M2794.0027 Introduction to Robotics
Spring 2015
Syllabus

Introduction: This course provides a rigorous foundation for the mechanics, planning, and control of robots. The emphasis will be on learning the fundamental concepts and principles that underly robotics—the intent is to help students acquire a unified set of analytical tools for the modeling, planning, and control of robots, together with a reliable physical intuition that recognizes the unique and interdisciplinary nature of robotics. While there will be some discussion of the latest research trends and technological innovations in robotics, the emphasis is strongly on content that will serve as a foundation for whatever trends may appear later. In addition to advanced courses that address specialized topics in robotics, courses in computer graphics and animation, computer vision, computer-aided design, and multibody dynamics—essentially, any course in which spatial motions and rigid body physics plays a central part—should benefit from the contents of this course.

Lectures: Lectures will be held on Mondays and Wednesdays from 14:05-15:20, in lecture hall 301-105. All lectures will be conducted in English.

Discussion Section: In addition to the lectures, students are expected to attend a one-hour discussion section each week. Discussion groups, consisting of approximately 15-20 students each, will be organized and run by the teaching assistants on a weekly basis, with the goal of reviewing the lecture material, solving practice problems, and giving the students an opportunity to ask questions. Discussion sections will meet on Thursdays and Fridays in the late afternoon; the meeting times and locations will be announced at a later date. The first discussion session will be held from the second week of the course. Attendance in the discussion sections is mandatory.

Course Instructor: The instructor for the course is Frank Chongwoo Park. His office is located in Building 301, Room 1515. He can be reached at 880-7133, or by email at *fcp@snu.ac.kr*. Regular office hours will be maintained on Mondays and Wednesdays from 3:30-4:30; other times can be arranged by appointment.

Teaching Assistants: The teaching assistants for the course are:

- Soocheol Noh (Head TA) (Email: prime73@snu.ac.kr)
- Jihoon Song (Email: sjh0419@snu.ac.kr)
- Taeyoon Lee (Email: alex07143@snu.ac.kr)
- Kyumin Park (Email: us01005@snu.ac.kr)
- Paolo Tommasino (Email: paolo@robotics.snu.ac.kr)

TA offices are located in the Robotics Laboratory, Building 302, Room 413. The main lab telephone number is 880-7149. Office hours maintained by each TA will be announced at a later date.

Course Webpage: A course webpage will be maintained at *http://etl.snu.ac.kr*. All lecture notes, homework assignments, solutions, and announcements will be made available on the course webpage. A monitored course discussion board will also be available. Personal communications with the teaching assistants should be conducted by email rather than through this course discussion board.

Course Materials: The course text will be a set of lecture notes entitled *Introduction to Robotics: Mechanics, Planning, and Control*, by F.C. Park and K.M. Lynch. Chapters will be distributed at least a week prior to their coverage in lectures. For those who desire additional sources, the following references are recommended:

- J. Craig, *Introduction to Robotics: Mechanics and Control*, Prentice Hall, 2004. This is one of the most widely used and classical textbooks in robotics. its scope is roughly equivalent to that covered in the course, although it does not introduce the product of exponentials formalism, and differs significantly in style and presentation.
- R. Murray, Z. Li, and S. Sastry, *A Mathematical Introduction to Robotic Manipulation*, CRC Press, 1994. This text is a graduate level introduction to the contents of this course. It is highly mathematical and contains advanced material beyond what is covered in this course, but adopts the same geometric approach to robot mechanics that we do, and is a useful reference to those who wish to probe more deeply.
- M. Spong, S. Hutchinson, M. Vidyasagar, *Robot Modeling and Control*, Wiley, 2005. The exposition is similar to Craig, but with broader coverage of topics, i.e., vision and visual servo control, basics of motion planning, and a very accessible treatment of geometric nonlinear control, in addition to the standard material on robot mechanics and control.
- B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, *Robotics: Modelling, Planning and Control*, Springer, 2011. An even broader coverage of topics than Spong *et al*'s book, this text also offers extensive coverage of mobile robots in addition to the standard material on robot mechanics, planning, and control.

