FLYING CAR NANODEGREE SYLLABUS

Term 1: Aerial Robotics

In the first term, you'll learn the core concepts required to design and develop robots that fly. Working with the quadrotor test platform and our custom flight simulator, you will implement planning, control, and estimation solutions in Python and C++. Throughout the term, you will have the opportunity to port code to, and experiment on, recommended hardware!

Course 1: Introduction

In this course, you will get an introduction to flight history, challenges, and vehicles. You will learn about our quadrotor test platform, work in our custom simulator, and build your first project—getting a quadrotor to take-off and fly around a backyard!

Lesson 1: Welcome!
Lesson 2: Intro to Autonomous Flight
Lesson 3: Project

Project 1: Backyard Flyer
In this project, you will write event-driven code in Python to get your drone to takeoff, fly a predetermined path, and land in a simulated backyard environment.

Course 2: Planning

Flying robots must traverse complex, dynamic environments. Wind, obstacles, unreliable sensor data, and other randomness all present significant challenges. In this course, you will learn the fundamentals of aerial path planning. You will begin with 2D problems, optimize your solutions using waypoints, and then scale your solutions to three dimensions. You will apply these skills in your second project—autonomously navigating your drone through a dense urban environment.

Lesson 1: Planning as Search
Lesson 2: Vehicle State Representation
Lesson 3: Graph State Spaces
Lesson 4: Moving into 3D
Lesson 5: Real World Planning
Lesson 6: Project: 3D Motion Planning

Project 2: 3D Motion Planning
In this project, you will move beyond the backyard test grounds and fly a drone around a complex urban simulated environment. To do so, you will load a map of a real city, plan a collision-free path between buildings, and watch your drone fly above city streets.

Course 3: Control

In the previous course, we implemented 3D path planning but assumed a solution for actually following paths. In reality, moving a flying vehicle requires determining appropriate low-level motor controls. In this course, you will build a nonlinear cascaded controller and incorporate it into your software in the project.

Lesson 1: Vehicle Dynamics
Lesson 2: Introduction to Vehicle Control
Lesson 3: Cascaded Control Architecture
Lesson 4: Full Vehicle Control
Lesson 5: Implementing Your Controller
Lesson 6: Vehicle Design Considerations
Lesson 7: Project

Project 3: Nonlinear Cascaded Controller
In this project, you will no longer assume vehicle actuation but rather implement your very own cascaded controller in C++. You will attempt different motions (slow, fast, slalom, etc.) and analyze performance under different weather conditions.

Course 4: Estimation

In this course, we will finish peeling back the layers of your autonomous flight solution. Instead of assuming perfect sensor readings, you will utilize sensor fusion and filtering. You will design an Extended Kalman Filter (EKF) to estimate attitude and position from IMU and GPS data of a flying robot.

Lesson 1: Introduction to Estimation
Lesson 2: Noise Models
Lesson 3: How Inertial Sensors Work
Lesson 4: How GPS Works
Lesson 5: Sensor Fusion: Kalman Filters
Lesson 6: The EKF and UKF
Lesson 7: Implementing your Estimator
Lesson 8: Project

Project 4: EKF
In this project, you will implement an EKF to estimate attitude and position from IMU and GPS data of a flying robot. After doing so, you will have implemented the full-stack for a single aerial robot!

Term 2: Autonomous Aerial Systems

In the first term, you implement the full-stack for a single autonomous aerial robot. In this term, you learn about flying cars and will implement the full-stack for *the entire autonomous aerial system*. After an intro course covering fixed wing aircrafts, you will learn how to update and optimize vehicle parameters and routes over “flying car-length” missions. You will then move beyond single vehicles and coordinate an entire fleet of flying cars. You will leverage cutting-edge technologies, learn real-world systems and regulations, and complete projects culminating in an entire “flying city” finale.

Course 5: Flying Cars

While quadrotors are the ideal test platform for aerial robotics, flying cars and other long-range aircrafts leverage the aerodynamic efficiencies of fixed wing flight. In this course, you will learn how to adapt Term 1 concepts and successfully fly a fixed wing aircraft in simulation. As an extracurricular project, you will also have the opportunity to explore and optimize hybrid vertical take-off and landing (VTOL) designs.

Project 5: Fixed Wing Flyer
In this project you will code a fixed wing aircraft. You will implement solutions to the comparably much more difficult control and estimation problems.

Extracurricular Project: VTOL Design
Unlike plane designs, which have converged on a common design, flying car design is a very open problem. Most proposed solutions are VTOL’s that use propellers to hover and fixed wings to cruise. In this extracurricular, you can explore the efficiency tradeoffs between different designs.

Course 6: System Identification

Flying cars are complex, human-carrying systems that fly long ranges over variable environments. As such, vehicle parameters—everything from mass to propellor efficiency to drag coefficient—might change, even in one mission. In this course, you will learn about system identification and calibration and use it to properly model an emergency aid vehicle.

Project 6: Adaptive Flight
In this project, you will develop an autonomous, adaptive aerial vehicle emergency aid vehicle. The main focus will be adapting your vehicle representation via system identification, even as the vehicle dispenses aid and thus experiences weight changes and aerodynamic shifts.

Course 7: Mission Optimization

Flying cars and other next-gen flight systems will deliver services on-demand via fleet. In this course, you will learn how to optimize not just one vehicle, but an entire fleet, for a set of given routes. This will involve a series of optimization lessons and will culminate in an on-demand flight project.

Project 7: Flying Fleet
In this project, you will take a set of passenger sources and destinations, as well as a fleet of vehicles, and optimize vehicle routes. In doing so, you will implement a ride-sharing system in the sky.

Course 8: Fleet Coordination

Future cities will not just have flying car fleets. Nor will they have only parcel drone fleets or meal delivery drone fleets. They will have all of these and more. In this course, you will learn how to coordinate all these diverse fleets, avoid conflicts and collisions, and work with a central traffic controller.

Project 8: Flying City
All your work in the program culminates in this grand finale. A vast and wide-ranging collection of flying drones and cars safely and autonomously zoom around the city of the future.