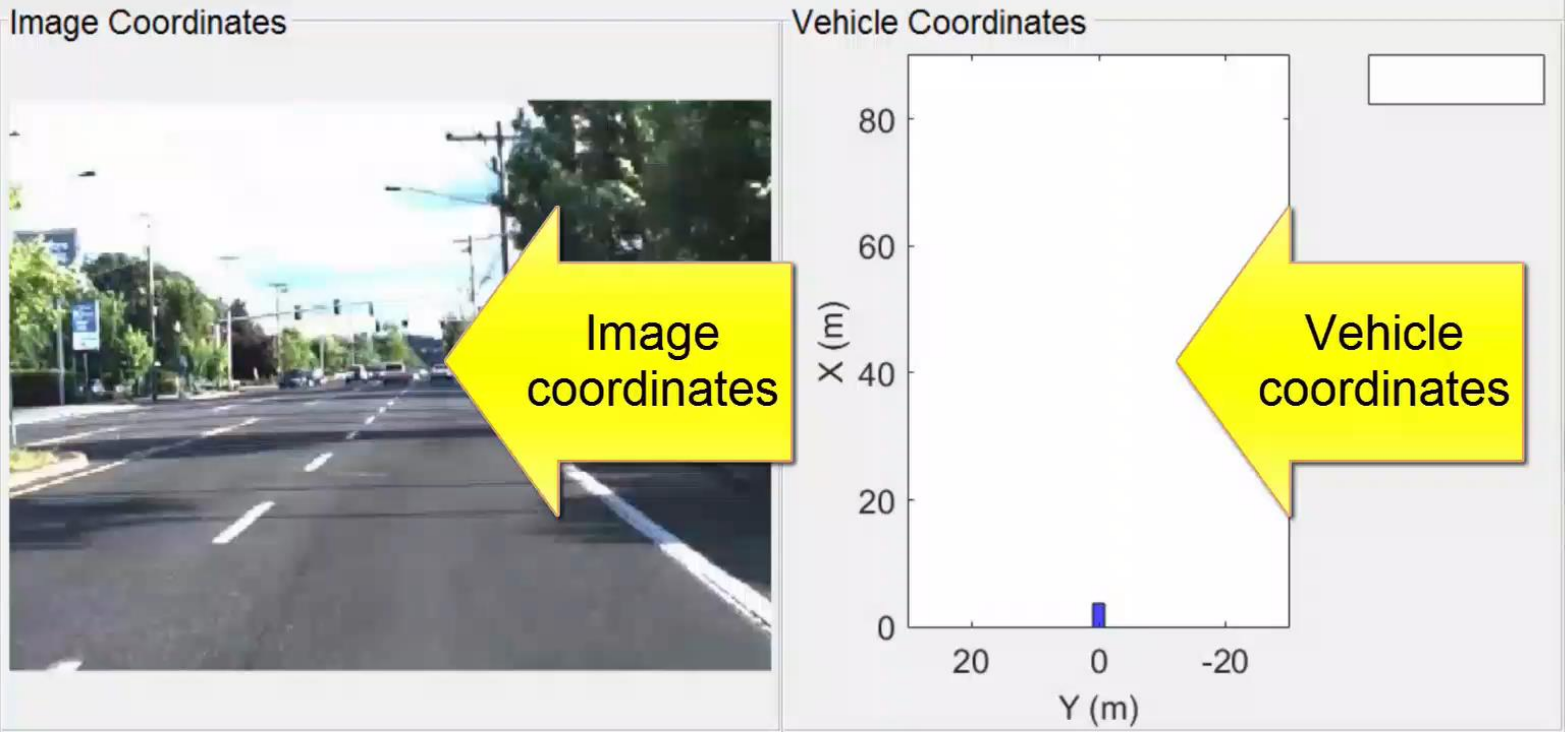
Lane detector

Inertial measurement unit

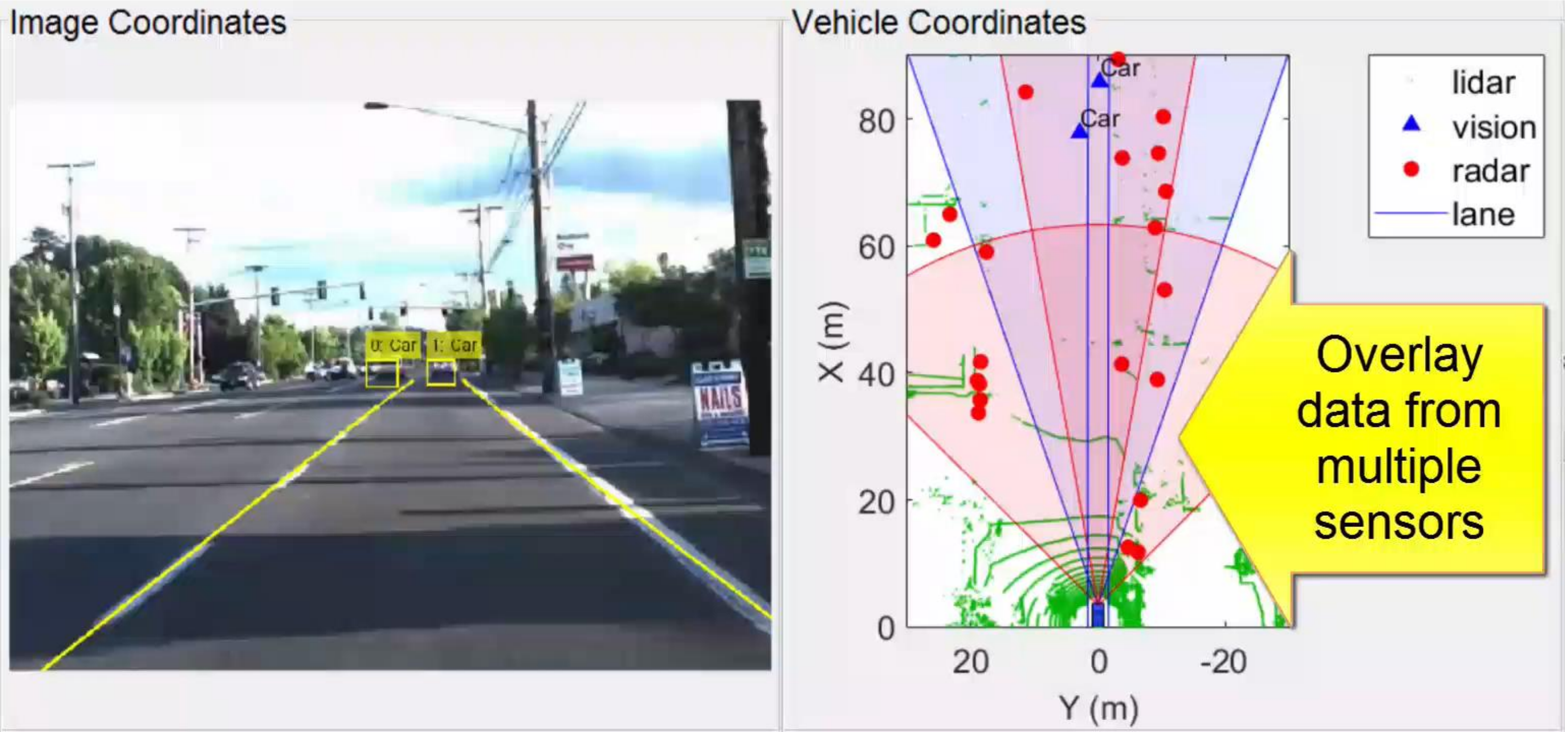
Examples of automated driving sensor data



Visualize sensor data



Visualize differences in sensor detections



Explore logged vehicle data

- Load **video data** and corresponding **mono-camera parameters**

```
>> video = VideoReader('01_city_c2s_fcw_10s.mp4')
>> load('FCWDemoMonoCameraSensor.mat', 'sensor')
```

- Load **detection sensor data** and corresponding **parameters**

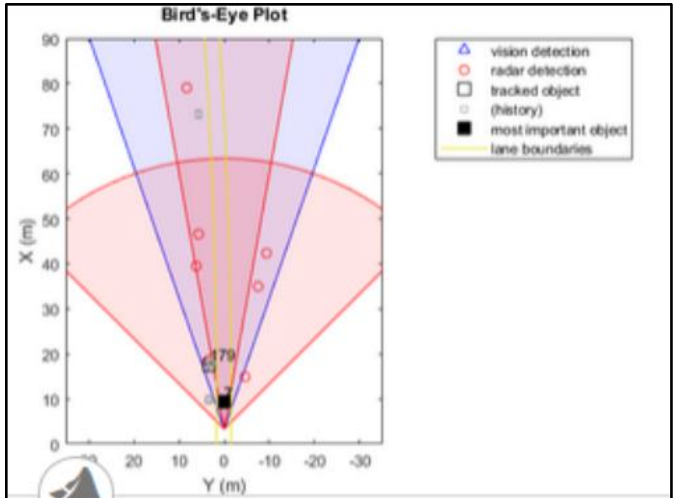
```
>> load('01_city_c2s_fcw_10s_sensor.mat', 'vision','lane','radar')
>> load('SensorConfigurationData.mat', 'sensorParams')
```

- Load **lidar point cloud data**

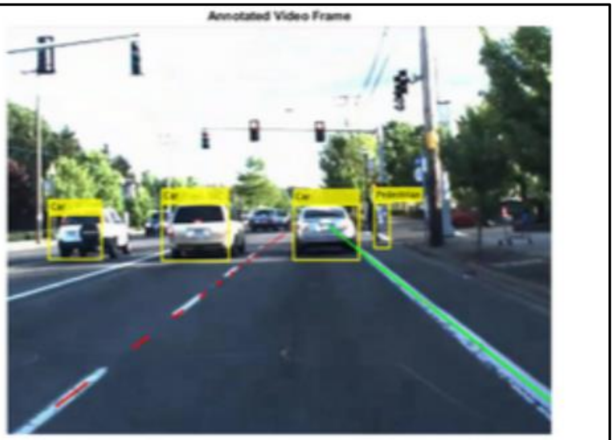
```
>> load('01_city_c2s_fcw_10s_Lidar.mat', 'LidarPointCloud')
```

Learn more about visualizing vehicle data

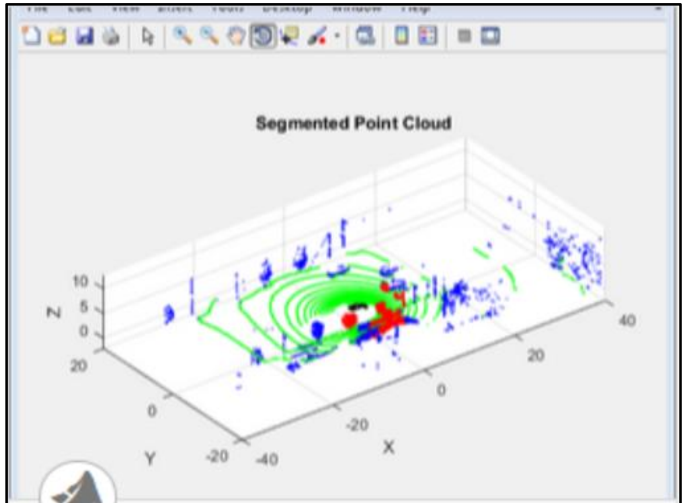
by exploring examples in the Automated Driving System Toolbox



Visualize Sensor Coverage, Detections, and Tracks



Annotate Video Using Detections in Vehicle Coordinates



Ground Plane and Obstacle Detection Using Lidar

- **Plot object detectors in vehicle coordinates**
  - Vision & radar detector
  - Lane detectors
  - Detector coverage areas
- **Transform between vehicle and image coordinates**
- **Plot lidar point cloud**

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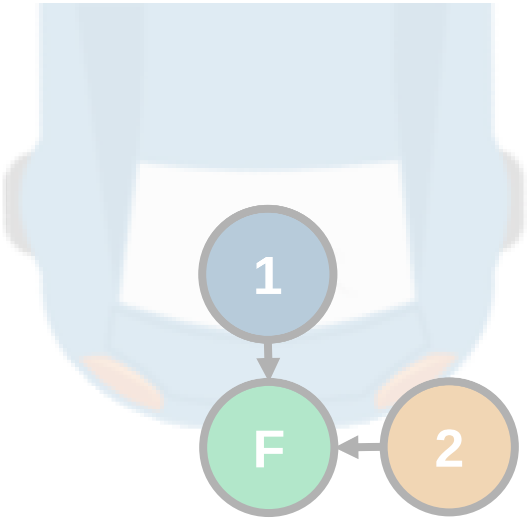
How can I visualize vehicle data?

