Course Mechanics

Lecturer: Max Di Luca

Mind, **B**rain, and **M**odels 2022/23

08/02/2023

People

- Module Leader: Max Di Luca
- TA: Kit Yeung
- Guest lecturers:
  - Dietmar Heinke
  - Alan Wing
  - Joe Galea
  - Howard Bowman

Delivery

- Canvas
- Hybrid: In-person + Zoom

Tentative schedule

Week		Lect	Lecturer	Lecture topic	Workshop topic
	1			Preparation	Matlab
08-Feb	2	1	Max	Models	2IFC experiment
15-Feb	3	2	Max	Bayesian	Distributions
22-Feb	4	3	Max+Min Li	Multisensory	Causal inference
01-Mar	5	4	Max	Control Theory	Inverted pendulum
08-Mar	6	5	Dietmar Heinke	Agent based	Social
15-Mar	7	6	Alan Wing	Synchronization	Clapping
22-Mar	8	7	Joe Galea	Cerebellum	Learning
19-Apr	9	8	Max	Touch	Fibers
26-Apr	10	9	Howard Bowman	Neural fields	Dynamics
03-May	11	10	Max	Visual processing	Convolution
9-May	12	11	Max	Project	Your choice

Assessment

2X 5%
- The first two submissions are peer-reviewed, pass/fail
  - Coding (only code submitted)
  - Reporting (code + report submitted)

8X 10%
- Each week you will have an assignment (code + report submitted)
  - A solution is going to be posted for the first part of the workshop on Thursdays
  - You will still need to implement some part of the code, perform the simulation, collect the data and write the report
  - Feedback is given when submitted, but grading is released on two dates
    - #1 grade (40%) comprises 4 reports
    - #2 grade (50%) comprises 4 reports + 1 free topic

1X 10%
- Free topic

Topics

- Lecture
- Lab
- Assignment
- Report
- Canvas
- Feedback
- Q&A

Specs

- Code
  - Needs to have comments and with variables having meaningful names
- Simulation
  - Why do you run it?
- Graphs
  - Axes need labels
  - Each graph needs to be described and referenced in the report

Computational Modeling

Lecturer: Max Di Luca

Mind, **B**rain, and **M**odels 2022/23 08/02/2023

- Trappenberg, TP (2002). Chapter 1. Fundamentals of computational neuroscience, Oxford University Press.
- Marr, D., (1982). Chapter 1. Vision, a computational investigation into human representation and processing of visual information, The MIT Press.

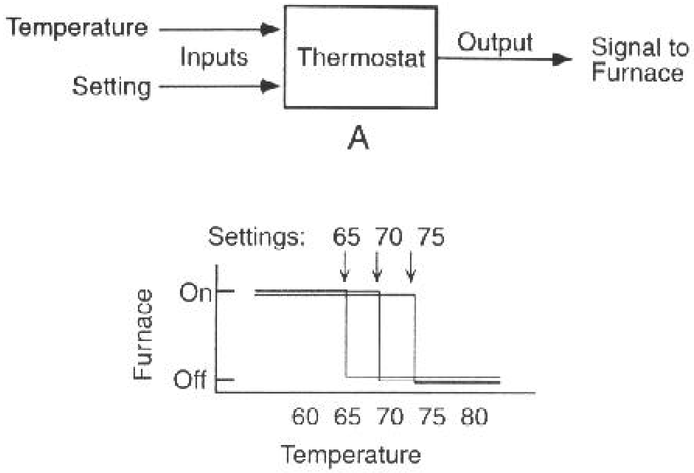
What is a model?

What a model is not?

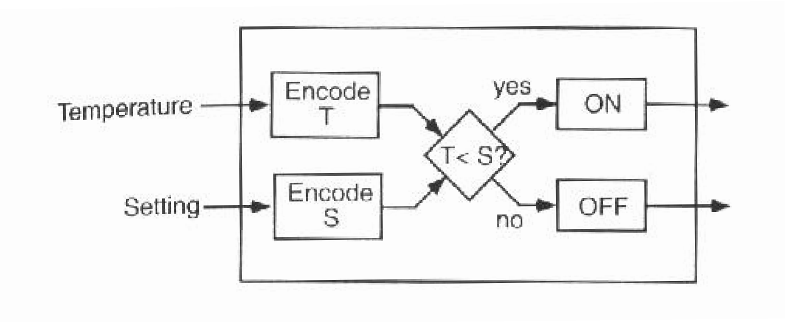
- "All models are wrong; some models are useful” George Box
  - Parsimony
  - Selective wrongness
- "All Models are Right, Most are Useless” Andrew Gelman
- Models vs Metaphors vs Analogies

