Introduction to Robotics

This course is organized over 7 lectures spread over 7 half days of 3 hours.

Each lecture is made of a 1.5 hour of class taught by the instructor. The course continues with a 1.5hour exercise session where the students solve written or computer exercises. The instructor provides individual guidance to each student in order to effectively progress in the exercises.

The evaluation of the attendees is made by one home/project assignment (50% grade) and one final 1.5 hour exam (50% final grade).

Instructor: Dr. Guillaume Ducard

Dr. Guillaume Ducard received his Master of Science (MSc) in Electrical Engineering from ETH Zurich in 2004. In 2007, he completed his doctoral work (PhD) on the topic: "Fault-tolerant Flight Control and Guidance for a Small Unmanned Aircraft," at the Institute for Dynamics Systems and Control (IDSC), ETH Zurich. Between 2008 and 2010, he worked as a postdoc at the IDSC, ETH Zurich, as a team leader for the project "The Flying Machine Arena," and lectured a number of classes at ETH. Since 2010, he is an assistant Professor at University of Nice Sophia Antipolis, France, where he teaches classes on control theory and signal processing, and he continues fundamental research about unmanned aircraft flight control. He is the author of one book and two book chapters by Springer, and a number of journal and conference papers. He is an IEEE member since 2007.

Course description

Common sensors in robotics, inertial measurement unit, GPS, barometer, airspeed meter, orientation representation, quaternions, complementary filtering, Kalman filtering, data fusion, and multi-sensor estimation, practical implementation on a microcontroller.

Goals of the course

In every-day applications ranging from mobile phones, cars, planes, etc., an inertial measurement unit (IMU) can be found as the primary sensor suite. In this lecture, the attendees will become familiar with the sensors of an IMU, namely accelerometers, gyrometers, and magnetometers.

Because in every robotic application, it is fundamental to know the orientation of the robot, the theory of attitude (orientation) representation and estimation will be presented during the class. In addition, the robot's pose (velocity and position) can be further estimated if additional sensors are added, for example a GPS receiver, a barometer and an (air-)speed sensor (these sensors will also be covered during the class).

At the end of the lecture, a small project is to be done. It involves a real IMU and a microcontroller board. Groups of student have to program the microcontroller to get the data from the IMU, process the sensor measurement data in order to generate an attitude estimate and display it on a 3D GUI.

Session 1: Sensors in robotics

- Accelerometers
- Gyroscopes
- Magnetometers
- GPS
- Barometers
- Airspeed sensors
- Sensor error model

Exercise 1 + discussion

Session 2: Orientation representation and Attitude dynamics (Rotational velocities)

- Frames and Transformations
- Attitude representation
- Euler angles
- Quaternions
- Direction cosine matrix
- Rotation matrix
- The Rodriguez formula
- Euler-angle-rates dynamics
- Quaternion dynamics

Exercise 2 + discussion

Session 3: Sensor fusion in robotics: using Kalman filters

- (Extended) Kalman Filters
- Worked example: Altitude estimation using an accelerometer and a barometer

Exercise 3 + discussion

Session 4: Sensor fusion in robotics: using a complementary filtering approach

- Theory of the approach
- Examples

Exercise 4 + discussion

Session 5: Practical session 1

3 hours

Session 6: Practical session 2

3 hours

Lecture 7: Practical session 3 and projects presentation

3 hours, the second half of the session will be dedicated to each student project presentation.

Final Exam: 1h30

The final exam is made of exercises and questions on the material covered during the lectures and exercise sessions.