Engineering Tripos Part IIA Project, GG4: Neural Control with Adaptive State Estimation, 2025-26

Leader

Dr Flavia Mancini [1]

Timing and Structure

Students work to their own schedule. A staffed "surgery" runs according to the lab timetable.

Prerequisites

Useful: 3F3 (Inference), 3F1 (Statistical Signal Processing), 3F4 (Systems and Control); Python (NumPy, Matplotlib, Jupyter)

Aims

The aims of the course are to:

- To introduce students to simulation and control of partially observed dynamical systems.
- To give practical experience with classical methods for state estimation.
- To explore optimal feedback control in a closed-loop system.
- To develop collaborative coding, analysis, and presentation skills.
- To foster understanding of robustness in estimation and control under noise and model mismatch.

Objectives

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

- Understand and apply state-space models to simulate dynamic systems.
- Implement and tune models to decode noisy observations.
- Design and use controllers for optimal state feedback control.
- Integrate estimation and control in a closed-loop system.
- Conduct experiments to assess tracking accuracy, control effort, and robustness.
- Collaborate effectively to develop shared code and produce a joint presentation.
- Present technical results clearly using plots, metrics, and structured reports.

Content

This lab explores how brain-machine interface (BMI)-like systems can decode noisy neural activity to control movement. In this design project, small groups will simulate and control a simplified neural interface system. A 2D cursor moves in a plane based on a latent trajectory, observed indirectly through noisy neural-like signals. Students will estimate the cursor's hidden state and control its movement toward a dynamic target. Over four weeks, they will explore estimation accuracy, control performance, and system robustness to disturbances and model mismatch. The project blends inference, control, signal processing, and neural data simulation in a realistic, design-oriented lab.

Week 1–2 (Group)

Introduction to classical filtering and control methods (primer provided).

Groups set up simulation environment and run example trajectories.

Implement group simulation code with documentation.

Deliverable: Group simulation code + brief documentation (group mark).

Week 3 (Individual)

Implement control loops.

Test closed-loop performance and robustness.

Continue experiments for final analysis.

Week 4 (Group & Individual)

Group presentation: approach, results, lessons learned (group mark).

Individual final report due end of Week 4: methods, results, discussion (individual mark).

Coursework

- Group Simulation Code & Documentation (Week 2): 10 marks
- Group Presentation (Week 4): 10 marks
- Individual Interim Report (end of Week 2: 20 marks
- Individual Final Report (Week 4): 40 marks

Examination Guidelines

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

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[1] mailto:fm456@cam.ac.uk
[2] https://teaching.eng.cam.ac.uk/content/form-conduct-examinations