Example: models of a thermostat

According to Marr (1982)

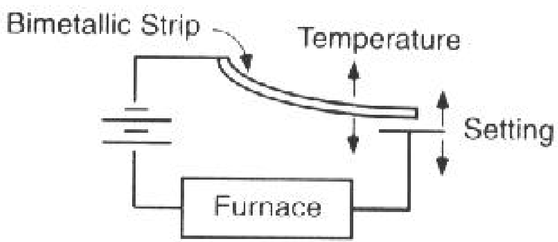


The **computational** level of description of an information processing system is the mathematical description of the mapping between the input to the system and its output



The **representation** and **algorithm** level of description of an information processing system specifies:

- the representation for the input and for the output
- the algorithm that transforms the input into the output



The **implementation** level of description of an information processing system specifies how an algorithm is embodied as a physical process in a physical system

Computational Models

- Descriptive/Phenomenological Models (What)
  - Quantitative description of input/output mapping
- Mechanistic Models (How)
  - Simulation
- Normative Models (Why)
  - Computational principles

What are models in Computational Neuroscience?

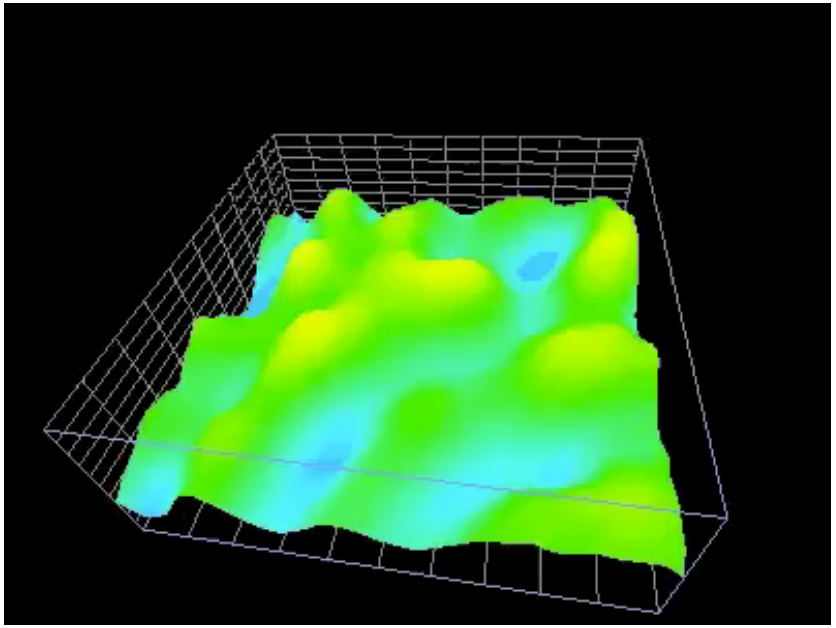
- "The goal of computational neuroscience is to **explain in computational terms how brains generate behaviors**" (T. J. Sejnowski)
- Computational neuroscience provides tools and methods for "characterizing **what nervous systems do**, determining **how they function**, and understanding **why they operate in particular ways**" (P. Dayan and L. Abbott)
- "The expression 'Computational neuroscience' reflects the possibility of generating **theories of brain function in terms of the information-processing properties** of structures that make up nervous systems. It implies that we ought to be able to exploit the conceptual and technical resources of computational research to help find explanations of how neural structures achieve their effects, what functions are executed by neural structures, and the nature of representation by states of the nervous system." (P. S. Churchland, C. Koch, T. J. Sejnowski)

Explanation direction

- Bottom-up strategy
  - higher-level functions can be neither addressed nor understood until all the fine-grained properties of each neuron and each synapse are understood.
  - network effects or system effects are emergent properties that that are not accessible at the single-unit level but need to be addressed by appropriate techniques
- Top-down strategy
  - dismissal of the organisation and structure of the nervous system as essentially irrelevant to determining the nature of cognition (Pylyshyn 1980; Fodor 1975).
  - computational space is consummately vast, and on their own, psychological and engineering constraints do not begin to narrow the search

Simulation

- Emergent properties
  - Dynamics
  - Population



Why models in computational neuroscience?