How can I detect objects in images?



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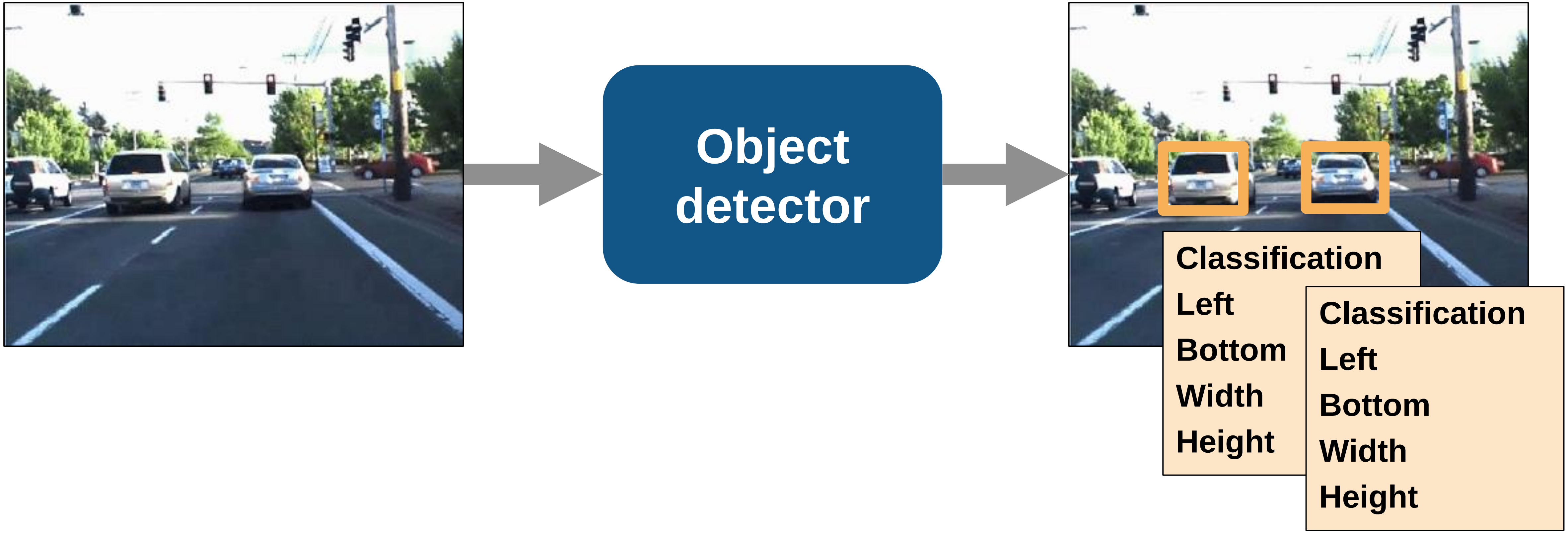
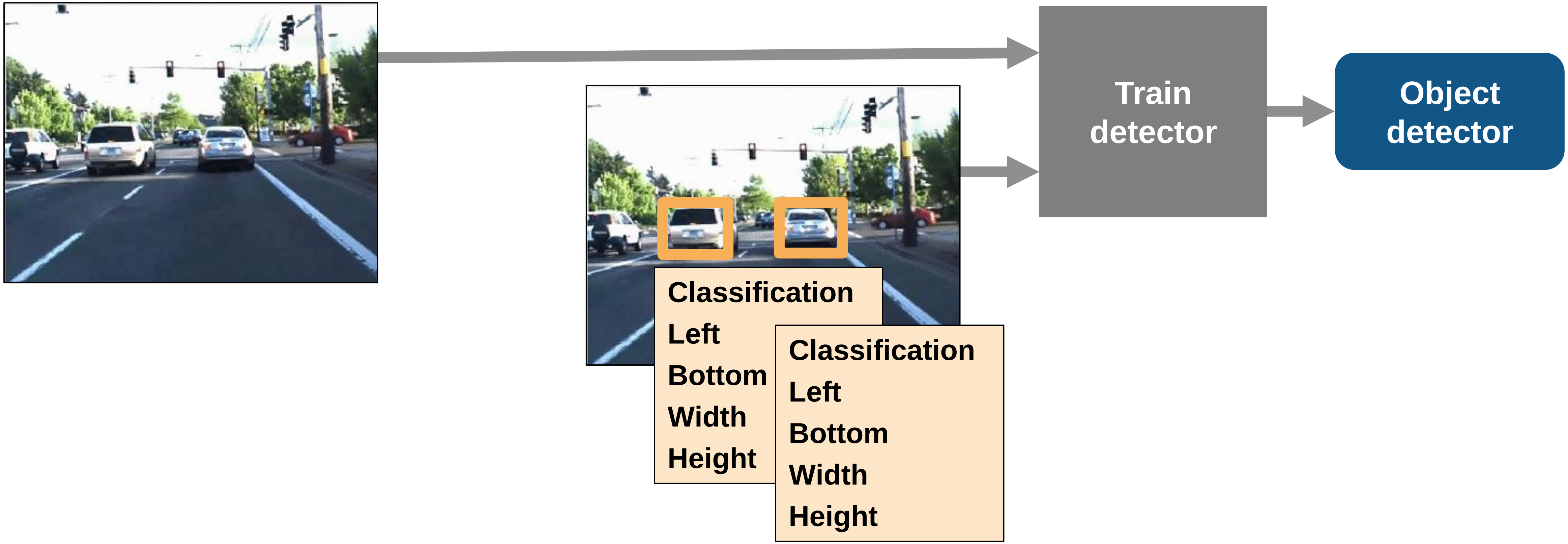


Train object detectors based on ground truth



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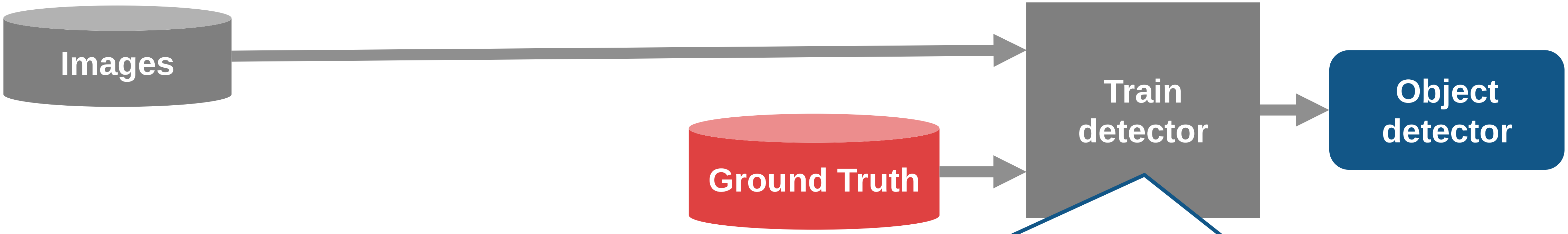
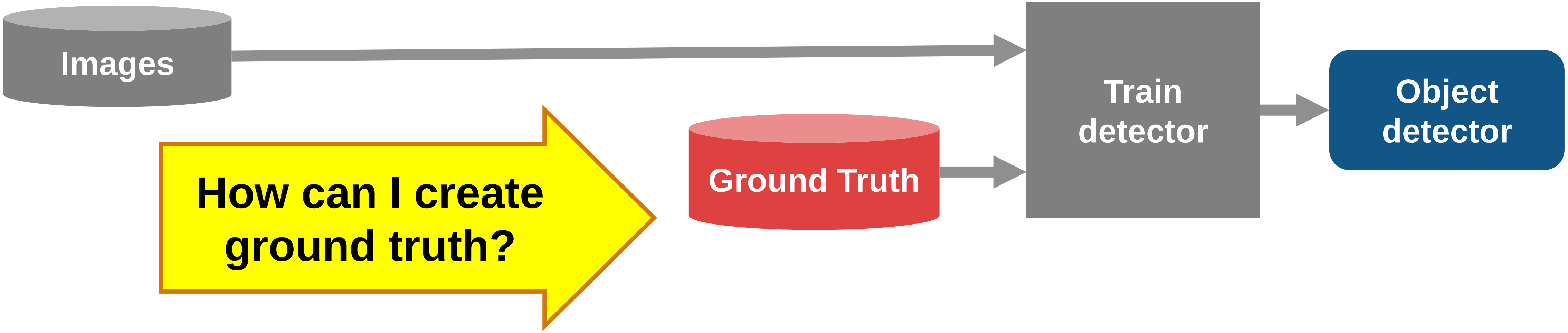


Design object detectors with the Computer Vision System Toolbox

Machine Learning	Aggregate Channel Feature	`trainACFObjectDetector`
	Cascade	`trainCascadeObjectDetector`
Deep Learning	R-CNN (Regions with Convolutional Neural Networks)	`trainRCNNObjectDetector`
	Fast R-CNN	`trainFastRCNNObjectDetector`
	Faster R-CNN	`trainFasterRCNNObjectDetector`

