SAE International
Professional Development

SYLLABUS
ROBOTICS FOR AUTONOMOUS VEHICLE SYSTEMS BOOTCAMP

Schedule
Live Virtual Classes

Theory Lectures
Participant to work through pre-recorded videos asynchronously

Practical Workshops
Fridays 9–10:30 AM EST via Zoom

Optional Office Hours
Tuesdays 9–10:30 AM EST and as needed

PARTNERING FOR SUCCESS

COURSE DESCRIPTION

Theories, principles, and strategies from robotics are used to design, implement, and evaluate autonomous vehicles as well as numerous varieties of autonomous robots. These are systems of systems (components, sub-systems, and systems) which are interconnected (mechanically, electrically and networked). This course will introduce students to both the fundamental advances in science as well as technology behind the systems-of-systems.

Students obtain team-work experience through course projects entailing collaborative report writing and presentations. Hands-on exercises lead up to a capstone course-project of building, programming, and testing a mobile robot. Team-oriented software development strategies, principled down- selection of cyber-physical components, and practical hardware and software implementations are emphasized. Team-members will identify objectives, responsibilities, task, timelines and deliverables based on the higher-level goals and deliverables.

COURSE OBJECTIVES

- Define the Sense-Think-Act in Real-Time paradigm and use it to explain how an autonomous vehicle operates.
- Evaluate different hardware and software solutions to typical autonomous operation problems, balancing cost, effectiveness, and integration concerns.
- Present alternate approaches for AV perception, localization, and planning problems.
- Install, configure, and use a variety of software frameworks and applications to solve robotics problems and program an AV.
- Outline benefits of effective collaboration strategies for software development teams (unit-testing, version-control, and continuous integration.
- Demonstrate a working AV performing basic motion and navigational tasks.

PREREQUISITES

- B.S. in Mechanical, Software, or Electrical Engineering, or Computer Science
- Interest in working on autonomous vehicles
- Some coding ability in C or Python
- Coursework in linear algebra, statistics

EQUIPMENT REQUIREMENTS

- An installation of Ubuntu 16.03 (installation options in course)
- Headset and webcam for online audio and video conferencing
- A joystick is not required but is useful for teleoperation

INSTRUCTORS

Venkat N. Krovi, Ph.D, FASME
Michelin Endowed Chair
Professor of Vehicle Automation
Clemson University -
International Center for
Automotive Research

Jeff Blackburn
Senior Product Sales Manager
Ansys Autonomy

WEEKLY SCHEDULE

All Preparation assignments to be completed before that week's lecture and workshop live sessions.

Week 0

PRE-COURSE PREPARATION

Assignments

- Ubuntu 16.04 Installation
- Robot Operating System (ROS) Installation
- Git Basics
- Ubuntu Primer (optional)
- Python Primer (optional)

Installations must be complete before the course begins.

Week 1

COURSE INTRODUCTION

- Demonstrate basic Linux (Ubuntu) command line use
- Describe how Robotics is used in Autonomous Vehicles
- Set up a Git repository and explore the Robot Operating System framework with a simple example

Week 2

MECHATRONICS

- Describe the Sense-Think-Act framework and its' relevance in an autonomous system
- Outline basic topology & commands of the Robot Operating System

Week 3

RE-INTRODUCTION/KINEMATICS

- Define Reactive control systems
- Understand homogeneous transformations
- Install Gazebo and explore the backend of the simulation framework

Week 4

VEHICLE ARCHITECTURE AND KINEMATICS

- Explain different Wheeled Mobile Robot architectures
- Define Differential & Ackerman drive types
- Explain forward/inverse kinematics and motion models
- Use Git for collaboration in a team setting
- Set up a vehicle model in Gazebo and implement longitudinal control

Week 5

SENSORS/PERCEPTION: LIDAR

- Describe the role of sensing systems in autonomous navigation.
- Implement lateral control for wall following
- Use OpenCV to implement a line follower

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Continued

Week 6

SENSORS/PERCEPTION: CAMERAS, VISION AND VISUAL INTELLIGENCE

- Explain how the camera works and how depth is calculated with a stereo camera
- Explore other vision-based sensors
- Implement a lane keeping controller on the car-like robot with OpenCV and ROS

Week 7

PERCEPTION: MACHINE LEARNING

- Explain basic machine learning concepts
- Understand the difference between traditional perception and ML
- Implement a ROS wrapper around trained models to detect and classify objects using Keras

Week 8

LOCALIZATION

- Describe different bayesian approaches to localization
- Understand costmaps and how to use them in the Navigation Stack
- Use the Navigation Stack in ROS to plan a path to a goal while performing obstacle avoidance

Week 9

SLAM

- Define SLAM & Differentiate several SLAM approaches
- Explore different localization algorithms
- Implement SLAM for mapping and use the Navigation Stack in ROS to localize and plan the robot motion

Week 10

NAVIGATION/PATH PLANNING

- Discuss the relative uses and merits of greedy non-greedypath planning approaches
- Use the Navigation Stack in ROS to extract waypoints for robot motion and implement a pure pursuit controller to navigate through them.

Weeks 11–12

FINAL PROJECT

Participants will work in teams to implement exercises on the hardware that will test their skills

- Virtual Hands-On Workshop
- Participants will work virtually in-teams or individually with a Turtlebot3 Burger
- Participants will implement exercises on the hardware that will test their skills in:
- Working with Lidar and Camera data
- Object Detection using pre-trained neural networks
- Generating maps and localizing within that environment
- Planning and control

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