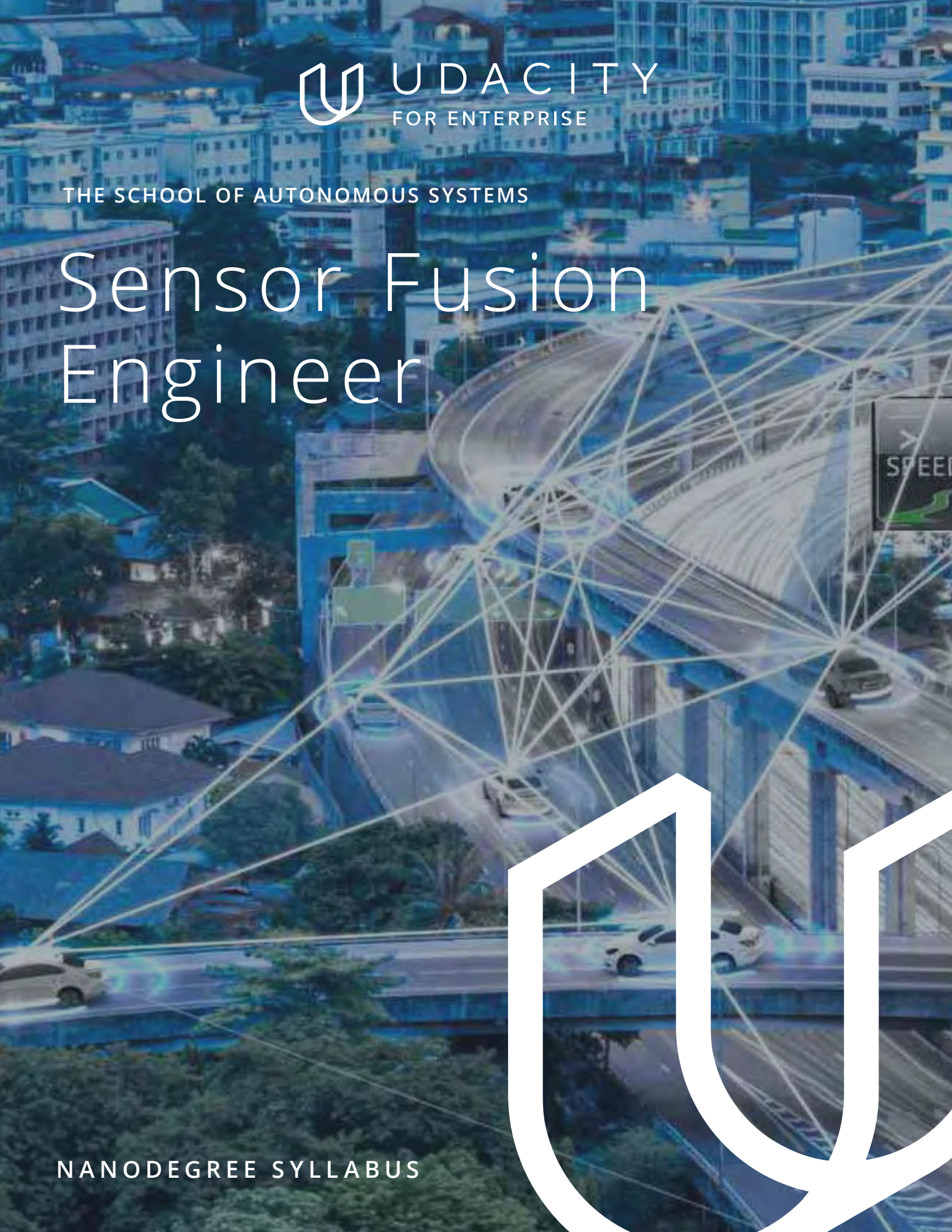

UDACITY
FOR ENTERPRISE
THE SCHOOL OF AUTONOMOUS SYSTEMS
Sensor Fusion Engineer
NANODEGREE SYLLABUS

Overview

This Nanodegree Program is built in partnership with

Mercedes-Benz

Learn to detect obstacles in lidar point clouds through clustering and segmentation, apply thresholds and filters to radar data in order to accurately track objects, and augment your perception by projecting camera images into three dimensions and fusing these projections with other sensor data. Combine this sensor data with Kalman filters to perceive the world around a vehicle and track objects over time.