Specify ground truth to train detector



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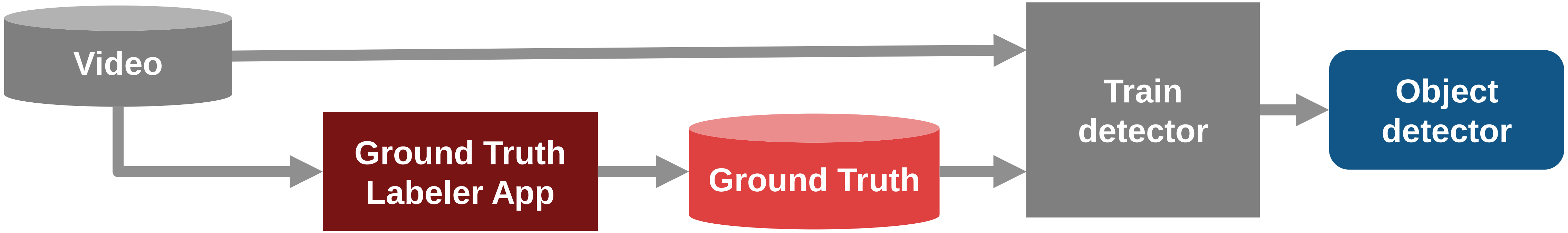
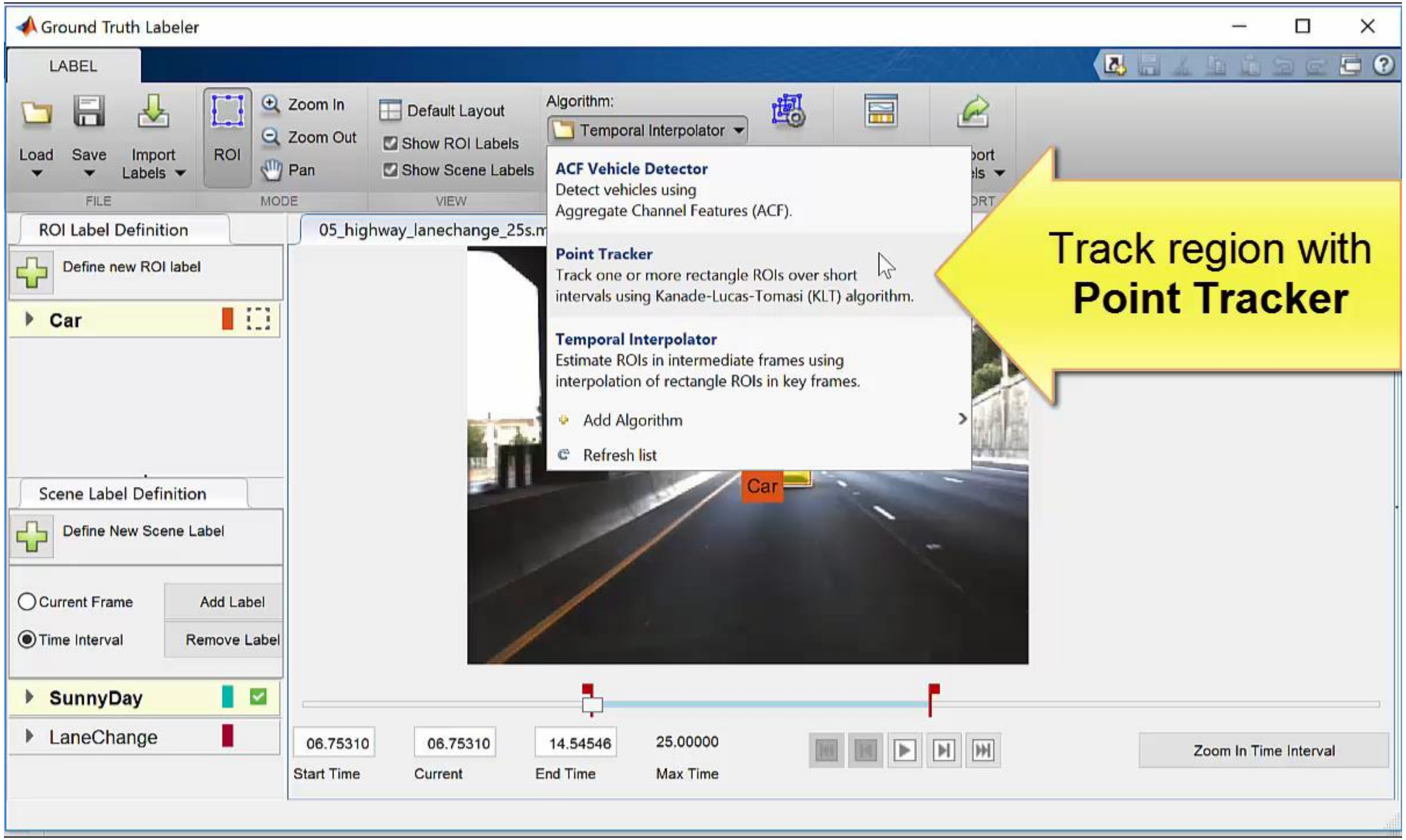
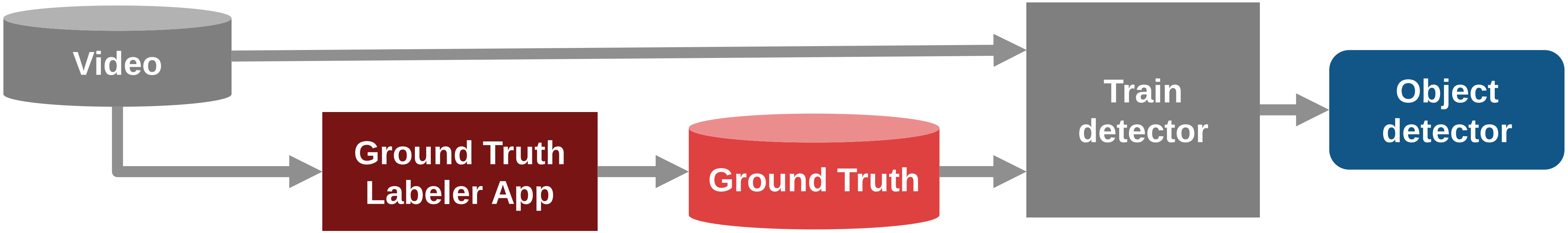


Automate labeling based on a manually labeled frame

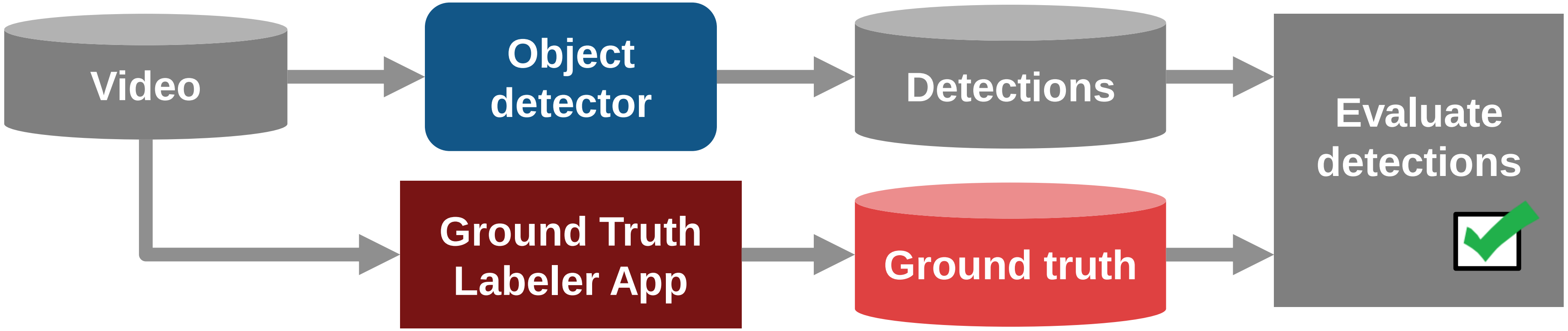
with point tracker



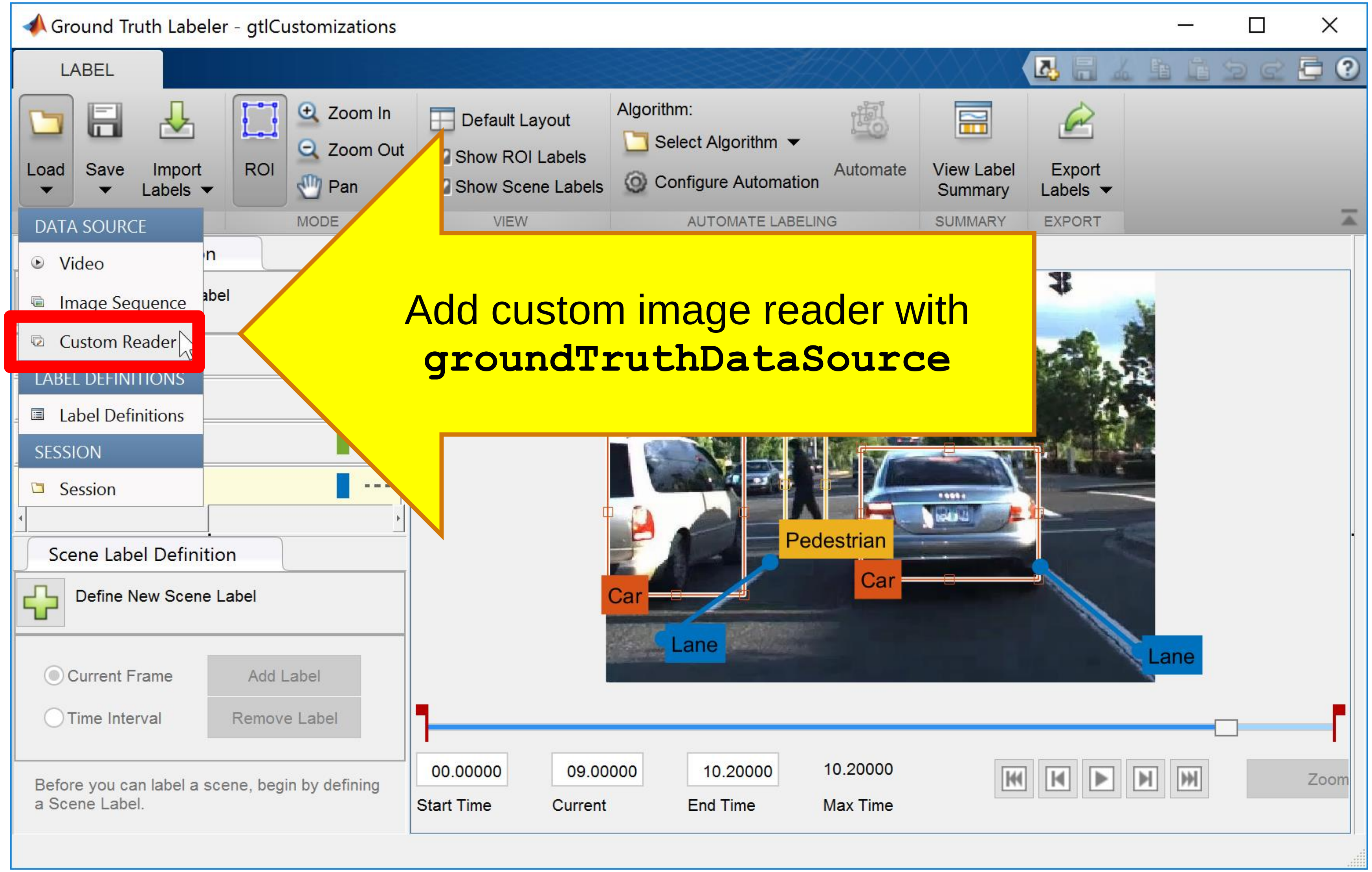
Ground truth labeling to train detectors



