1 Course Outline

This is an introductory course on Robotics. The focus is on kinematics and dynamics of serial linkages and rigid bodies, as applied to robot arms, flying robots, etc. The course covers such topics as singularities and null spaces, inverse kinematics and dynamics, trajectory planning.

2 Grading Policy

Grading criteria:

- A: 85-100 points
- B: 64-84 points
- C: 50-64 points
- D: less than 50 points

Credit distribution:

- Lab 1 - up to 10 points
- Homework 1 - up to 10 points
- Homework 2 - up to 10 points
- Homework 3 - up to 10 points
- Midterm - up to 30 points
- Exam - up to 30 points

2.1 Late Submission Policy

Points might be deducted if the work is submitted after deadline

3 Course Outline

3.1 Knowledge Areas (in terms of application)

- Robotics
- Automation
- Control
- Computer vision

3.2 Course Delivery

Two lectures and two practical sessions a week (those could be labs, seminars, practice with equipment).

3.3 Prerequisite courses

- Strong prerequisites: Linear Algebra, Classical Mechanics.
- Weak prerequisites: Calculus, Control Theory.
- Required background knowledge: Python (alternatively Matlab or any other language suitable to work with linear algebra-heavy problems), Ubuntu (for ROS-related practical sessions)

3.4 Expected Learning outcomes

The course will provide an opportunity for participants to:

- Understand how to do frame transformations on serial linkages, finding positions and orientations of the links of these mechanisms, understanding concepts in analytical and numeric forward and inverse kinematics, understanding role of jacobians and their fundamental subspaces, understand for dynamical equations are derived, how inverse dynamics is solved, what is trajectory planning.
- Learn how to use URDF to describe robots, how to use jacobians to solve problems relating task and joint velocities, as well as forces and joint torques, learn analytic and software-based methods for dynamics equation generation, learn collocation methods for trajectory planning.
- Being able to write software and other code-based solutions for robot arm motions grounded in robot kinematics and dynamics.

3.5 Expected acquired core competencies

- Forward and inverse kinematics.
- Jacobian-based analysis.
- Dynamics, derivations.

3.6 Reference Materials

- Annotated slides
- Online materials
- Educational videos

3.7 Computer Resources

Students will need to run computer experiments on a laptop and/or on lab computers, as well as working with the hardware.

3.8 Laboratory Exercises

There are a series of labs and electronic handouts prepared for the course.

3.9 Laboratory Resources

Students will be required to use and modify a software tool written in Python which run on multiple platforms (Linux, Microsoft Windows, and Mac OS). The tool requires freely available software libraries.

3.10 Cooperation Policy and Quotations

We encourage intensive discussion and collaboration in this class. You should feel free to discuss all aspects of the class with classmates and work with them to complete your assignments and project report. However, if you are working together, you must provide details of your contribution and that of others.

4 Course Structure

The course structure is given in the table 1.

Table 1: Course Structure

Lecture 1-3	Introduction. 2D linkages: joints, forward kinematics, angular velocity, rotation matrices. 3D linkages: forward kinematics, angular velocity, rotation matrices.	Lab 1
Lecture 4-7	Fundamental subspaces of linear operators. Jacobians, velocity. Inverse kinematics. Task prioritization.	Homework 1
Lecture 8-10	Lagrange to Manipulator equations. Inverse dynamics. Trajectory planning. CTC; force control, impedance. Quadratic programming in Robotics.	Homework 2
Lecture 11-13	Rotations: quaternions, SO(3), Euler angles. Systems with constraints. Recap.	Homework 3