Program Information

ESTIMATED TIME
4 months
Study 10 hours/week

LEVEL
Specialist

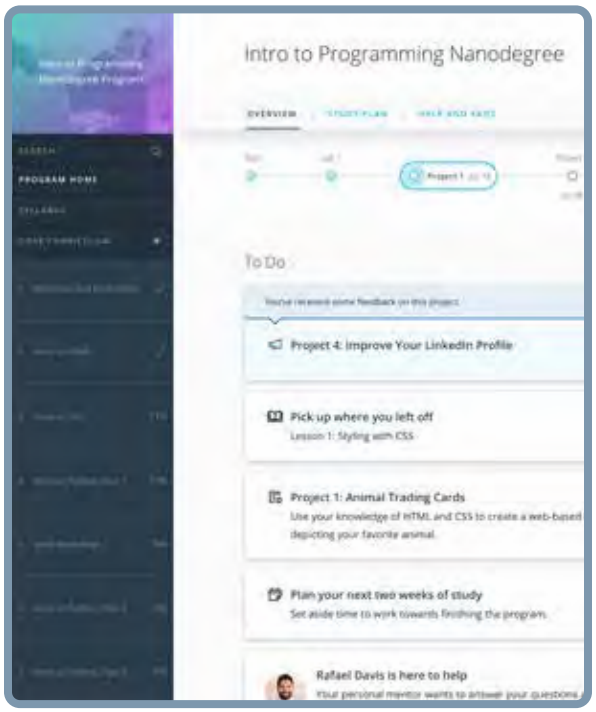
PREREQUISITES
You should have the following knowledge:

- Advanced knowledge in any object-oriented programming language, preferably C++
Intermediate Probability
- Intermediate Calculus
- Intermediate Linear Algebra
- Basic Linux Command Lines

HARDWARE/SOFTWARE REQUIRED
None

LEARN MORE ABOUT THIS NANODEGREE
Contact us at enterpriseNDs@udacity.com

Our Classroom Experience



REAL-WORLD PROJECTS

Learners build new skills through industry-relevant projects and receive personalized feedback from our network of 900+ project reviewers. Our simple user interface makes it easy to submit projects as often as needed and receive unlimited feedback.

KNOWLEDGE

Answers to most questions can be found with Knowledge, our proprietary wiki. Learners can search questions asked by others and discover in real-time how to solve challenges.

LEARNER HUB

Learners leverage the power of community through a simple, yet powerful chat interface built within the classroom. Learner Hub connects learners with their technical mentor and fellow learners.

WORKSPACES

Learners can check the output and quality of their code by testing it on interactive workspaces that are integrated into the classroom.

QUIZZES

Understanding concepts learned during lessons is made simple with auto-graded quizzes. Learners can easily go back and brush up on concepts at anytime during the course.

CUSTOM STUDY PLANS

Mentors create a custom study plan tailored to learners' needs. This plan keeps track of progress toward learner goals.

PROGRESS TRACKER

Personalized milestone reminders help learners stay on track and focused as they work to complete their Nanodegree program.

Learn with the Best

David Silver

HEAD OF CURRICULUM

David Silver leads the Udacity Curriculum Team. Before Udacity, David was a research engineer on the autonomous vehicle team at Ford. He has an MBA from Stanford, and a BSE in Computer Science from Princeton.

Stephen Welch

INSTRUCTOR

Stephen is a Content Developer at Udacity and has worked on the C++ and Self-Driving Car Engineer Nanodegree programs. He started teaching and coding while completing a Ph.D. in mathematics, and has been passionate about engineering education ever since.

Andreas Haja

INSTRUCTOR

Andreas Haja is an engineer, educator and autonomous vehicle enthusiast with a PhD in computer science. Andreas now works as a professor, where he focuses on project-based learning in engineering. During his career with Volkswagen and Bosch he developed camera technology and autonomous vehicle prototypes.