Ground truth labeling to evaluate detectors



Customize Ground Truth Labeler App



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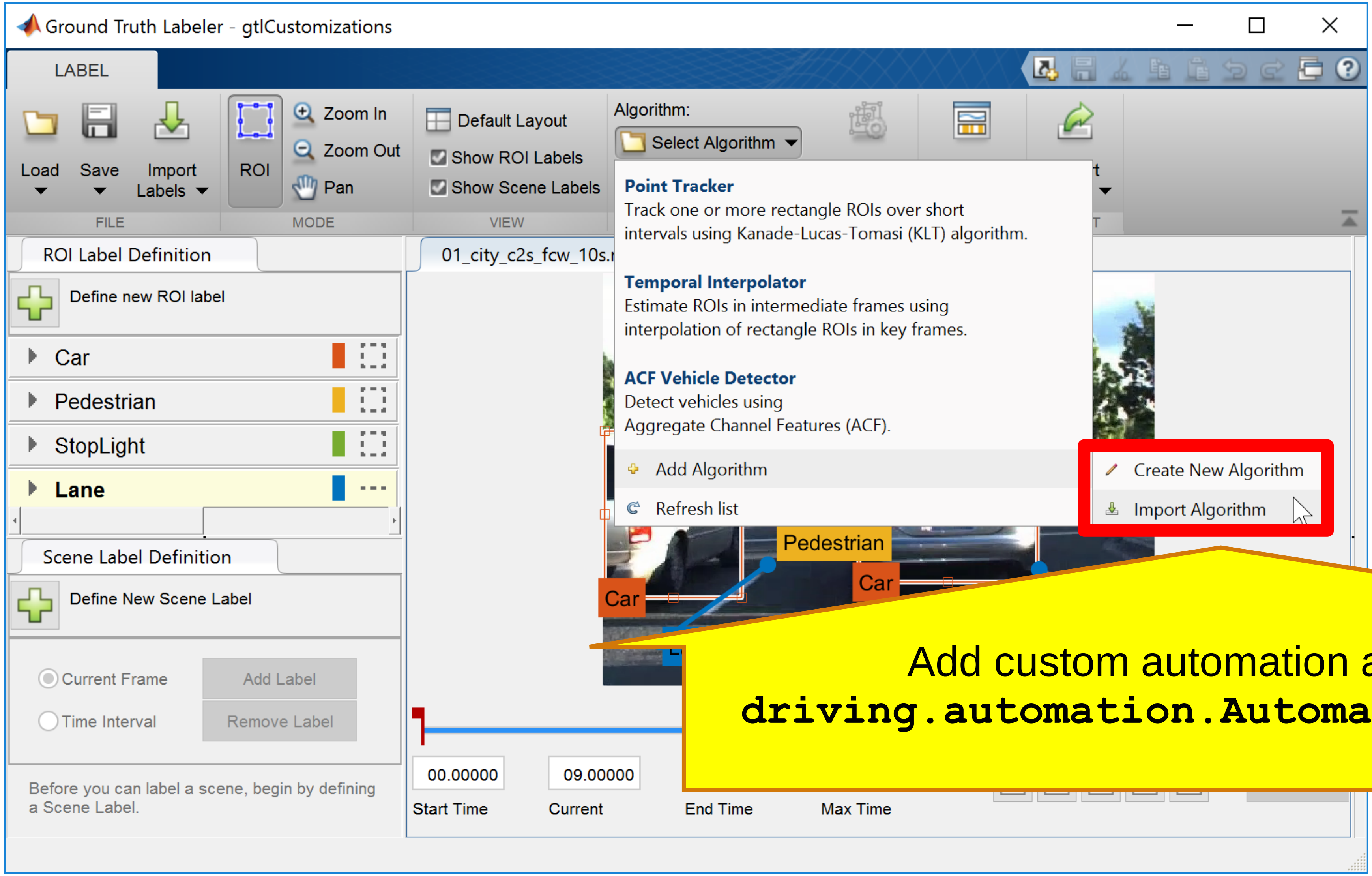
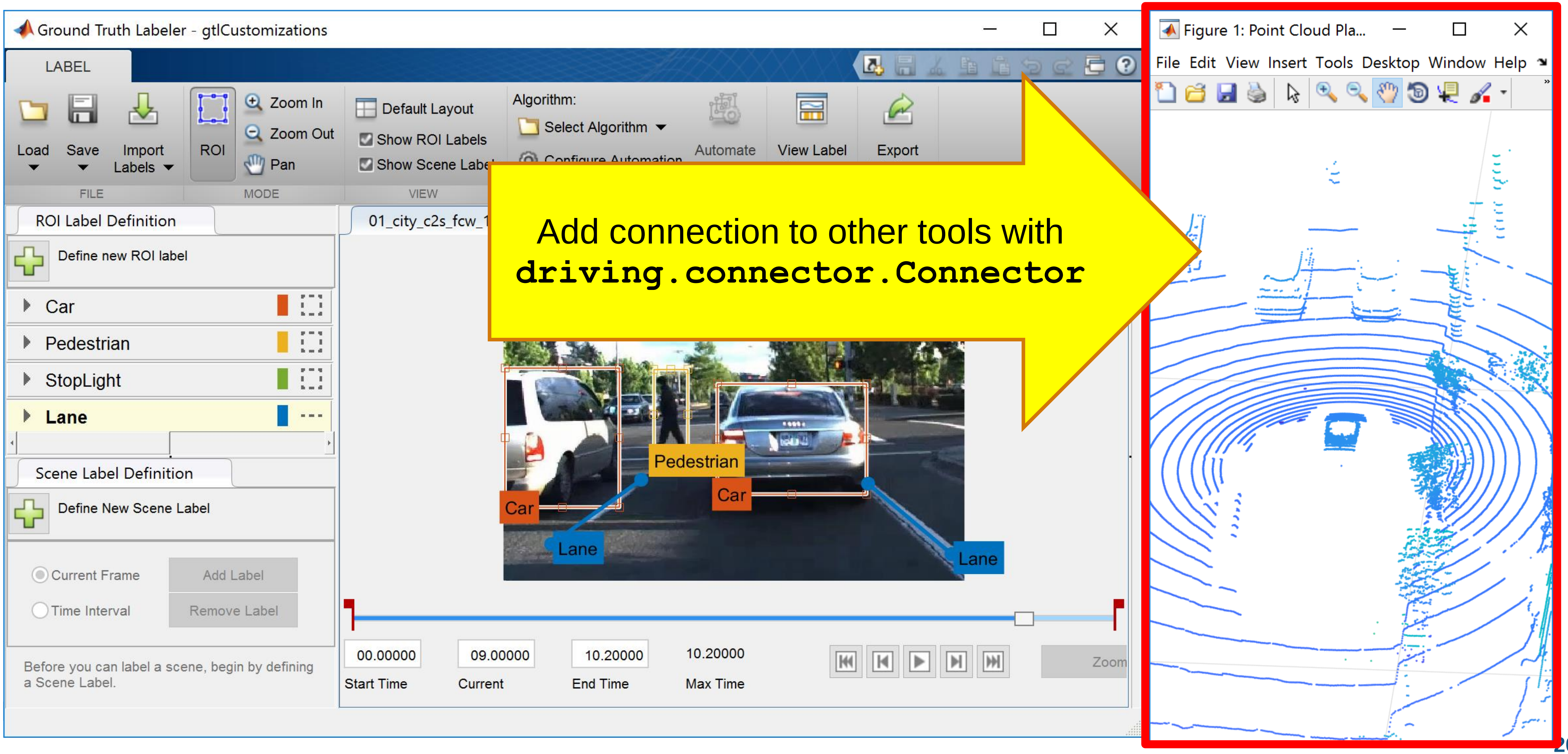


Add custom automation algorithm
`driving.automation.AutomationAlgorithm`

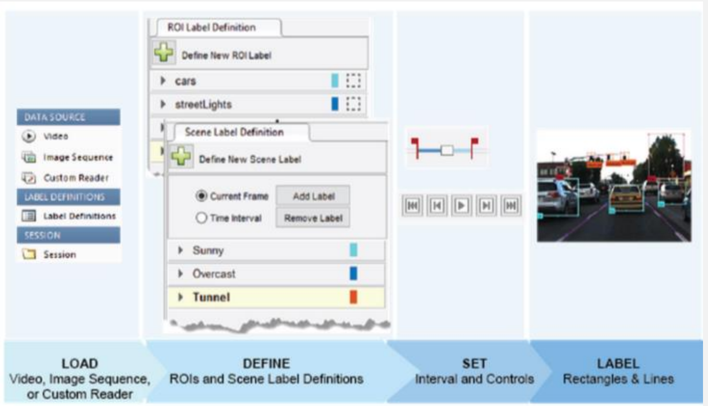
Customize Ground Truth Labeler App



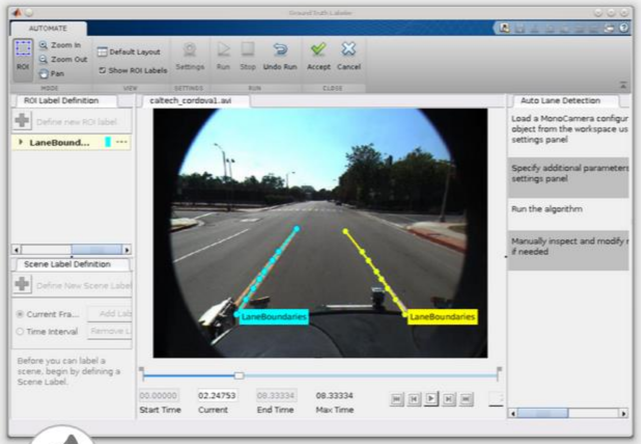
Add connection to other tools with `driving.connector.Connector`

Learn more about detecting objects in images

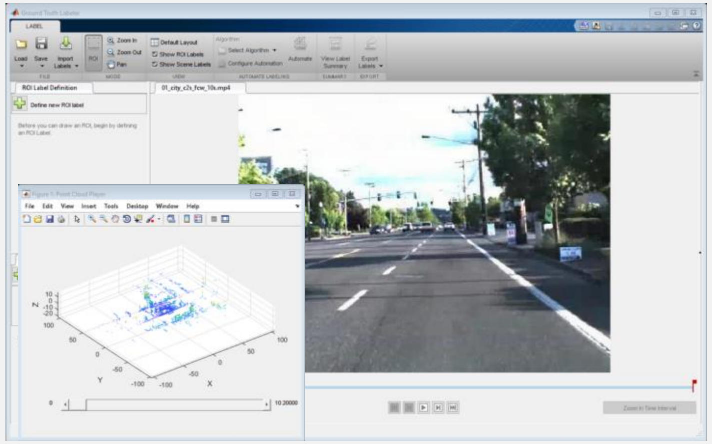
by exploring examples in the Automated Driving System Toolbox



Define Ground Truth Data for Video or Image Sequences



Automate Ground Truth Labeling of Lane Boundaries



driving.connector.Connector class

Connect Lidar Display to Ground Truth Labeler

- **Label detections** with Ground Truth Labeler App
- **Add automation algorithm** for lane tracking
- **Extend connectivity** of Ground Truth Labeler App

Learn more about detecting objects in images

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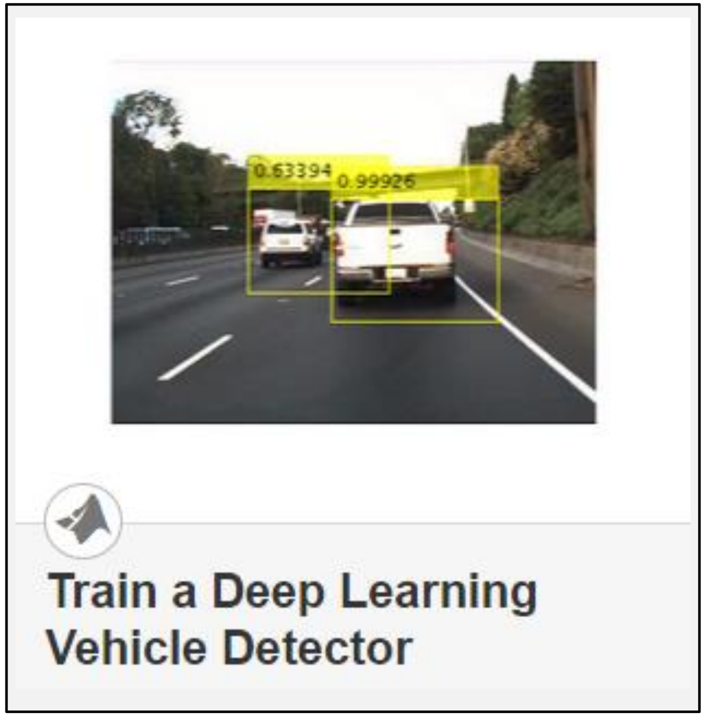

