# Aerial Robotics

| Code | Credit Hours |
|---|---|
| AE- 445 | 1-1 |

**COURSE DESCRIPTION**:

This course aims to introduce concepts of the holistic design of autonomous aerial robots. The focus of the course will be on Unmanned Aerial Vehicle design, data acquisition through sensors and incorporation of intelligence for autonomous flight control. The course will also build the concepts of hardware and software related to Autonomous Flight Stack Implementation including UAV's dynamics, flight control, simultaneous localization and mapping, path planning and autonomous navigation. A brief introduction of Robot Operating System and Flight Controllers will also be taught as a part of this course.

**TEXT AND MATERIAL**

**Textbooks:**

1. F. Lewis, **"Aircraft Control and Simulation"**, Wiley Latest Available Edition
2. S. Leutenegger,C. Huerzeler, A.K. Stowers, K. Alexis, M. Achtelik, D. Lentink, P. Oh, and R. Siegwart. **"Flying Robots", Handbook of Robotics** Latest Available Edition .

**Reference Material:**

1. K. Valavanis, and P. Vachtsevanos, **"Handbook of Unmanned Aerial Vehicles"**, Springer 2020
2. R. Beard, and T. W. McLain, **"Small Unmanned Aircraft: Theory and Practice"**, Princeton University Press 2012

**PREREQUISITE:**

Control Systems

**ASSESSMENT SYSTEM FOR THEORY**

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| Quizzes | 10% |
| Assignments | 10% |
| Mid Terms | 30% |
| ESE | 50% |

**ASSESSMENT SYSTEM FOR LAB:**

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| Quizzes | 10%-15% |
| Lab Work/ Report | 60-80% |
| Lab ESE/Viva | 20-30% |

## Teaching Plan (Theory)

| Week No | Topics | Learning Outcomes | Delivery Method |
|---|---|---|---|
| `1 | **Introduction to Aerial Robotics** | Introduction to Aerial Robotics, Historical Background of Aerial Robots, Current Trends in Aerial Robotics, Impact in Society, Challenges in Aerial Robotics, and Aerial Robot Platforms | Lecture and discussion |
| 2 | **Introduction to Aerial Robotics** | The Aerial Robot Loop, Introduction to Perception & State Estimation, Flight Control System, Path Planning, Course Projects Assigned to Teams | Lecture and discussion |
| 3 | **Navigation Sensors** | Classification of Sensors, Typical Navigation Sensors, Inertial Sensors (Accelerometers, Gyroscopes), Magnetometers (digital compass), Pressure Sensors, Barometric pressure for altitude sensing, Airspeed measurements, GPS, Camera based navigation systems, Time-of-Flight sensors | Lecture and discussion |
| 4 | **Navigation Sensors** | LIDAR, SLAM - A micro-introduction | Lecture and discussion |
| 5 | **Micro Aerial Vehicle Dynamics** | MAV Dynamics, MAV Propellers | Lecture and discussion |
| 6 | **Coordinate Frames** | Coordinate Frames, Rotation of Reference Frame, Inertial & Vehicle Frames, How to represent orientation? (Euler Angles, Quaternions), Robot Kinematics. | Lecture and discussion |
| 7 | **State Estimation** | Sensor Model, Motion Model, Introduction to Probabilistic Robotics. | Lecture and discussion |
| 8 | **Flight Controls Introduction** | Attitude Control, Position Control | Lecture and discussion |
| 9 | **MID TERM EXAM** | | |
| 10-11 | **Flight Controls Introduction** | , Model Predictive Control | Lecture and discussion |
| 12 | **PID Control** | PID Controller Design for Micro Aerial Vehicles. | Lecture and discussion |
| 13 | **Autopilot Study** | Autopilot Functionality Stack | Lecture and |

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| 14 | **Autopilot Study** | 2D Case Study | Lecture and discussion |
| 15 | **Aerial Robot Motion Planning** | Trends in Motion Planning, Fundamental Problem of Path Planning, Coverage Path Planning Problem, Rapidly-exploring Random Trees (RRTs) Algorithm. | Lecture and discussion |
| 16 | **Aerial Robot Path Planning** | Sampling-based Inspection Path Planning, Exploration of Unknown Environment) | Lecture and discussion |
| 17 | **Aerial Robot Path Planning** | Rapidly-exploring Random Tree-Of-Trees (RRTOT | Lecture and discussion |
| 18 | **End semester exam (ESE)** | | |

## Teaching Plan (Lab)

| Exp. No. | Description |
|---|---|
| 1. | Introduction to ROS Topics, Services, Actions and Nodes. Simple interaction with the course |
| 2. | Simulation environment Overview of ROS using Python |
| 3. | Software representation of a Robot using Unified Robot Description Format (URDF), ROS parameter |
| 4. | Server and adding real-world object representations to the simulation environment. |
| 5. | ROS simulation tools: Gazebo and Vrep |
| 6. | Drone Design in ROS: Fixed wing |
| 7. | Drone Design in ROS: Quadcopters |
| 8. | Map creation with GMapping package, autonomously navigate a known map with ROS navigation. |
| 9. | Motion planning with single drone: Concept of SLAM |
| 10. | Motion planning with multi-drones: Concepts of SWARM |
| 11. | Introduction to Pixhawk controllers |
| 12. | Implementation of flight navigation and control on DJI Tello drones |
| 13. | Swarm Intelligence implementation on DJI Tello drones |
| 14. | Project |
| 15. | Lab Exam |