Abdullah Zaidi

INSTRUCTOR

Abdullah holds his M.S from the University of Maryland and is an expert in the field of Radio Frequency Design and Digital Signal processing. After spending several years at Qualcomm, Abdullah joined Metawave, where he now leads Radar development for autonomous driving.

Course 1: Lidar

Process raw lidar data with filtering, segmentation, and clustering to detect other vehicles on the road. Understand how to implement Ransac with planar model fitting to segment point clouds. Also implement Euclidean clustering with a KD-Tree to cluster and distinguish vehicles and obstacles.

Project: Lidar Obstacle Detection

Filter, segment, and cluster real point cloud data to detect obstacles in a driving environment.

LESSON TITLE	LEARNING OUTCOMES
INTRODUCTION TO LIDAR & POINT CLOUDS	• Lidar data representation • Work with a simulator to create PCD • Visualize Lidar data
POINT CLOUD SEGMENTATION	• Use PCL to segment point clouds • Use the RANSAC algorithm for planar model fitting
CLUSTERING OBSTACLES	• Use PCL to cluster obstacles • Use a KD-Tree to store point cloud data • Implement Euclidean Clustering to find clusters • Apply building boxes around clusters
WORKING WITH REAL POINT CLOUD DATA (PCD)	• Work with real self-driving car PCD data • Filter PCD data • Play back multiple PCD files • Apply point cloud processing to detect obstacles

Course 2: Radar

Analyze radar signatures to detect and track objects. Calculate velocity and orientation by correcting for radial velocity distortions, noise, and occlusions. Apply thresholds to identify and eliminate false positives. Filter data to track moving objects over time.

Project: Radar Obstacle Detection

Calibrate, threshold, and filter radar data to detect obstacles in real radar data.

LESSON TITLE	LEARNING OUTCOMES
INTRODUCTION TO RADAR	• Handle real radar data • Calculate object headings and velocities • Determine the appropriate sensor specifications for a task
RADAR CALIBRATION	• Correct radar data to account for radial velocity • Filter noise from real radar sensors
RADAR DETECTION	• Threshold radar signatures to eliminate false positives • Predict the location of occluded objects.

Course 3: Camera

Fuse camera images together with lidar point cloud data. Extract object features from camera images in order to estimate object motion and orientation. Classify objects from camera images in order to apply a motion model. Project the camera image into three dimensions. Fuse this projection into three dimensions to fuse with lidar data.

Project: Camera and Lidar Fusion

Detect and track objects in 3D space from the benchmark KITTI dataset based on camera and lidar measurements. Compute time-to-collision based on both sensors and compare the results. Identify the best combination of keypoint detectors and descriptors for object tracking.

LESSON TITLE	LEARNING OUTCOMES
SENSOR FUSION & AUTONOMOUS DRIVING	• Understand the SAE levels of autonomy. • Compare typical autonomous vehicle sensor sets including Tesla, Uber and Mercedes. • Compare camera, lidar and radar using a set of industrygrade performance criteria.
CAMERA TECHNOLOGY AND COLLISION DETECTION	• Understand how light forms digital images and which properties of the camera (e.g. aperture, focal length) affect this formation. • Manipulate images using the OpenCV computer vision library. • Design a collision detection system based on motion models, lidar and camera measurements.
RADAR DETECTION	• Threshold radar signatures to eliminate false positives. • Predict the location of occluded objects.
CAMERA AND LIDAR FUSION	• Project 3D lidar points into a camera sensor. • Use deep-learning to detect vehicles (and other objects) in camera images. • Create a three-dimensional object from lidar and camera data.