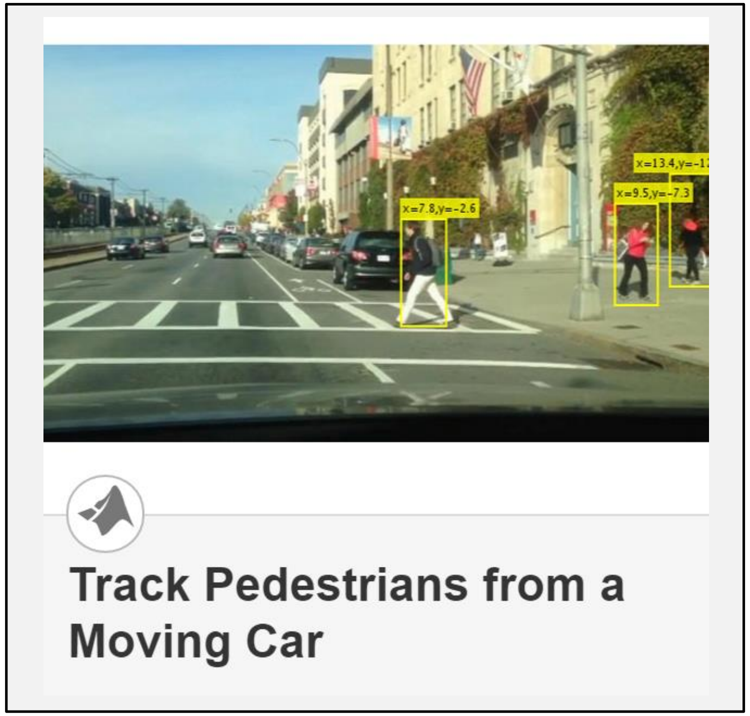

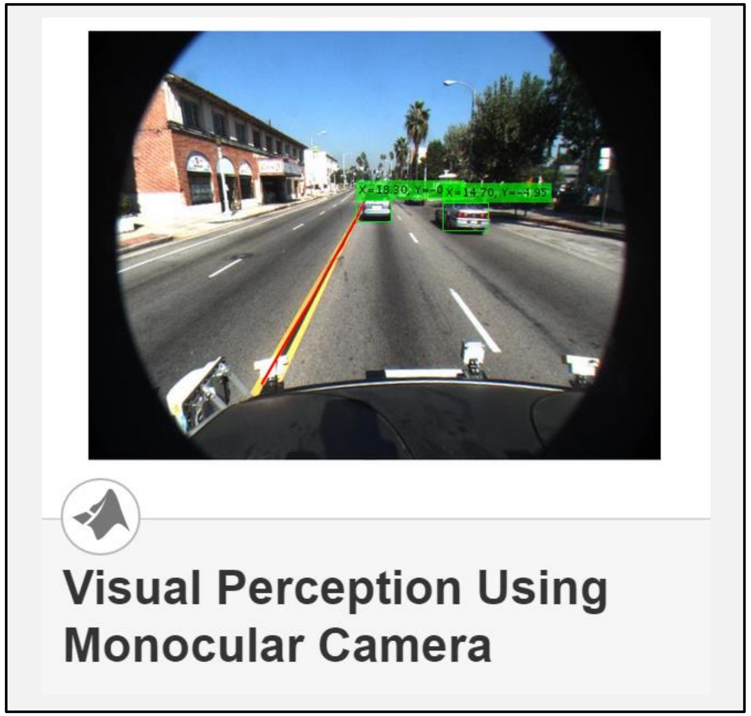

- **Train object detector** using deep learning and machine learning techniques
- **Explore pre-trained pedestrian detector**
- **Explore lane detector** using coordinate transforms for mono-camera sensor model

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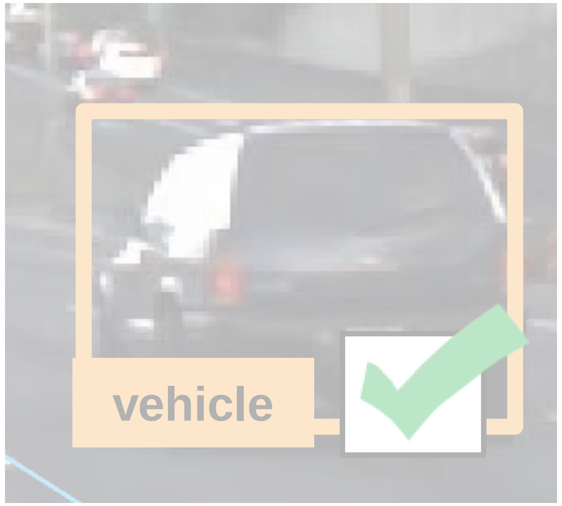

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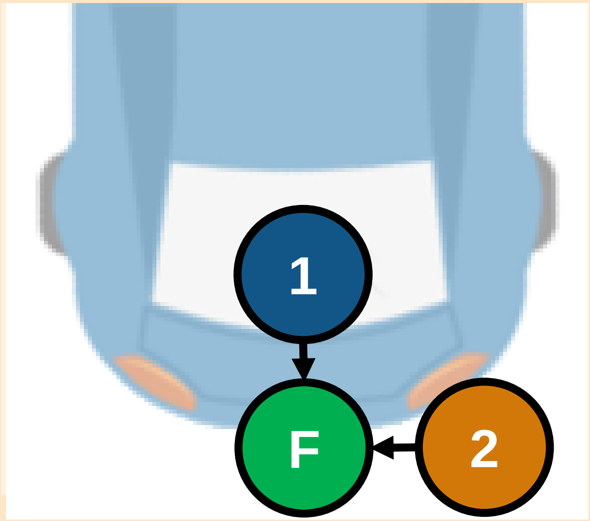
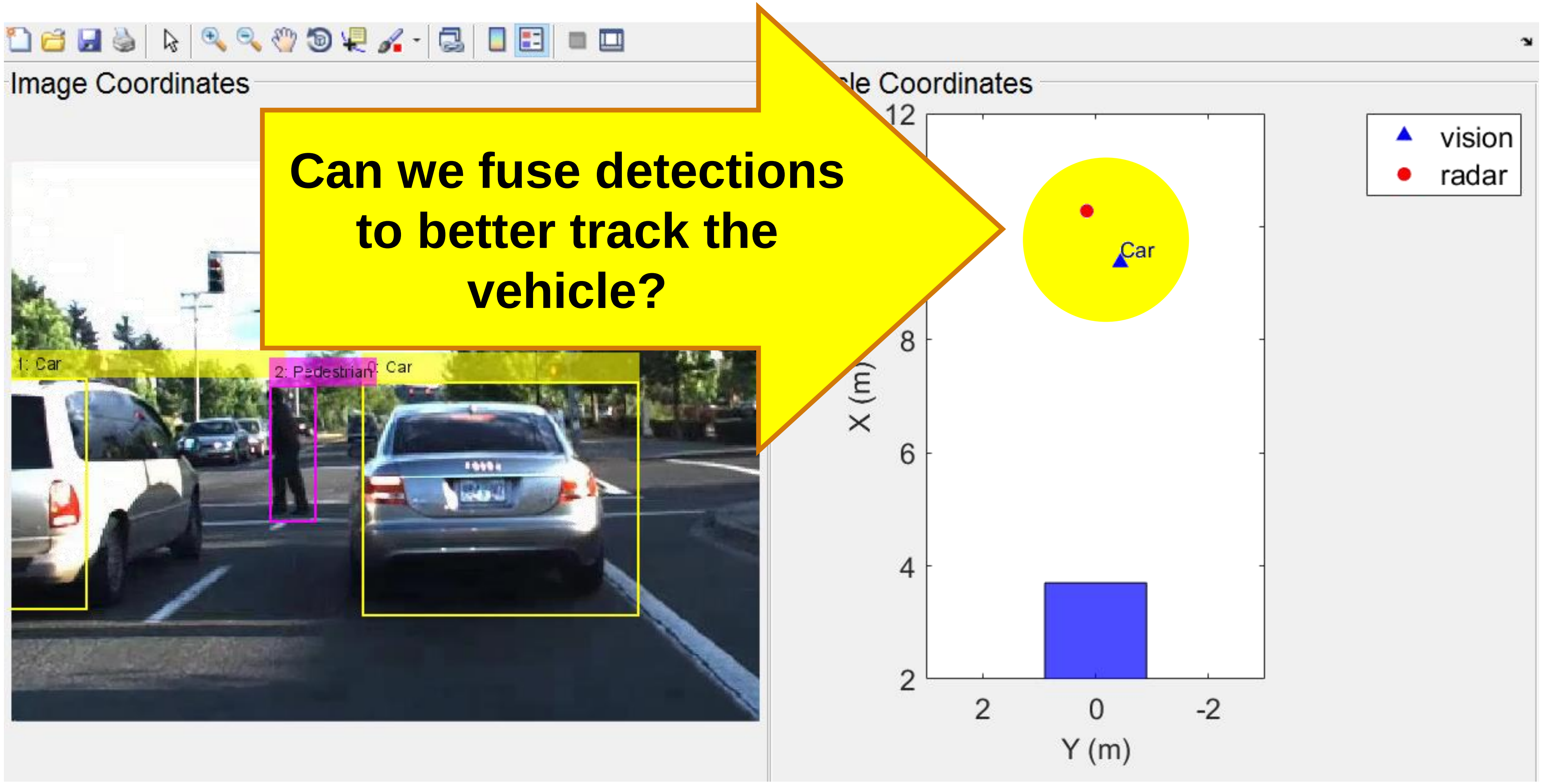
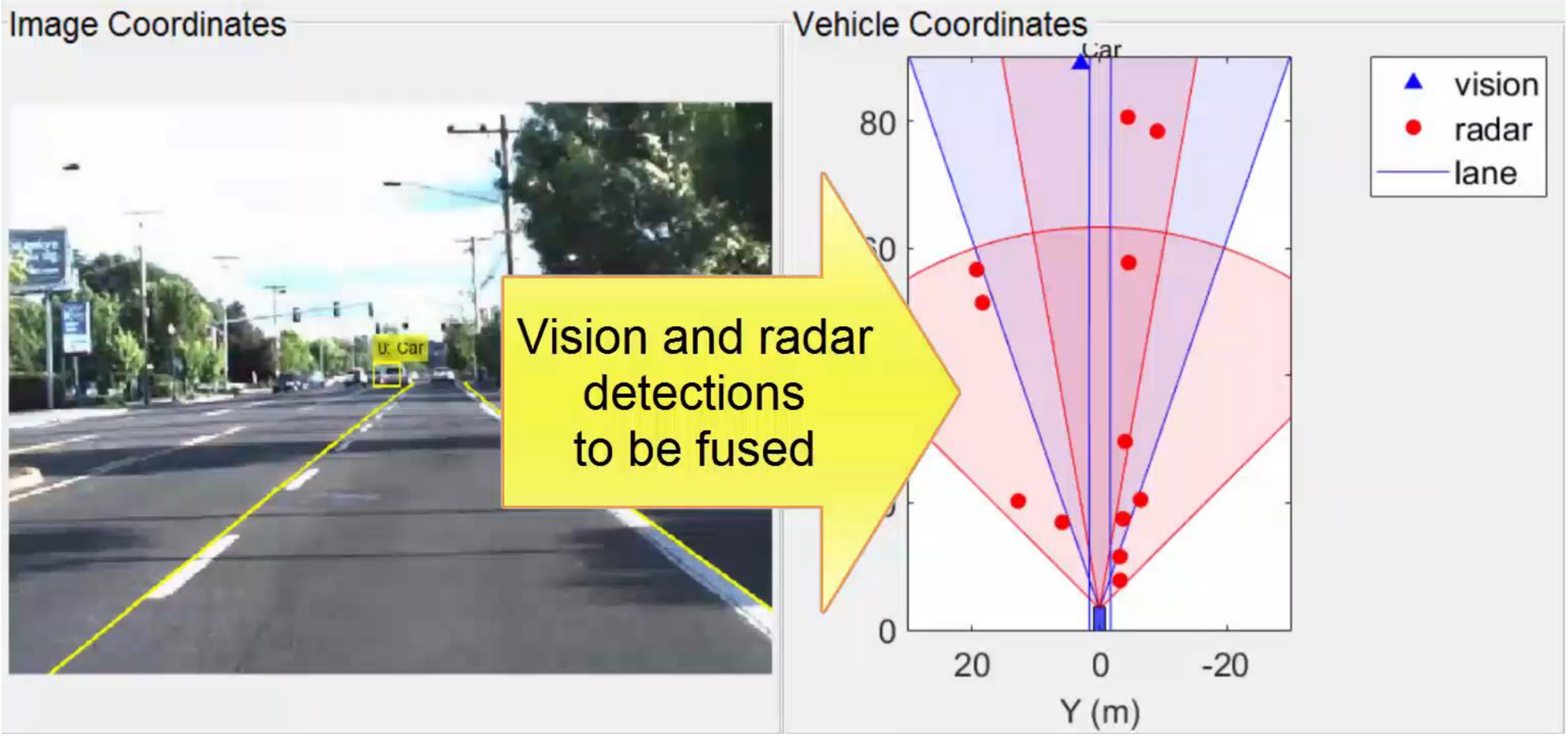


How can I fuse multiple detections?

