School of Informatics Teaching Course Proposal Form

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Proposal

Course Name: Robot Learning and Sensorimotor Control
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Course Year: 5
Names of any courses that this new course replaces :
RLSC (10 points)

Course Outline

Course Level: 11
Course Points: 20
Subject area: Informatics
Programme Collections:
Computer Science, Artificial Intelligence, Cognitive Science.

Teaching / Assessment

Number of Lectures: 36 one-hour lectures
Number of Tutorials or Lab Sessions: None
Identified Pre-requisite Courses: None (although recommended to take R:SS)
Identified Co-requisite Courses: None
Identified Prohibited Combinations: None

Assessment Weightings:
Written Examination: 60%
Assessed Coursework: 30%
Oral Presentations: 10%

Description of Nature of Assessment:

The final exam accounts for 60% of the score. There will be two written assignments, worth 15% each, which will include an implementation on a full physics simulation environment (to be done individually) and an oral presentation of a research paper review (10%) which will be done in teams of 2 or 3 depending on class size.

Course Details

Brief Course Description:

This course is designed as a follow up to the introductory course on Robotics: Science and Systems and will gear students towards advanced topics in applying Machine Learning towards Adaptive Control and Planning in Robots and in using these insights to understand human sensorimotor control. Control of complex, compliant, multi degree of freedom (DOF) sensorimotor systems like humanoid robots or autonomous vehicles have been pushing the limits of traditional planning and control methods. This course aims at introducing a machine learning approach to the challenges and will take the students through various aspects involved in motor planning, estimation, prediction, optimal control and learning for adaptation with an emphasis on the computational perspective. We will learn about statistical machine learning tools and methodologies particularly geared towards problems of real-time, online learning for robot control.

Specific methods for implementing optimal control in real world systems with contacts and learning methods geared towards making them adaptive will be explored. Issues and possible approaches for learning in high dimensions, planning under uncertainty and redundancy, sensorimotor transformations and stochastic optimal control will be discussed. This will be put in context through exposure to topics in human motor control, experimental paradigms and the use of computational methods in understanding biological sensorimotor mechanisms.

Detailed list of Learning Objectives:

1: Demonstrate knowledge of key areas of robot dynamics control and kinematic planning.

2: Analyze and evaluate conceptual and empirical problems in adaptive control and robot learning.

3: Analyze and implement a subset of established algorithms in dynamics learning and stochastic optimal control.

4: Demonstrate understanding of issues related to optimality in human motor control; develop ability to frame human motor control problems in an optimization framework.

Syllabus Information:

1. Machine Learning Tools for Robotics - Regression in High Dimensions - Dimensionality Reduction - Online, incremental learning - Multiple Model Learning
2. Optimal Control Approaches - LQR, LQG, Dynamic Programming, Trajectory Optimization: Direct and Shooting Methods (iLQR, DDP)
3. Adaptive Learning and Control - Predictive Control - Underactuation - Multi-contact modelling and optimization - Constrained Operational Space Control - Hierarchical QP and Stack of task formulation - Trajectory based optimization methods - Re-planning in alternate spaces
4. Interaction and Robust Control - Cartesian Impedance Control - Passivity Methods - Lyapunov Stability - LQR-Trees and Sum-of-Squares Programming
5. Movement Primitives - Rhythmic vs Point to Point Movements - Dynamical Systems and DMPs - Path Integral Methods - Learning by Demonstration
6. Planning and Optimization - Stochastic Optimal Control - Bayesian Inference Planning - RL, Apprenticeship Learning and Inverse Optimal Control
7. Understanding Human Sensorimotor Control - Force Field and Adaptation - Optimal control theory for Explaining Sensorimotor Behaviour - Cue Integration and Sensorimotor Adaptation - Impedance Control - Human(oid) Locomotion and Stability

Recommended Reading List:

1. Robert F. Stengel, Optimal Control and Estimation
2. Howie Choset et. al, Principles of Robot Motion: Theory, Algorithms, and Implementations
3. Mark W. Spong, Seth Hutchinson and M. Vidyasagar, Robot Modeling and Control
4. Sebastian Thrun, Wolfram Burgard and Dieter Fox, Probabilistic Robotics
5. Betts, Practical Methods for Optimal Control and Estimation Using Nonlinear Programming
6. Sciliano, Khatib (ed.) Springer Handbook of Robotics

Any additional case for support information:

This proposal is to expand the Robot Learning and Sensorimotor Control offering to a 20 point course to address 2 issues: (i) to expand the scope to include some new developments in machine learning and go more in depth on both the optimal control and human sensorimotor control side (thanks to expertise from new hire); (ii) address concerns of students that they would like to see more in depth coverage of some basic topics with worked out examples [this gives us more contact time to do this].