Course 4: Kalman Filters

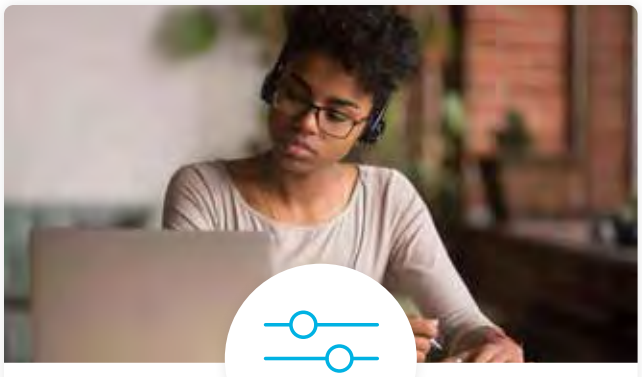
Fuse data from multiple sources using Kalman filters. Merge data together using the prediction-update cycle of Kalman filters, which accurately track object moving along straight lines. Then build extended and unscented Kalman filters for tracking nonlinear movement.

Project: Unscented Kalman Filters

Put your skills to the test! Code an Unscented Kalman Filter in C++ in order to track highly non-linear pedestrian and bicycle motion.

LESSON TITLE	LEARNING OUTCOMES
KALMAN FILTERS	• Construct Kalman filters. • Merge data from multiple sources. • Improve tracking accuracy. • Reduce sensor noise.
LIDAR AND RADAR FUSION WITH KALMAN FILTERS	• Build a Kalman Filter in C++. • Handle both radar and lidar data.
EXTENDED KALMAN FILTERS	• Predict when non-linear motion will cause errors in a Kalman filter. • Program an extended Kalman filter to cope with non-linear motion. • Construct Jacobian matrices to support EKFs.
UNSCENTED KALMAN FILTERS	• Estimate when highly nonlinear motion might break even an extended Kalman Filter. • Create an unscented Kalman Filter to accurately track non-linear motion.

Our Nanodegree Programs Include:



Pre-Assessments

Our in-depth workforce assessments identify your team's current level of knowledge in key areas. Results are used to generate custom learning paths designed to equip your workforce with the most applicable skill sets.

Dashboard & Progress Reports

Our interactive dashboard (enterprise management console) allows administrators to manage employee onboarding, track course progress, perform bulk enrollments and more.

Industry Validation & Reviews

Learners' progress and subject knowledge is tested and validated by industry experts and leaders from our advisory board. These in-depth reviews ensure your teams have achieved competency.

Real World Hands-on Projects

Through a series of rigorous, real-world projects, your employees learn and apply new techniques, analyze results, and produce actionable insights. Project portfolios demonstrate learners' growing proficiency and subject mastery.

Our Review Process

Real-life Reviewers for Real-life Projects

Real-world projects are at the core of our Nanodegree programs because hands-on learning is the best way to master a new skill. Receiving relevant feedback from an industry expert is a critical part of that learning process, and infinitely more useful than that from peers or automated grading systems. Udacity has a network of over 900 experienced project reviewers who provide personalized and timely feedback to help all learners succeed.

Vaibhav
UDACITY LEARNER

"I never felt overwhelmed while pursuing the Nanodegree program due to the valuable support of the reviewers, and now I am more confident in converting my ideas to reality."

now at

CODING VISIONS INFOTECH

All learners benefit from:

- Line-by-line feedback for coding projects
- Industry tips and best practices
- Advice on additional resources to research
- Unlimited submissions and feedback loops

How it Works

Real-world projects are integrated within the classroom experience, making for a seamless review process flow.

- Go through the lessons and work on the projects that follow
- Get help from your technical mentor, if needed
- Submit your project work
- Receive personalized feedback from the reviewer
- If the submission is not satisfactory, resubmit your project
- Continue submitting and receiving feedback from the reviewer until you successfully complete your project

About our Project Reviewers

Our expert project reviewers are evaluated against the highest standards and graded based on learners' progress. Here's how they measure up to ensure your success.

900+

Expert Project Reviewers

Are hand-picked to provide detailed feedback on your project submissions.

1.8M

Projects Reviewed

Our reviewers have extensive experience in guiding learners through their course projects.

3

Hours Average Turnaround

You can resubmit your project on the same day for additional feedback.

4.85 /5

Average Reviewer Rating

Our learners love the quality of the feedback they receive from our experienced reviewers.

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For more information visit: www.udacity.com/enterprise