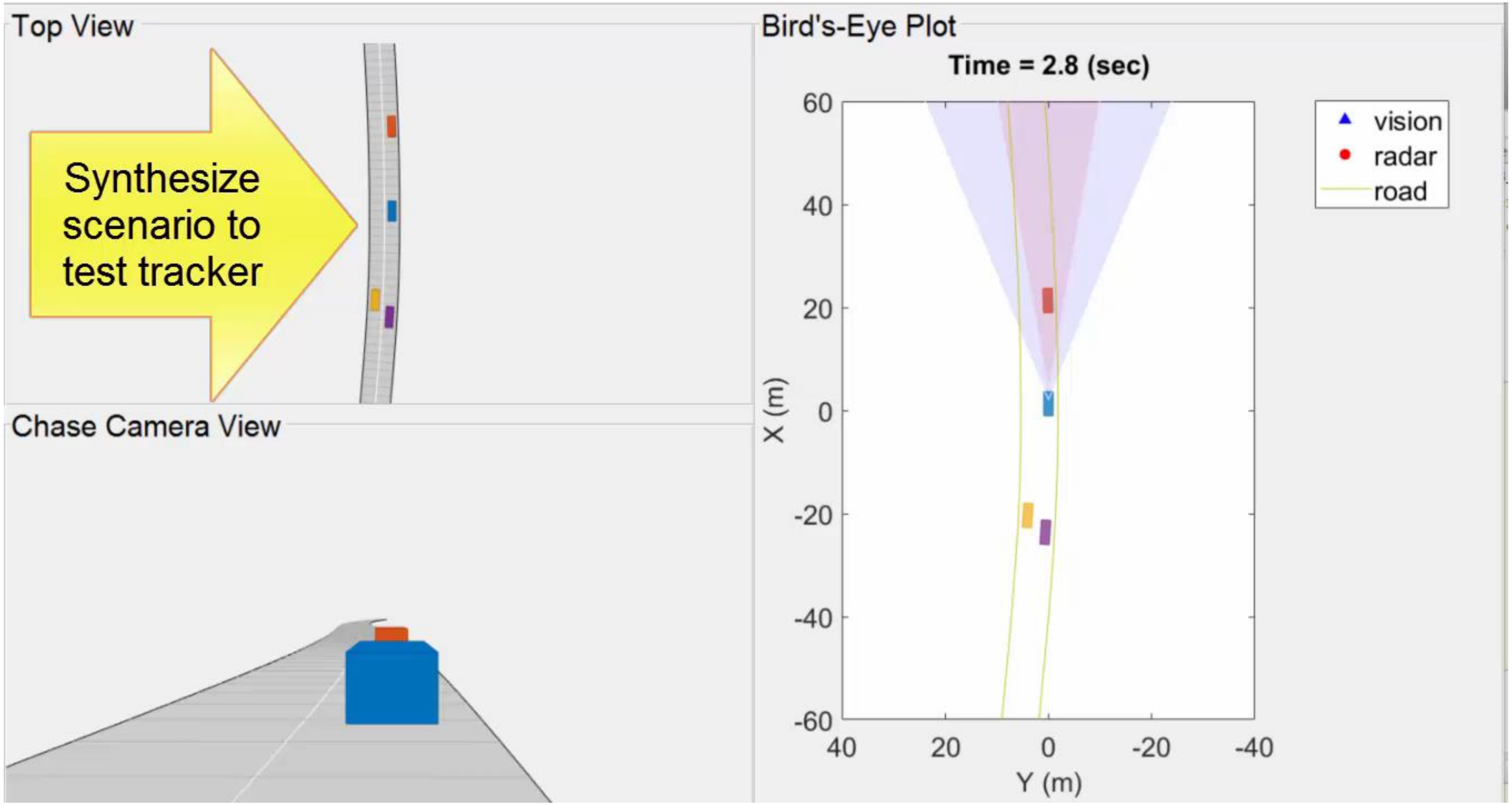
Example of radar and vision detections of a vehicle



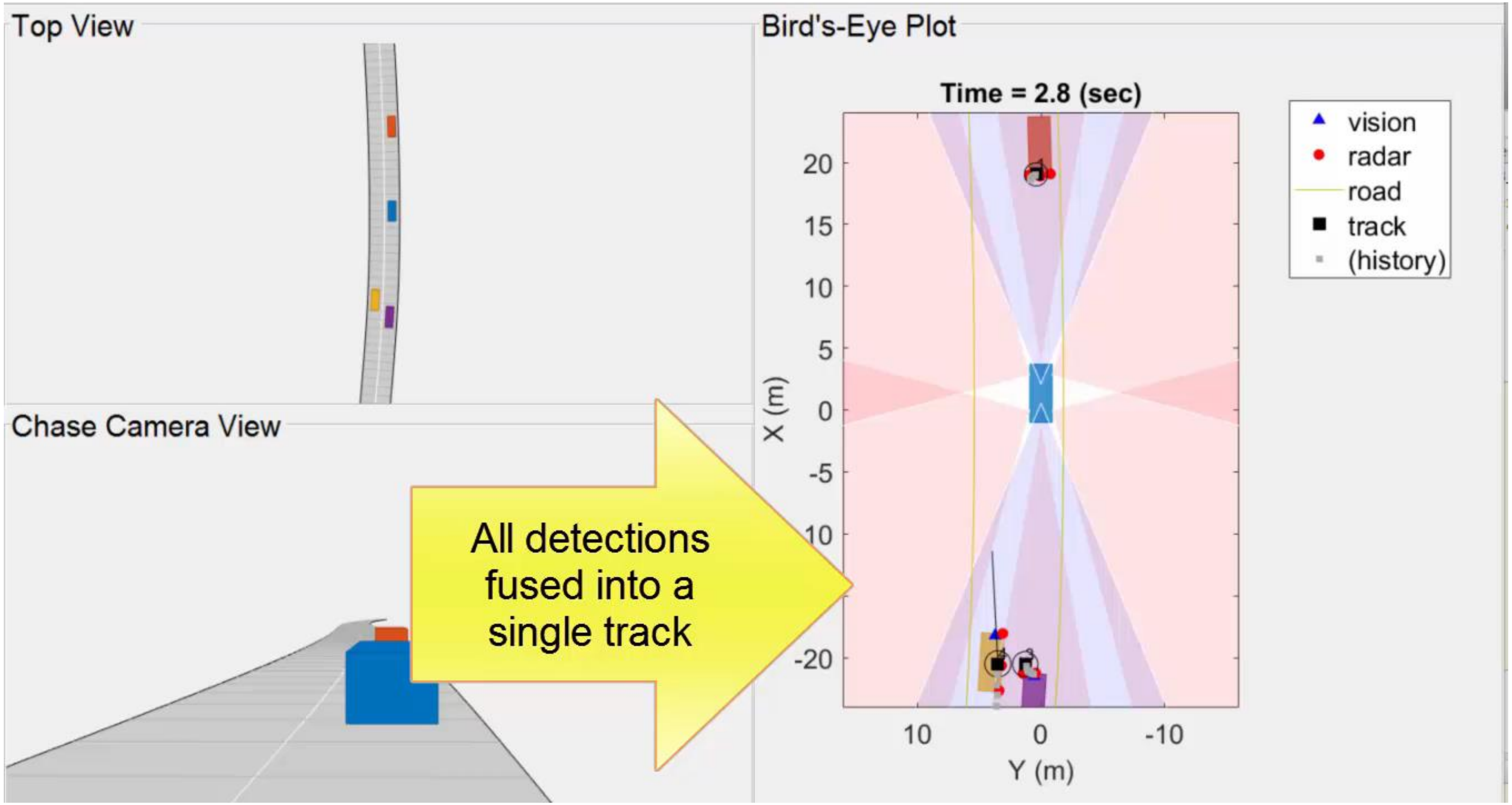
Fuse detections with multi-object tracker



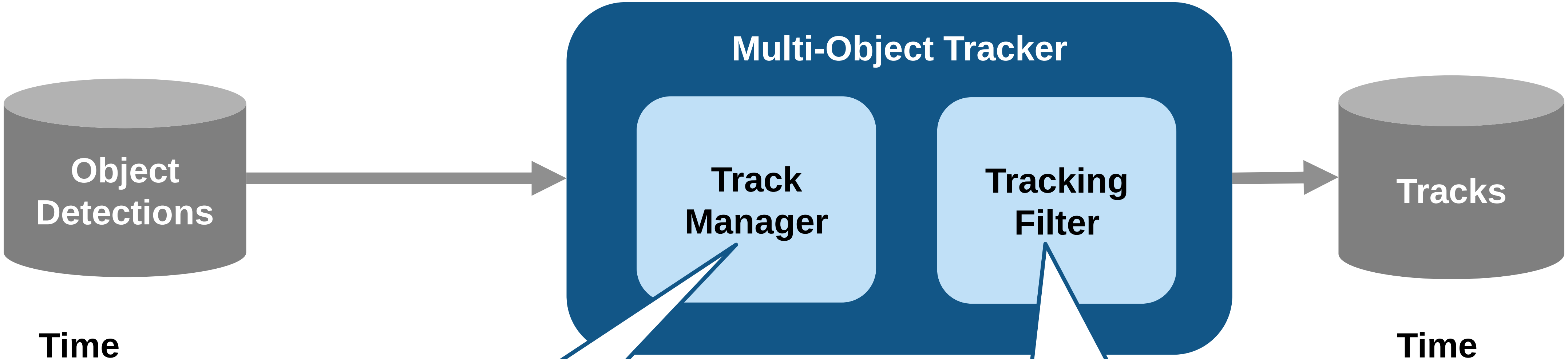
Synthesize scenario to test tracker



Test tracker against synthesized data



Track multiple object detections



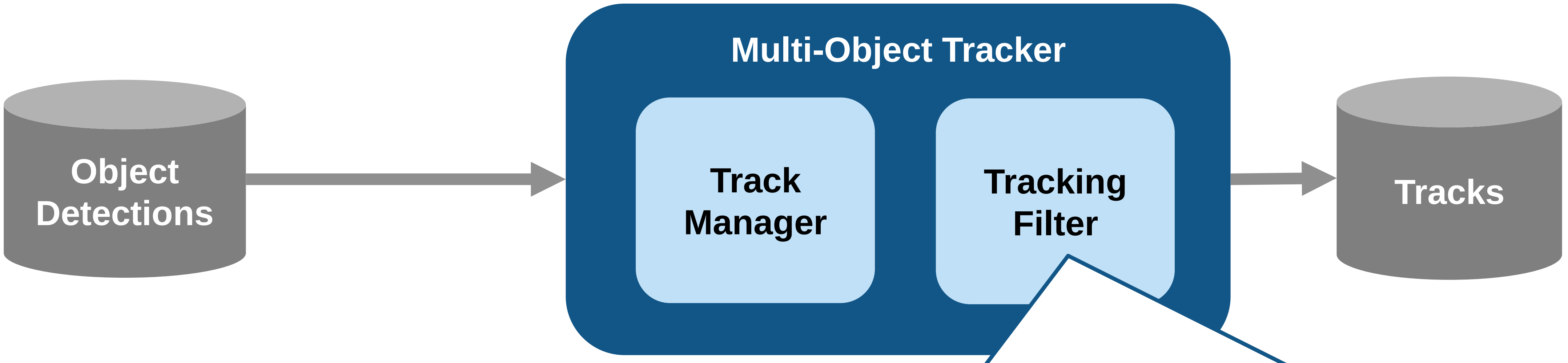
Time
Measurement
Measurement Noise

- Assigns detections to tracks
- Creates new tracks
- Updates existing tracks
- Removes old tracks

