Mobile Robot Systems, Lent 2020-2021 - Dr. Amanda Prorok

Detailed Course Syllabus *(subject to minor adaptations during course of term)*

1. **Introduction (Jan 21)**
    1. Why study robotics?
    2. The basics of mobile autonomy
    3. History of robotics research
2. **Basics of autonomy / architectures (Jan 26)**
    1. Autonomy and sensor-actuator loops
    2. Reactive vs deliberative decision-making (and control)
    3. Control architectures
3. **Robot motion and control (Jan 28)**
    1. Motion models; wheeled robots
    2. Kinematics (first-order); forward and inverse kinematics
    3. Open-loop vs closed-loop control; intro to PID control.
4. **Perception (Feb 2)**
    1. Sensors and sensor
    2. Odometry
    3. Maximum likelihood estimation and sensor fusion
5. **Localization & Mapping (Feb 4)**
    1. Noise and belief representation
    2. Bayes rule, Bayes filter, Particle Filter, KF
    3. Grid localization and map representations
6. **Navigation & Path Planning (Feb 9)**
    1. Basic concepts
    2. Reactive navigation (without a roadmap)
    3. Deliberative planning (with a roadmap)
7. **MRS 1: systems of multiple robots (Feb 11)**
    1. Introduction to Multi-Robot Systems (MRS)
    2. Centralized vs decentralized architectures
    3. Collective movement (formations, flocking)
8. **MRS 2: task assignment (Feb 16)**
    1. Intro to assignment and task allocation
    2. Distribution (mean field approach)
    3. Assignment (discrete)
    4. Decentralized approaches; market-based, threshold-based
9. **MRS 3: multi-robot navigation and path planning (Feb 18)**
    1. Coordination vs collision avoidance
    2. Discrete domain: path finding
    3. Continuous domain: reciprocal velocity obstacle method
10. **Introduction to learning action policies through reinforcement learning (Feb 23)**
    1. Introduction and formal background
    2. Model-free learning algorithms
    3. Open problems (reward shaping and sim2real)
11. **Guest Lecture, Dr Fulvio Forni; Control by interconnection: shaping interaction (Feb 25)**
    1. Energy-based control
    2. Virtual model control
    3. Impedance control
12. **Guest Lecture, Dr Fumiya Iida: Bio-inspired navigation (March 2)**
    1. Animal navigation strategies; bio-inspired mobile/flying robot navigation
    2. Optic-flow and visual landmark navigation
    3. Sensory motor coordination

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Lectures:
Tuesdays and Thursdays. Pre-recorded material. Movies will be made available here:
https://www.youtube.com/playlist?list=PLaTKfS3-bDpDyOwrxLcQRGxY9XJw33ANo
and also here:
https://www.cl.cam.ac.uk/teaching/2021/MobRobot/video/

Interactive sessions with lecturer (Zoom):
Tuesdays: Jan 26, Feb 2, Feb 9, Feb 16, Feb 23
Time: 16:15-17:00.

Online Q&A sessions with teaching assistants (Zoom):
Tuesdays: Jan 26, Feb 2, Feb 9, Feb 23, March 2.
Time: 17:00-18:00.

Teaching assistants:
Steven Morad: sm2558@cam.ac.uk
Jan Blumenkamp: jb2270@cam.ac.uk
Ryan Kortvelesy: rk627@cam.ac.uk
Hai Zhong: hz376@cam.ac.uk

Additional project support:
Qingbiao Li: ql295@cam.ac.uk
Alex Raymond: ar968@cam.ac.uk

Deadlines:

Assignment 1: Feb 10, 2021 (noon)
Assignment 2: March 3, 2021 (noon)

Ticking session 1: Feb 16, 2021, 16:00-18:30
Ticking session 2: March 9, 2021, 16:00-18:30

Hand-in of project report:
CST MPhil and ENG Part IIB students: April 27, 2021 (noon)

Mini-project presentations (Zoom):
CST MPhil students: May 4, 2021
ENG Part IIB students: TBD (outside exam period)

Project work:
Only CST MPhils and ENG Part IIB students are to complete the project work. ENG Part IIB students will work in groups of 2 (or, exceptionally, 3). MPhil students will work individually.

Assessment:

CST Part II students: Each assignment (report + ticking scores) will compose 50% of the final mark.
CST MPhil / ENG Part IIB students: Each assignment will compose 30% of the final mark. The project will compose 40% of the final mark. When handed in as group-work in groups of 2-3, and the report will clearly state what each group member contributed. The overall project mark will be composed by a report score (60%) and a presentation score (40%). Project marks will reflect the contribution of each team member. Every team member is expected to make a similar, significant contribution to the project, and where this happens all team members will receive the same mark. Report format: students will hand in 6-page double-column report (conference-formatted), one report per student team.