ELEC4220 Introduction to Robotics: From Mobile Robots to Manipulators

Course Description

This course introduces basic building blocks of robots: actuators (DC and servo motors), sensors (proprioceptive/exteroceptive, passive/active); controller platforms as well as mechanical modules; and basic concepts of robotics: rigid motion and configuration space, kinematics, dynamics, trajectory generation and planning, locomotion, localization and mapping, navigation and control. Using these basic building blocks and robotic concepts, students will learn how to design and build a robot prototype that meets certain design specifications. Design examples include a mobile robot to engage in a competition, a robotic manipulator in a typical assembly task, an unmanned aerial vehicle (UAV) in a surveillance application, etc. *Prerequisite(s):* ELEC 3200

List of Topics

1. Course introduction; joints, links, and actuators; degrees of freedom of a mechanism; Gruebler's formula and other methods for analyzing a mechanism's degrees of freedom
2. Grasping: contact models, convexity test for force closure
3. Grasping: Nguyen's theorem for determining planar force closure, extensions to the spatial case
4. Angular velocities; velocity and acceleration analysis using moving frames
5. Rotations: the rotation group *SO(3)*, Euler angle and roll-pitch-yaw parametrizations of rotations
6. Rigid-body motions: the 4X4 homogeneous transformations and the Special Euclidean group *SE(3)*
7. Forward kinematics of open chains: the Denavit-Hartenberg representation
8. Screw theory: exponential representation of rotations
9. Screw theory: exponential representation of rigid-body motions
10. Forward kinematics of open chains: the product-of-exponentials formula
11. Differential kinematics: angular and spatial velocities
12. Differential kinematics: the manipulator Jacobian
13. Differential kinematics: statics, kinematic singularity analysis, and other applications involving the manipulator Jacobian
14. Inverse kinematics of six degree-of-freedom open chains: architectures that admit closed-form solutions
15. Inverse kinematics of six degree-of-freedom open chains: numerical methods
16. Kinematics of wheeled mobile robots
17. Motion planning: the potential field method

18. Motion planning: randomized sampling algorithms
19. Basics of robot control: independent joint PD control
20. Basics of robot control: model-based control, force control

Statement of Objectives/Outcomes:

On completion of this course, students will be able to:

CO1 - recognize the history and development of the robotics field

CO2 - identify the basic building blocks of robots and concepts of robotics

CO3 - analyze, design and debug building modules for robots

CO4 - design and build a robot that meets a given set of specifications

CO5 - work in a team environment: learn and practice effective project and time management

CO6 - execute a complete project from problem formulation, design/implementation, up to verification and documentation

Textbook(s):

Lecture notes entitled *Introduction to Robotics: Mechanics, Planning, and Control,* by F.C. Park and K.M. Lynch

Reference Books/Materials:

1. J. Craig, *Introduction to Robotics: Mechanics and Control*, Prentice Hall, 2004.
2. R. Murray, Z. Li, and S. Sastry, *A Mathematical Introduction to Robotic Manipulation*, CRC Press, 1994.
3. M. Spong, S. Hutchinson, M. Vidyasagar, *Robot Modeling and Control*, Wiley, 2005.
4. B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, *Robotics: Modelling, Planning and Control*, Springer, 2011.

Relationship of Course to Program Outcomes:

Please refer to the Report Section 4.3.2 (iii).

Grading Scheme:

Homework or laboratory assignments	30%
Final term project	15%
Midterm Exam	25%
Final Exam	30%