- Predicts and updates state of track
- Supports linear, extended, and unscented Kalman filters

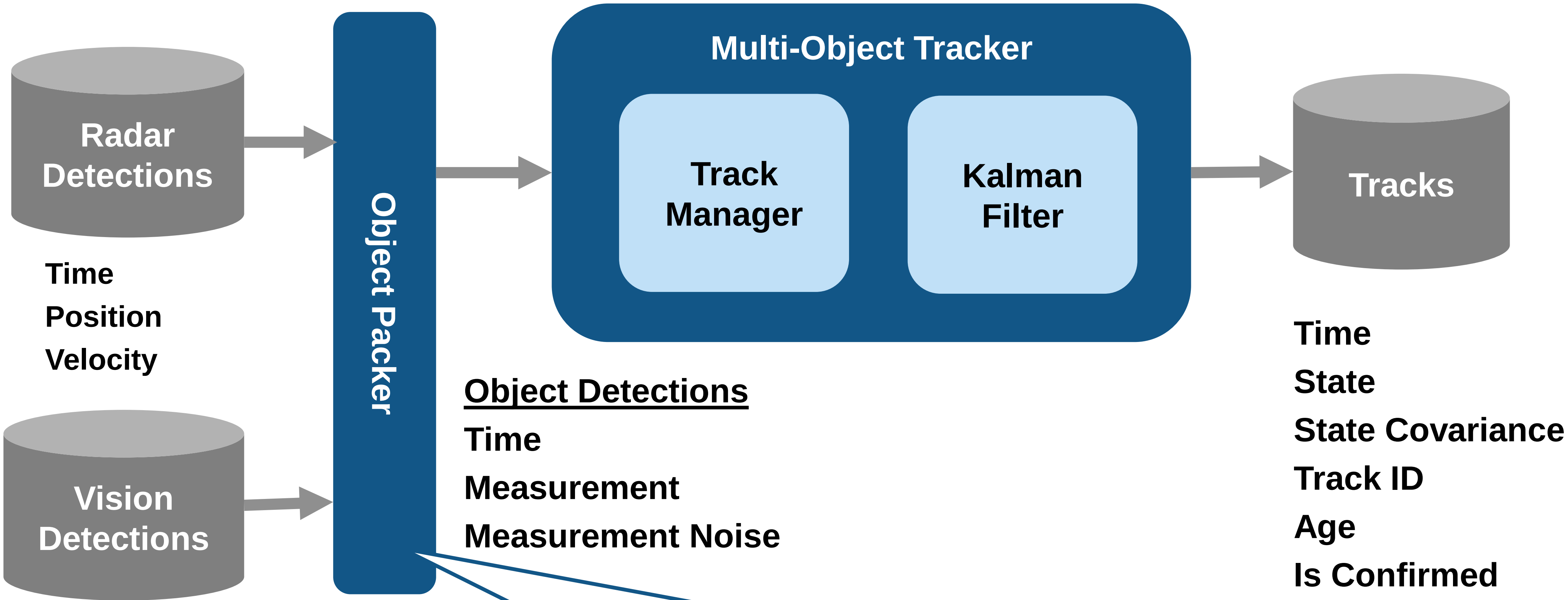
Time
State
State Covariance
Track ID
Age
Is Confirmed
Is Coasted

Examples of Kalman Filter (KF) initialization functions



	Linear KF (`trackingKF`)	Extended KF (`trackingEKF`)	Unscented KF (`trackingUKF`)
Constant velocity	`initcvkf`	`initcvekf`	`initcvukf`
Constant acceleration	`initcakf`	`initcaekf`	`initcaukf`
Constant turn	Not applicable	`initctekf`	`initctukf`

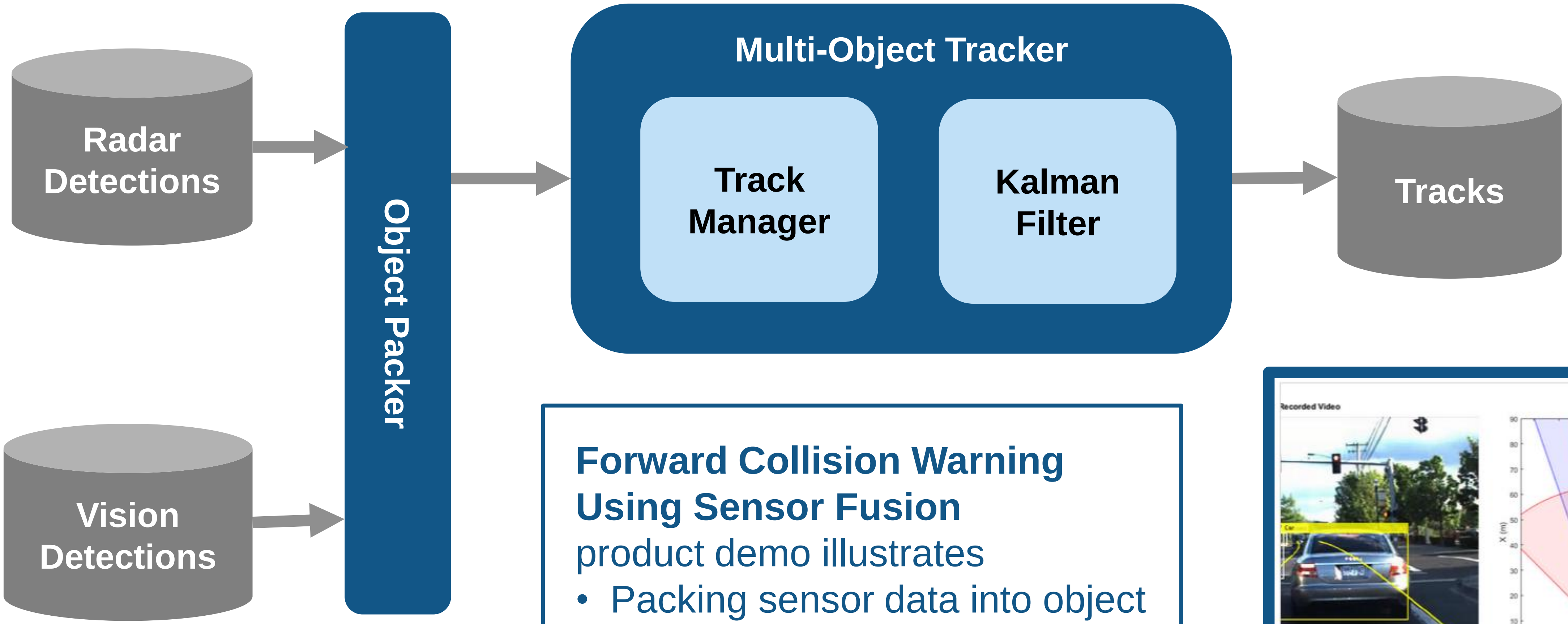
Fuse and track multiple detections from different sensors



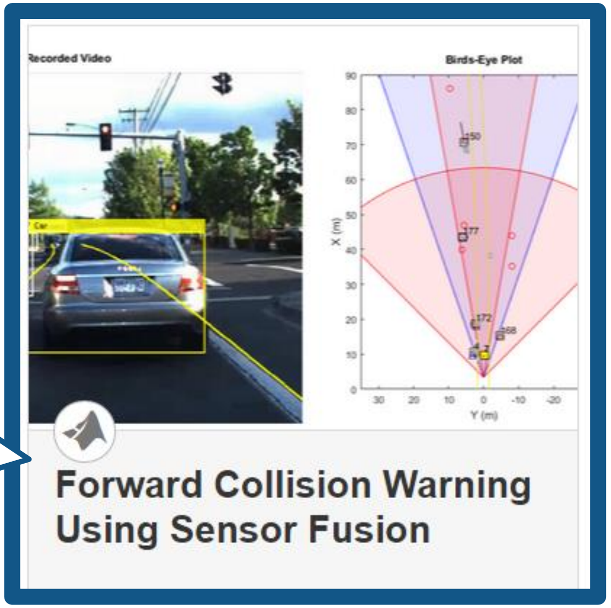
Time
Position
Velocity

- Typically unique to application and sensors
- Map sensor readings into measurement matrix
- Specify measurement noise for each sensor

Explore demo to learn more about fusing detections

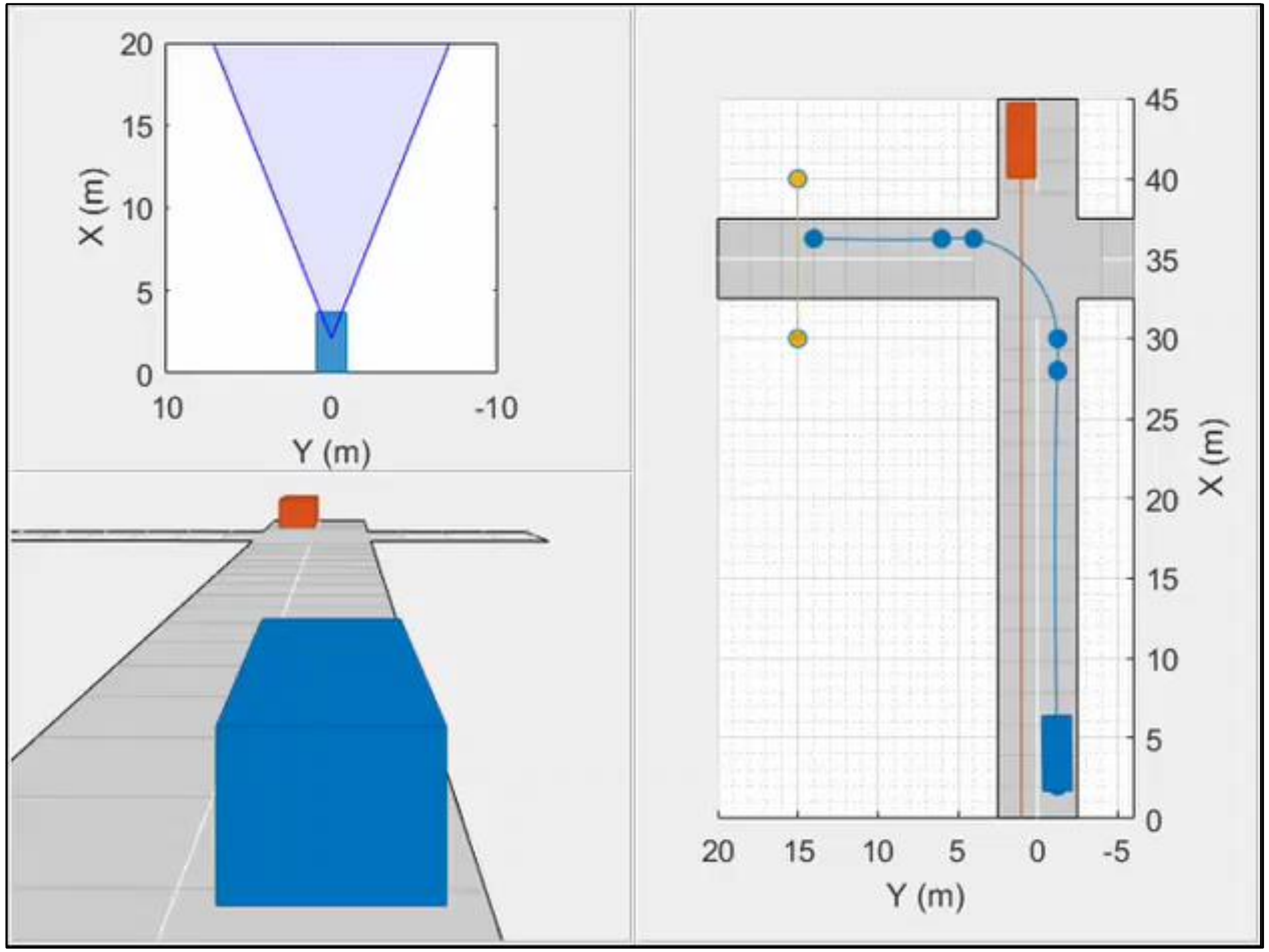


Forward Collision Warning Using Sensor Fusion
product demo illustrates
- Packing sensor data into object detections
- Initializing Kalman filter
- Configuring multi-object tracker



