M2794.0057 Advanced Topics in Dynamics, Control, and Robotics: Optimization and Machine Learning in Robotics: A Geometric Perspective Fall 2016 Syllabus

Introduction: Methods from machine learning are starting to play a greater role in robotics, by enabling robots to learn from experience and to acquire skills needed to operate autonomously in unstructured environments. Some of these skills include sensorimotor capabilities such as locomotion, grasping, object recognition, manipulation, and the learning of complex tasks. Also in the context of automation, where emphasis is placed on reliability and efficiency over extended periods, machine learning methods are being used for, e.g., inspection tasks in manufacturing assembly.

The aims of this course are to learn the fundamentals of machine learning in a robotics and automation context, and to examine the state-of-the-art in how machine learning algorithms are being used to enhance the operational capabilities of robots. A unique and defining feature of this course is the geometric perspective from which we approach the main concepts. While it is by now well-established that machine learning has strong connections to probability and statistics and also optimization, its connections to geometry have not been developed to the same extent. One of our aims in this course is to make more explicit the connections to geometry (particularly differential geometry) and also to mathematical optimization, both to put the theory on a firmer mathematical footing and to exploit the available tools and concepts from geometry for designing better algorithms.

The course is organized as a series of lectures given by the instructor, with occasional guest lecturers invited to cover specialized topics. Course participants will serve as scribes, and at the end of the course a set of edited and refined lecture notes will be compiled.

Prerequisites: This course is a graduate advanced topics course, and students are expected to have previous exposure to the fundamentals of systems and control theory, and also to basic concepts in robot mechanics and control. An introductory graduate course in systems and control or equivalent, and an undergraduate course in robotics, computer vision, or equivalent, are necessary prerequisites. Students should also have studied probability and statistics as covered in an undergraduate applied mathematics course. The course also draws heavily upon methods of linear algebra, and as such courses on multidimensional systems analysis and optimization, while not required, will be helpful. **All students should obtain prior permission of the instructor at the beginning of the course**.

Course Instructor: The instructor for this course is Frank Chongwoo Park (fcp@snu.ac.kr). F.C. Park's His office is located in Building 301, Room 1515, Tel. (02) 880-7133. Meetings can be arranged by previous appointment.

Lectures: The course format will primarily be based on two weekly lectures given by the instructors. The lectures will be given on Tuesdays and Thursdays from 15:30–17:00 in Building 301, Room 301. **All the lectures will be given in English.** Towards the end of the course, select guest lectures covering advanced topics and applications may also be offered. An important component of the course will be the edited lecture notes prepared and compiled by course participants.

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.

Course Materials: This course will draw upon a number of educational resources and materials. For the foundational material on machine learning, the lectures topics will cover selected chapters from "Machine Learning: A Probabilistic Perspective" by Kevin P. Murphy (MIT Press) and "Pattern Recognition and Machine Learning" by Christopher M. Bishop (Springer). For reinforcement learning, "Probabilistic Robotics" by Sebastian Thrun et al. (MIT Press) will be the primary reference. Note however that our primary aim in this course is to approach this material from a geometric perspective as much as possible, and as such, supplemental lecture notes, papers, and handouts will be distributed to the class throughout the course. Students are also encouraged to seek out and share any new materials they discover that are relevant to the course.

Grading: The grading for the course will be based on a combination of lecture notes prepared by each student, homework assignments, a midterm exam, and an independently completed course project. Details of the course project will be given later in the course, and will involve the design and implementation of a machine learning algorithm to a current problem in robotics or a related area.