Donders Institute
for Brain, Cognition and Behaviour

Computational Cognitive Neuroscience

Course information

Radboud University Nijmegen

Computational Cognitive Neuroscience

Organized by the Donders Institute for Brain, Cognition and Behaviour
Centre for Cognition, Department of Artificial Intelligence

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Prerequisites

- Programming experience
- Mathematical skills at the AI Bachelor level (probability theory, calculus and linear algebra)

Learning goals

After successful completion of the course, students

- understand the mathematical principles underlying four basic computational models in neuroscience: Bayesian modelling, neural networks, reinforcement learning and optimal control theory
- are able to implement basic models in Python
- have in-depth knowledge about how these models are used in different fields of cognitive (neuro)science
- are able to apply this knowledge to their own research proposal or model implementation

Course contents

During this course, students will gain an understanding of four important approaches in computational neuroscience: Bayesian modelling, neural networks, reinforcement learning and optimal control theory.

Part 1 of the course consists of a series of introductory lectures in which the basic conceptual and mathematical principles of these different approaches will be discussed and students will get familiar with basic Python implementations of these models.

During Part 2 various lecturers will discuss how these computational approaches are used in different areas of (cognitive) neuroscience; e.g. as a model for perception or single neuron coding or as a way to explain consciousness or motor control. During this part the students will learn how these computational approaches can be used to tackle neuroscientific problems. This will prepare them for the third part in which they have to apply this knowledge.

Part 3 consists of two options: one reflective and one computational. Students can choose which best matches their interest and background. The reflective option consists of writing a grant proposal in which the student proposes a novel application of the learned computational models to a specific (neuro)-cognitive problem. The computational option consists of implementing a computational model to solve a particular task the brain needs to solve as well. The output here is working code and a NIPS (nips.cc) style paper which describes the research question, model and results.

Literature

Lecture notes, selected papers, final assignments.

Teaching methods

Lectures, practical sessions, exercises

Exam information

The final grade is based on practical assignments, a final exam and the final assignment.

Course setup

The course consists of the following components:

1. Lectures
2. Practical assignments
3. Final assignment
4. Pitch presentation
5. Final exam

1. Lectures

The first few lectures will give an overview of the conceptual and mathematical basics of Bayesian modelling, neural networks, reinforcement learning and optimal control theory. There will be practical assignments accompanying these lectures to familiarize the students with implementing these kind of models. In the second part guest lectures will give examples on how these models can be applied in neuroscientific research.

2. Practical assignments

A second component of the course is the practical. In the practical sessions, you will learn how to implement various models discussed in class and make exercises to increase your understanding of the topic. You have to score at least a sufficient for these assignments to participate in the final exam and pass the course.

Next to the practical session, the practical assistants have walk-in hours in which students can individually ask questions about material discussed in class. Practical assignments need to handed in via Blackboard as one pdf document. For feedback on the practical solutions, please use the walk in hours.

3. Final assignment

The final assignment will make up 50% of the final grade. You can choose between a computational or a conceptual version of the final assignment. Both are aimed at applying the knowledge learned during the lectures of the course.

Computational

If you choose the computational final assignment, you are asked to implement a computational model yourself in Python. The aim of the model is that it can contribute to our understanding of how the brain might tackle a certain computational problem. To test and validate your model you can either use freely available neuroimaging data (there are some sources, but beware that the chance is small that you find exactly the data you need), or run you model on simulated data.

Your assignment will be judged mainly by the following points:
- A clean and correctly working implementation in Python.
- It's usability for explaining brain function.
- Your elaboration of the background of the problem you try to study and how your model can contribute.

Conceptual

The conceptual final assignment consists of writing a grant proposal for a 4-year PhD research project. This research project should combine computational modelling with neuroscience. A clear research question has to be formulated and coupled to computational modelling. This could mean proposing experiments to test an already existing computational model of a cognitive process or proposing new computational models to explain cognitive processes. The research covered during the guest lectures can be seen as examples.
The proposal should describe 4 years' worth of research to investigate the overarching question. The proposal should be approximately 4-5 pages with a maximum of 2000 words (excluding figures and references). The format of the research proposal can be found on Blackboard.

4. **Pitch presentation**

At the end of the course you have to present your final assignment to your fellow students in a 3-minute pitch using **1 slide**. You have to hand in your slide one day before your presentation (January 9th or January 16th). Doing the pitch is a prerequisite for taking part in the exam!

In the pitch you should mention the following:

- **The problem** your assignment was aimed at
- **How** you have/proposed to solve it
- The scientific/societal **relevance** of your project

Please realize that 3 minutes is very short, so try to be to the point and make it understandable for everybody.

4. Grading

The final mark will be based on three parts:

i. Final assignment (50%)
ii. Closed book exam (50%)
   There will be a final, written closed-book exam. This will consist of a series of open questions. Examinable is:

- All that has been discussed during lectures
- All background reading material
- All material handled in the practical sessions

Lecture program

The course consists of multiple lectures and associated required reading. Lecture slides and required reading will be made available on Blackboard. Some of the lectures will be given by guest lecturers.

Deadlines

- Practical assignments: Before the final lecture (November 14th 2016)
- 1-page proposal final assignment: The week after the final lecture (November 21st 2016)
- Final assignment: Before the pitch presentations (January 10th 2017)
- Hand in pitch slides: One day before pitch presentations (January 9th or January 16th 2017)