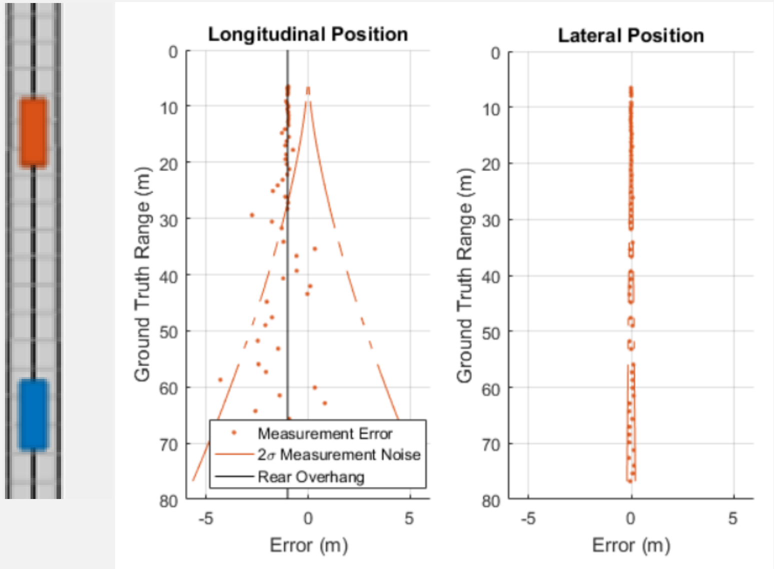
Virtual scenario generation

- Specify driving scenario and roads
- Add ego vehicle
- Add target vehicle and pedestrian actor
- Play scenario with chase plot
- Create birds eye plot to view sensor detections
- Play scenario with sensor models



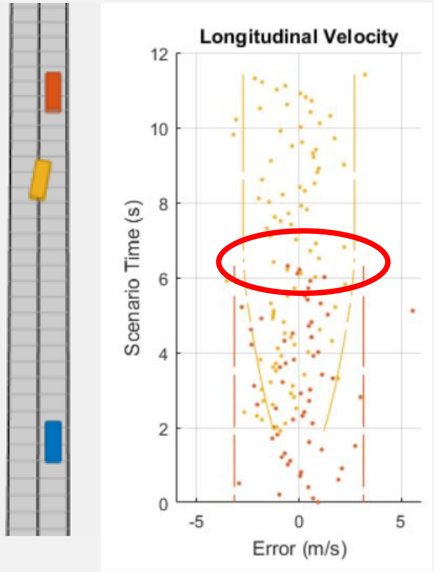
Simulate effects of vision detection sensor

Range Effects



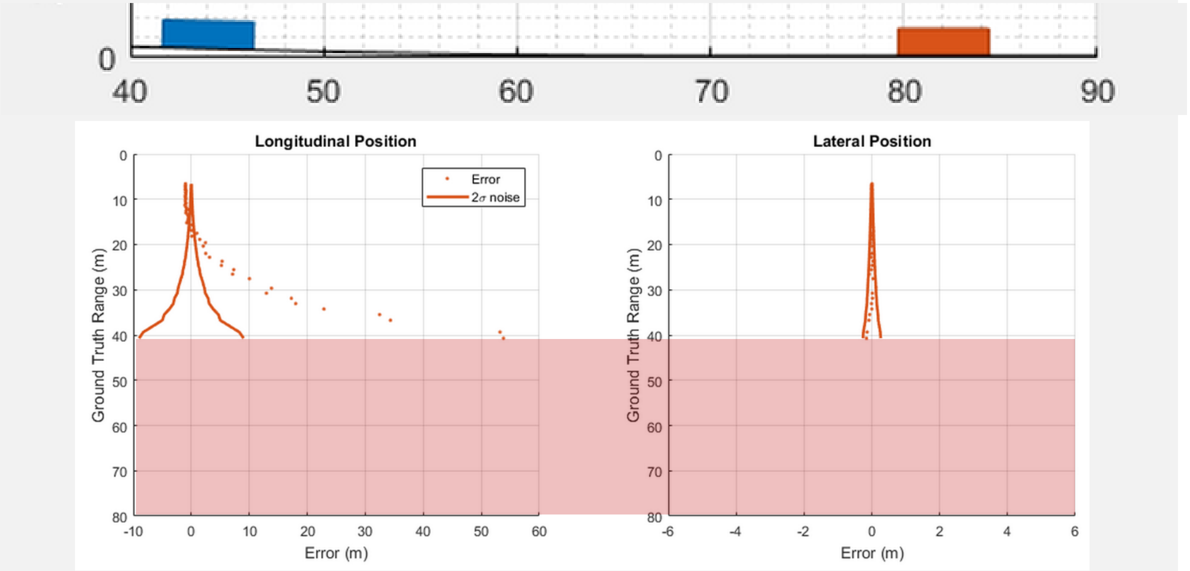
Range measurement accuracy degrades with distance to object	Angle measurement accuracy consistent throughout coverage area

Occlusion Effects



Partially or completely occluded objects are not detected

Road Elevation Effects

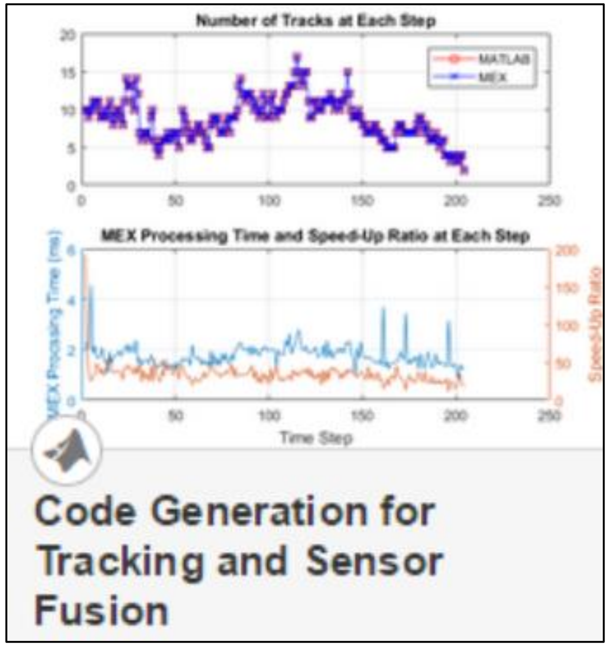


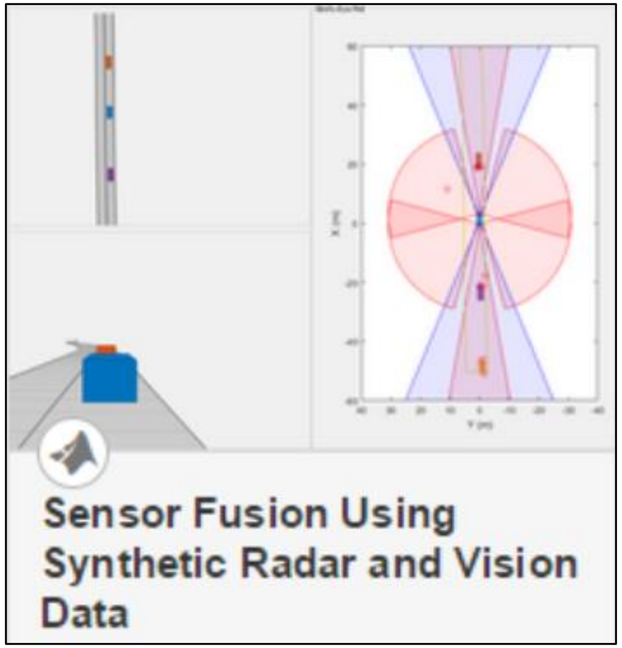
Objects in coverage area may not be detected because they appear above the horizon line

Large range measurement errors may be introduced for detected objects

Learn more about sensor fusion

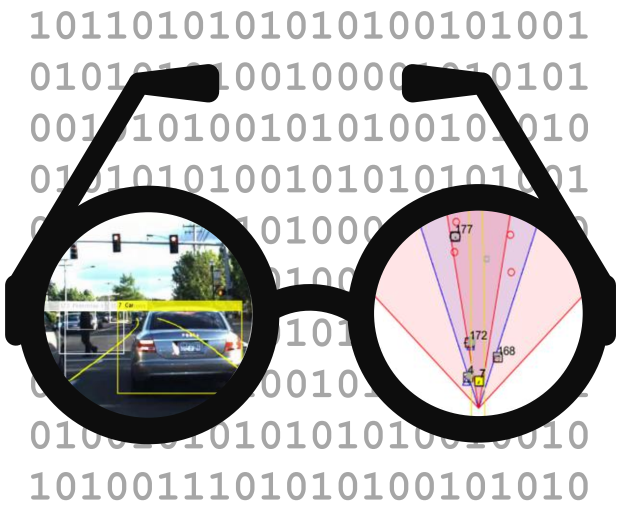
by exploring examples in the Automated Driving System Toolbox





- **Design** multi-object tracker based on logged vehicle data
- **Generate C/C++** code from algorithm which includes a multi-object tracker
- **Synthesize driving scenario** to test multi-object tracker

The Automated Driving System Toolbox helps you…

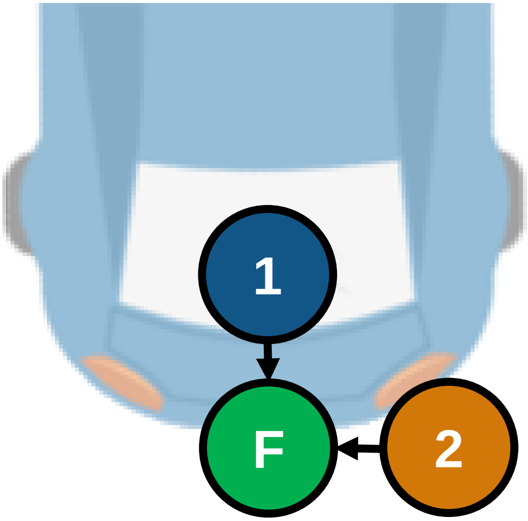


Visualize vehicle data

- Plot sensor detections
- Plot coverage areas
- Transform between image and vehicle coordinates

Detect objects in images

- Train deep learning networks
- Label ground truth
- Connect to other tools



Fuse multiple detections

- Design multi-object tracker
- Generate C/C++
- Synthesize driving scenarios