Video lectures for the course are also available at (i) http://snuon.snu.ac.kr (search for "Introduction to Robotics"); (ii) http:/www.edx.org (search for "SNUx Robotics Mechanics and Control, Parts I and II"). These video lectures were recorded in the spring semester of 2013. For 2015 we will be covering material not covered in the video lectures (i.e., robot dynamics, motion planning basics), and omitting certain material from the video lectures (i.e., closed chains and parallel manipulators).

Grading: The grading for the course will be based on two in-class examinations (45% combined), a final exam (45%), and participation in discussion sections (10%). Weekly problem sets will be assigned but not graded. The weights are approximate, and may be adjusted accordingly at the discretion of the instructor.

Prerequisites: The only prerequisites for the course are an understanding of rigid-body physics and mathematics at the sophomore level. The kinematics of particles and rigid bodies as covered in a sophomore dynamics course is useful but not necessary. There will be extensive use of concepts and techniques from linear algebra and differential equations; previous exposure to these subjects (corresponding to the material covered in a sophomore engineering mathematics course) is helpful but not essential, as these concepts will be covered in class.

Lecture Schedule: We will attempt to adhere as closely as possible to the following schedule of topics (topics for the final 2-3 lectures may be rearranged or modified depending on circumstances):

- **March 2** (M): Course introduction
- **March 4** (W): Joints, links, and actuators; mobility of a mechanism; Gruebler's formula and other methods for analyzing a mechanism's mobility (**No discussion sections this week**)
- **March 9** (M): Force closure: contact models, convexity test
- **March 11** (W): Force closure: Nguyen's theorem for determining planar force closure, extensions to the spatial case
- **March 16** (M): Planar force closure: Nguyen's theorem for determining planar force closure, extensions to the spatial case
- **March 18** (W): Angular velocities, velocity and acceleration analysis using moving frames
- **March 23** (M): Rotations: the rotation group $SO(3)$, Euler angle and roll-pitch-yaw parametrizations of rotations
- **March 25** (W): Rigid-body motions: the 4×4 homogeneous transformations and the Special Euclidean group $SE(3)$
- **March 30** (M): Forward kinematics of open chains: the Denavit-Hartenberg representation
- **April 1** (W): Screw theory: exponential representation of rotations
- **April 6** (M): Screw theory: exponential representation of rigid-body motions
- **April 8** (W): **Examination I** (**No discussion sections this week**)
- **April 13** (M): Forward kinematics of open chains: the product-of-exponentials formula
- **April 15** (W): Differential kinematics: angular and spatial velocities
- **April 20** (M): Differential kinematics: the manipulator Jacobian
- **April 22** (W): Differential kinematics: statics, kinematic singularity analysis, and other applications involving the manipulator Jacobian
- **April 27** (M): Inverse kinematics of six degree-of-freedom open chains: architectures that admit closed-form solutions
- **April 29** (W): Inverse kinematics of six degree-of-freedom open chains: numerical methods; inverse kinematics of redundant open chains
- **May 4** (M): Dynamics of a single rigid body
- **May 6** (W): Dynamics of open chains: the Lagrangian formulation
- **May 11** (M): Dynamics of open chains: the Newton-Euler formulation
- **May 13** (W): Motion planning: the potential field method
- **May 18** (M): Motion planning: randomized sampling algorithms

- **May 20** (W): **Examination II** (**No discussion sections this week**)
- **May 25** (M): NO LECTURE (Official Holiday)
- **May 27** (W): NO LECTURE (IEEE Int. Conf. Robotics and Automation)
- **June 1** (M): Basics of robot control: independent joint PID control control
- **June 3** (W): Basics of robot control: dynamic model-based control
- **June 8** (M): Basics of robot control: force control, hybrid force-position control
- **June 10** (W): **Final Exam** (3 hours, 6-9PM, covering the entire course)