Evolution vs. Engineering

- Evolutionary changes are made within a context
- Evolution is a tinkerer that modifies available materials (Jacob 1982)
- Any function is part of a larger system and is consistent with the general design
- Neurobiological constraints (Churchland 1986)

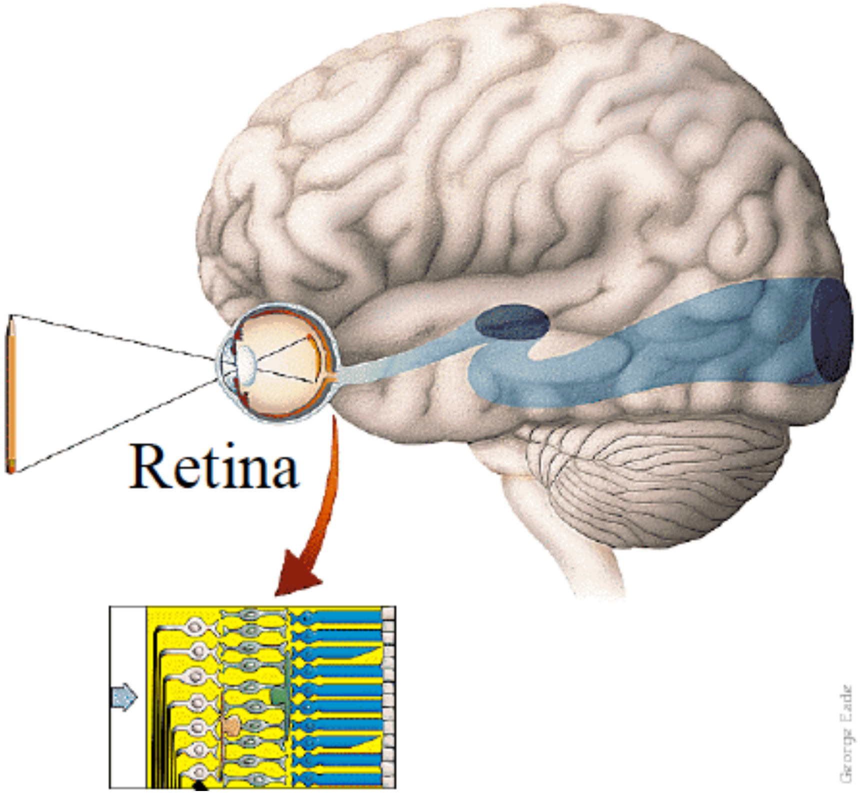
Example: Receptive field

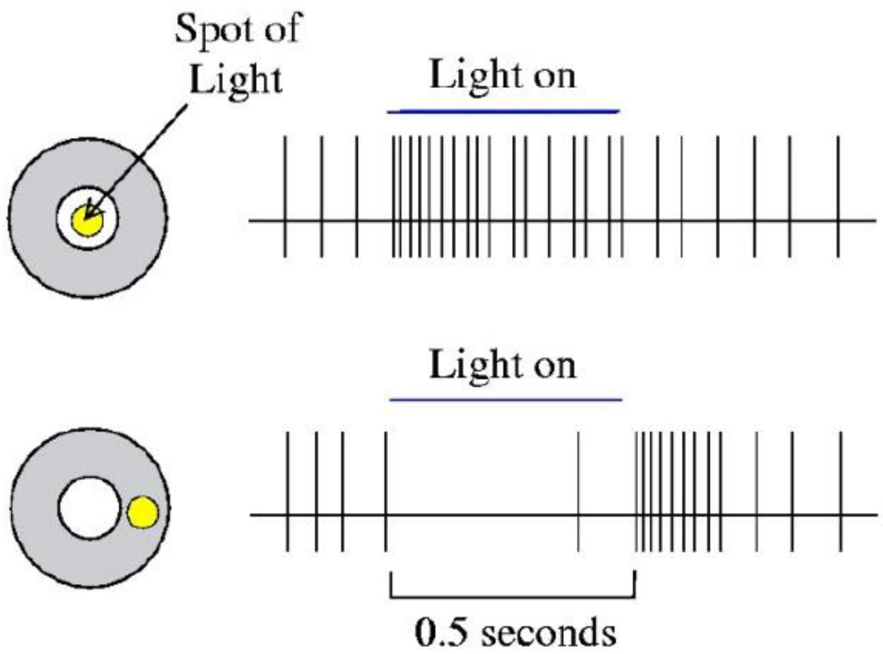
Specification of the stimulus properties that generate a neural response

