ACC: ACC 3

ACC Bucket : Robotics-3

Course: Robotics: Applications

OVERALL COURSE OBJECTIVES: The overarching objective of this course is to foster participants' abilities to comprehend and implement key robotic algorithms, enhance practical programming skills, and master core concepts of robotics including estimation and learning, navigation, and planning. This is aimed at equipping the learners with the necessary skills to effectively contribute to the evolving field of robotics and related applications.

LEARNING OUTCOMES: On successful completion of the course the students shall be able to:

1. Understand and apply probabilistic generative models and Bayesian filtering for robotic localization and mapping.
2. Gain hands-on programming experience, demonstrating foundations of robot movement, planning, and perception.
3. Utilize mathematical and programming methods that researchers use in robotics labs, including dynamic simulations.
4. Implement and operate a mobile inverted pendulum (MIP) or navigational rover, demonstrating understanding of control systems.
5. Apply concepts of state estimation and local linearization in the context of robotic functioning.
6. Demonstrate knowledge in feedback motion planning for autonomous mobility in robots.

COURSE CONTENT:

Module 1: State Estimation and Localization for Self-Driving Cars [26 Hours]

.This course, offered by the **University of Toronto**, provides a deep dive into the fundamental methods used for determining a self-driving car's **state** (position, orientation, velocity, etc.) and its **localization** on the road. It introduces you to the mathematical models for typical vehicle sensors like **GPS** and **IMUs** (Inertial Measurement Units) and teaches you how to fuse this noisy, potentially conflicting sensor data using core estimation algorithms. You will explore and apply the widely used **Kalman Filter** family of algorithms, which includes the **Extended Kalman Filter (EKF)** and **Unscented Kalman Filter (UKF)**, to estimate vehicle trajectory and pose over time. The course also covers how to use **LIDAR** data for environmental perception and **Point Cloud Registration** for accurate map alignment, culminating in the study of multisensor fusion techniques essential for robust real-time autonomy.

Sub-Topics

Least Squares Estimation (Batch and Recursive Forms)

Linear and Nonlinear Kalman Filters

Extended Kalman Filter (EKF) and Error State Extended Kalman Filter (ES-EKF)

Unscented Kalman Filter (UKF)

GNSS/INS Sensing for Pose Estimation

LIDAR Sensing and Point Cloud Registration

Multisensor Fusion for State Estimation

Formative **Assessments:**

Graded Quizzes: 2 total

Programming Assignments: 2 total (including the Final Project)

Ungraded Labs: 1 total

Discussion Prompts: 2 total

Module 2: Modern Robotics, Capstone Project, Mobile Manipulation [20 Hours]

This Capstone Project, offered by **Northwestern University**, serves as the culmination of the Modern Robotics specialization, integrating several key concepts to perform a complete **mobile manipulation** task. The project involves simultaneously controlling the motion of a **wheeled mobile base** (specifically the KUKA youBot with omnidirectional wheels) and its **5-joint robot arm** to achieve a pick-and-place operation. You will implement and test the required software in a cross-platform robot simulator (V-REP/CoppeliaSim). The focus is on the practical application of theoretical knowledge, including **trajectory generation** for both the base and the end-effector in 3D space, **odometry** calculation, and implementing both **feedforward** and **feedback (PI) control** laws to ensure the robot accurately and smoothly tracks the desired path.

Sub-Topics
Introduction to the Capstone Project and the KUKA youBot Kinematics

Odometry for Wheeled Mobile Robots and Kinematic Simulator

Reference Trajectory Generation in SE(3) for the End-Effector

Feedforward Control of the End-Effector

Feedforward-plus-Feedback (PI) Control for Trajectory Stabilization

Formative Assessments:

Capstone Peer Review: 1 total (Final Submission)

Discussion Prompts: 4 total

Milestone Readings/Assignments: 3 total (Milestone 1, 2, 3)

ASSESSMENT:

For summative assessments, Coursera will provide question banks for which exams can be conducted on the Coursera platform or the faculty will create their own assessments.

Note: If a Course or Specialization becomes unavailable prior to the end of the Term, Coursera may replace such Course or Specialization with a reasonable alternative Course or Specialization.