Engineering Tripos Part IIB, 4M20: Introduction to Robotics, 2022-23

Module Leader

Prof F Iida [1]

Lecturers

Dr A Prorok, Prof F Iida, Dr F Forni, Dr R Harle [2]

Timing and Structure

Michaelmas term, 100% coursework

Prerequisites

3C5 useful; 3C8 useful; 3F2 useful; 3F3 useful

Aims

The aims of the course are to:

- Introduce fundamentals of robotics
- Learning technologies and techniques to design, assemble, and control robots
- Hands-on exercises on robot development through projects
- Presentation of research and development

Objectives

As specific objectives, by the end of the course students should be able to:

- Learning different design strategies and architectures of robots
- Design methods of automated complex systems
- Development of simulated complex robots
- Model-based analysis robot performance

Content

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

1. Introduction (A. Prorok) -- Oct. 6

    a. Why study robotics?

    b. The basics of mobile autonomy

c. History of robotics research

2. Architectures (A. Prorok) -- Oct. 13

a. Autonomy and sensor-actuator loops

b. Reactive vs deliberative decision-making (and control)

c. Control architectures

3. Introduction to kinematics (F. Iida) -- Oct. 20

a. Motion models; robots with non-holonomic constraints

b. Kinematics; forward and inverse kinematics

c. Open-loop vs closed-loop control; intro to PID control.

4. Introduction to dynamics (F. Forni) -- Oct. 27

a. Dynamics models

b. Open-loop and closed-loop control

c. PID control applied to dynamic systems.

5. Perception and Localization (R. Harle) -- Nov. 3

a. Sensors and sensor models, odometry

b. Maximum likelihood estimation and sensor fusion

c. Bayes rule, Bayes filter, Particle Filter, KF

d. Grid localization and map representations

6. Navigation and Planning (A. Prorok) -- Nov. 10

a. Reactive navigation (without a roadmap)

b. Deliberative planning (with a roadmap)

c. Planning in multi-robot systems

7. Multi-Robot Systems (A. Prorok) -- Nov.17

a. Introduction to Multi-Robot Systems (MRS)

b. Centralized vs decentralized architectures

c. Collective movement (formations, flocking)

d. Task allocation problems

8. Introduction to Advanced Robotics (A. Prorok) -- Nov. 24

a. Introduction to reinforcement learning methods

b. Open robotics problems

Pre-recorded material is available here:

https://www.youtube.com/playlist?list=PLaTKfS3-bDpDyOwrxLcQRGxY9XJw33ANo [3]

Coursework

The assignments will be 100% coursework and consist of two elements: (1) experimental work using a robot simulator and real robots, and (2) theory / understanding. The exercises will require data collection and analysis. The balance between practice and theory will depend on the exercise topic. Each student will submit a written report. Students will be expected to be able to demonstrate any results reported in their hand-in.

Each assignment will compose 45% of the final mark; the remaining 10% of the mark will be determined by the student's performance in a 1-on-1 viva with either the lecturer or a senior assessor. The mark for each assignment will be determined in part by the score achieved in the written report, and in part by the performance of the student during a questioning session. The lecturers will hold an in-person questioning session.

Deadlines:
Assignment 1: Nov. 7, (noon)

Assignment 2: Nov. 28 (noon)

Viva session 1: Nov. 8, 16:00-18:30 (Location - CST: Intel Lab, ENG: James Dyson Building Seminar Room)

Viva session 2: Nov. 29, 16:00-18:30 (Location - CST: Intel Lab, ENG: James Dyson Building Seminar Room)

Assistance:

Piazza (course Q&A wiki):

piazza.com/cam.ac.uk/fall2022/l310 [4]

Teaching Assistants' Office Hours:

Tuesdays, MT term.
CST: Office SN05, time: 16:00-17:00. ENG: By email appointment

Teaching Assistants:

CST:
Matteo Bettini: mb2389@cam.ac.uk [5] Jan Blumenkamp: jb2270@cam.ac.uk [6] Jennifer Gielis: jag233@cam.ac.uk [7] Steven Morad: sm2558@cam.ac.uk [8] Ajay Shankar: as3233@cam.ac.uk [9]

ENG:
Elijah Almanzor: eda26@cam.ac.uk [10] Fan Ye: fy264@cam.ac.uk [11]

Assessment:

Undergraduate students: The assignments will be 100% coursework and consist of two elements: (1) experimental work using a robot simulator and real robots, and (2) theory / understanding. The exercises will require data collection and analysis. The balance between practice and theory will depend on the exercise topic. Each student will submit a written report. Students will be expected to be able to demonstrate any results reported in their hand-in.

Each assignment will compose 45% of the final mark; the remaining 10% of the mark will be determined by the student's performance in a 1-on-1 (in-person) viva with either the lecturer or a senior assessor. The mark for each assignment will be determined in part by the score achieved in the written report, and in part by the performance of

the student during the viva session.

Please note that these assignments will NOT be anonymously assessed (like other ENG 4th year modules) because of the unique operations of this module.

Booklists

Recommended further reading materials will be instructed in the lectures.

Examination Guidelines

Please refer to Form & conduct of the examinations [12].

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Links
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