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SCHOOL OF AUTONOMOUS SYSTEMS

Sensor Fusion

Syllabus

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Overview

The Sensor Fusion Engineer Nanodegree program consists of four courses that teach the fundamentals of sensor fusion and perception for self-driving cars. The program covers lidar, radar, camera, and Kalman filters, and includes lessons on working with real-world data, filtering, segmentation, clustering, and object tracking. In addition, students will work on a capstone project that involves building a complete sensor fusion pipeline for autonomous vehicles. Upon completing the program, graduates will have the skills and knowledge necessary to design and implement sensor fusion systems for self-driving cars.

Nanodegree Program | Advanced | 63 hours | 4.8 (184 Reviews)

Prerequisites

Prior to enrolling, you should have the following knowledge:

Basic calculus | Basic probability | Intermediate C++ | Linear algebra

You will also need to be able to communicate fluently and professionally **in written and spoken English**.

Skills You'll Learn

Lidar Obstacle Detection

Point clouds | Point cloud data | Ransac algorithm | Curve fitting | Object clustering | K-d trees | Point cloud library | Lidar visualization | Lidar | Lidar data representation | Lidar simulator | Euclidean clustering | Bounding boxes

Camera

Sensor fusion | Digital cameras | Digital image keypoint descriptors | Object tracking | Sift algorithm | Autonomous vehicle fluency | Sae j3016 levels of driving automation standard | Autonomous vehicle sensor selection | Object motion models | Computer vision image filtering | Image gradient calculation | Object detection | Yolo algorithm | Digital image keypoints | Computer vision image transformations | Lidar measurement models | Harris detector | Camera measurement models | Feature detection | Collision detection | Opencv

Radar

Radar | Radar clutter thresholding | Fourier transforms | Radar angle of arrival | Cluster models | Multi-target object tracking | Radar range resolution | Radar velocity estimation | Radar velocity resolution | Radar range estimation | Radar angle resolution

Kalman Filters

Kalman filters | Unscented kalman filters | Basic trigonometry | Non-linear motion tracking | Extended kalman filters | Sensor fusion | Sensor specifications | Robot trajectory generation | C++ for robotics | Object tracking | Jacobians

Courses

01. Welcome — 1 hour

L1	Welcome to the Sensor Fusion Engineer Nanodegree Program	Welcome to the Sensor Fusion Engineer Nanodegree Program! In this lesson, you will learn more about the structure of the program and meet the team.
L2	Introduction to Sensor Fusion	
L3	Getting Help	You are starting a challenging but rewarding journey! Take 5 minutes to read how to get help with projects and content.

02. Lidar Obstacle Detection — 24 hours

L1	Introduction to Lidar and Point Clouds	Learn about lidar and point clouds. Use a simulation highway environment to explore lidar sensing and generate point clouds.
L2	Point Cloud Segmentation	In this lesson, you will be using Ransac with a plane model to segment point cloud data and separate it into points that are part of the road and points that are not.
L3	Clustering Obstacles	Perform Euclidean clustering, and learn how to build KD-Trees to use them to do efficient nearest neighbor search for clustering.
L4	Working with Real PCD	Take what you have learned in the previous lessons and apply it to real pcd being played back in a video.
L5	Project: Lidar Obstacle Detection Project	In this lesson, students will submit the project that they have developed over the previous lessons.

03. Camera — 12 hours

L1	Introduction	Introduction to the instructor, and the guest Timo Rehfeld, Mercedes-Benz R&D North America, and the course overview.

L2	Autonomous Vehicles and Computer Vision	Learn about the various levels of autonomy, some typical sensor sets, basics of camera technology, and an introduction into the OpenCV computer vision library.
L3	Engineering a Collision Detection System	Learn the collision detection basics, and estimating the TTC with Lidar and Camera.
L4	Tracking Image Features	Learn about the intensity gradient and filtering techniques; extract corners, infer features of an image, and track an object across multiple images.
L5	Project: Camera Based 2D Feature Tracking	
L6	Combining Camera and Lidar	Learn to improve the tracking process results by combining the Camera and Lidar output
L7	Project: Track an Object in 3D Space	
L8	Final Thoughts from Timo	

04. Radar

6 hours

L1	Introduction	
L2	Radar Principles	Review Radar functionality, FMCW waveform, Radar Hardware, Schematic and the Radar Equation
L3	Range-Doppler Estimation	Estimate the range and velocity of the target using the FMCW radar
L4	Clutter, CFAR, AoA, and Clustering	Discuss - Clutter formation and then its removal using CFAR technique. After that
L5	Project: Radar Target Generation and Detection	

05. Kalman Filters

20 hours

L1	Introduction and Sensors	Meet the team at Mercedes who will help you track objects in real-time with Sensor Fusion.

L2	Kalman Filters	Learn from the best! Sebastian Thrun will walk you through the usage and concepts of a Kalman Filter using Python.
L3	Lidar and Radar Fusion with Kalman Filters in C++	In this lesson, you'll build a Kalman Filter in C++ that's capable of handling data from multiple sources. Why C++? Its performance enables the application of object tracking with a Kalman Filter in real-time.
L4	Unscented Kalman Filters	While Extended Kalman Filters work great for linear motion, real objects rarely move linearly. With Unscented Kalman Filters, you'll be able to accurately track non-linear motion!
L5	Project: Unscented Kalman Filter Highway Project	In this lesson, students will submit the project that they have developed over the previous lessons.
L6	Geometry and Trigonometry Refresher	This optional content is designed to refresh your knowledge of trigonometry and geometry.

06. Appendix

L1	Kalman Filter in MATLAB	

Meet Your Instructors

David Silver

Staff Software Engineer at Kodiak Robotics

David works on Self-driving trucks at Kodiak. As a Staff Software Engineer, David writes planning, control, simulation and mapping software for self-driving trucks.

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.

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.

Andreas Haja

Instructor

Andreas Haja is an engineer, educator, and autonomous vehicle enthusiast. Andreas now works as an engineering professor in Germany. Previously, he developed computer vision algorithms and autonomous vehicle prototypes using C++.

Aaron Brown

Senior Software Engineer

Aaron has over 7 years in the autonomous vehicle field, starting as a Udacity content developer then instructor, focusing on Lidar in the Sensor Fusion and Self-Driving Car Nanodegree Program. For the last 5 years, he's been with Mercedes-Benz R&D North America, working in functional testing, Sensor Fusion, and Machine Learning driven by a passion for technological evolution and problem-solving.

Why Udacity

Demonstrate proficiency with practical projects

Projects are based on real-world scenarios and challenges, allowing you to apply the skills you learn to practical situations, while giving you real hands-on experience

- ✓ Gain proven experience
- ✓ Retain knowledge longer
- ✓ Apply new skills immediately

24/7 access to real human support

Reviewers provide timely and constructive feedback on your project submissions, highlighting areas of improvement and offering practical tips to enhance your work

- ✓ Get help from subject matter experts
- ✓ Gain valuable insights and improve your skills
- ✓ Learn industry best practices