

## Engineering Tripos Part IIB, 4M20: Introduction to Robotics, 2021-22

### Module Leader

[Dr A Prorok](#) [1]

### Lecturers

Dr A Prorok, Dr F Iida, Dr F Forni, Dr R Harle

### 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. 7 (*Zoom live-stream*)

a. Why study robotics?

b. The basics of mobile autonomy

- c. History of robotics research

2. Architectures (A. Prorok) -- Oct. 14 (*in-person, West Cambridge Computer Lab LT1*)

- a. Autonomy and sensor-actuator loops
- b. Reactive vs deliberative decision-making (and control)
- c. Control architectures

3. Introduction to kinematics (F. Forni and F. Iida) -- Oct. 21 (*pre-recorded*)

- 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. Iida and F. Forni) -- Oct. 28 (*in-person, West Cambridge Computer LabLT1*)

- a. Dynamics models
- b. Open-loop and closed-loop control
- c. PID control applied to dynamic systems.

5. Perception and Localization (R. Harle) -- Nov. 4 (*in-person, West Cambridge Computer LabLT1*)

- a. Sensors and sensor models, odometry
- b. Maximum likelihood estimation and sensor fusion

- c. Noise and belief representation
- d. Bayes rule, Bayes filter, Particle Filter, KF
- e. Grid localization and map representations

6. Navigation and Planning (A. Prorok) -- Nov. 11 (*in-person, West Cambridge Computer Lab LT1*)

- a. Basic concepts
- b. Reactive navigation (without a roadmap)
- c. Deliberative planning (with a roadmap)
- d. Planning in multi-robot systems

7. Multi-Robot Systems (A. Prorok) -- Nov.18 (*in-person, West Cambridge Computer Lab LT1*)

- a. Introduction to Multi-Robot Systems (MRS)
- b. Centralized vs decentralized architectures
- c. Collective movement (formations, flocking)
- d. Task assignment

8. Introduction to Advanced Robotics (A. Prorok) -- Nov. 25 (*in-person, West Cambridge Computer Lab LT1*)

- a. Introduction to reinforcement learning methods
- b. Model-based vs model-free approaches
- c. Open robotics problems

## 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. 1, (noon)

Assignment 2: Nov. 22 (noon)

Viva session 1: Nov. 2, 16:00-18:30 (Location: William Gates Building, Intel Lab)

Viva session 2: Nov. 23, 16:00-18:30 (Location: William Gates Building, Intel Lab)

Coursework	Format	Due date & marks
<b>[Coursework activity #1 title / Interim]</b>  Coursework 1 brief description  <u>Learning objective:</u> <ul style="list-style-type: none"> <li>• study basic properties of finite difference methods.</li> <li>• learn to use Linux system and Fortran 90</li> <li>• Complete and validate a basic Euler code</li> </ul>	Individual Report  anonymously marked	Monday at noon  [45%]
<b>[Coursework activity #2 title / Final]</b>  Coursework 2 brief description  <u>Learning objective:</u> <ul style="list-style-type: none"> <li>• Extend and improve the Euler code</li> <li>• Use it to investigate challenging flows</li> </ul>	Individual Report  anonymously marked	Monday at noon  [45%]
<b>Viva</b>  Location: William Gates Building, Intel Lab		Sessions: No  16:00 - 18.30  [10%]

## Booklists

Please refer to the Booklist for Part IIB Courses for references to this module, this can be found on the associated Moodle course.

## Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [2].

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## Links

[1] <mailto:asp45@cam.ac.uk>

[2] <https://teaching.eng.cam.ac.uk/content/form-conduct-examinations>