- Descriptive Model (What)
- Mechanistic Model (How)
- Normative Model (Why)

https://www.youtube.com/watch?v=OGxVfKJqX5E

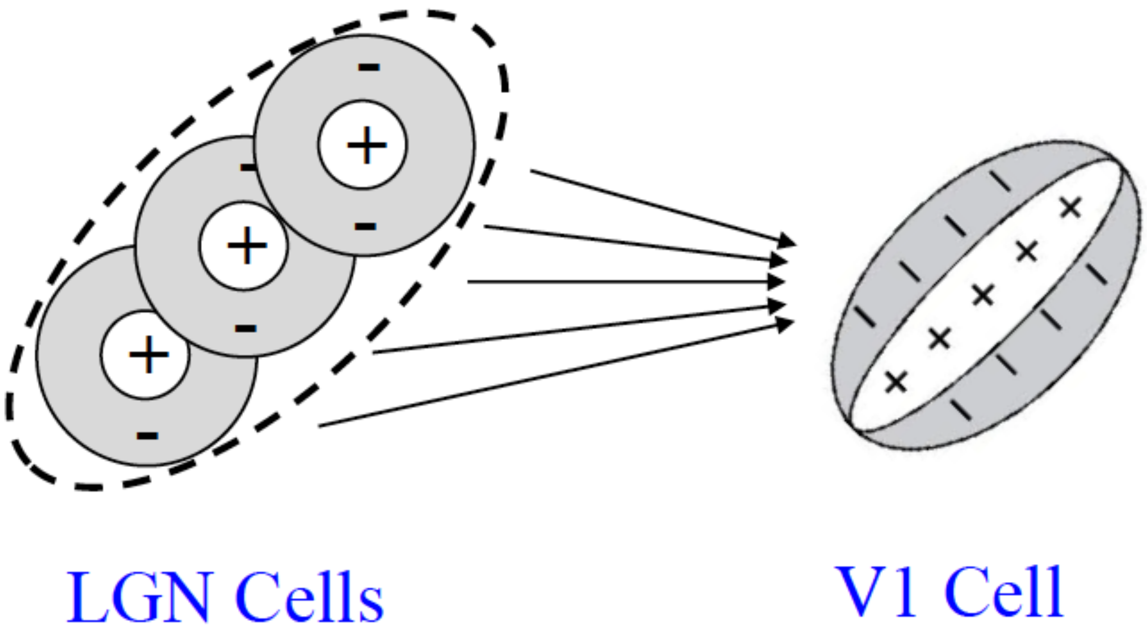
Descriptive





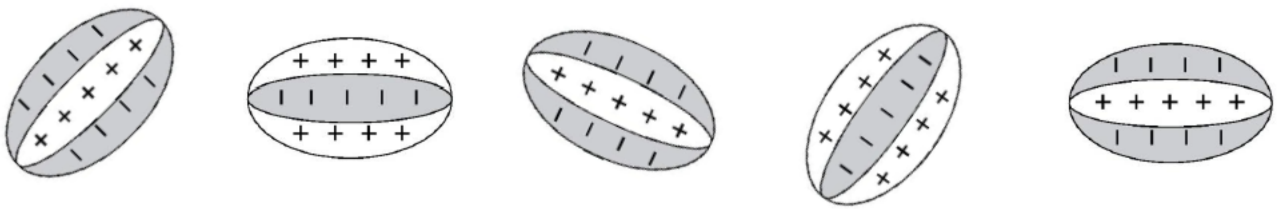
Mechanistic

- Lateral inhibition
- Converging inputs



Normative

- Efficient Coding Hypothesis: The goal of the visual system is to represent images as faithfully and efficiently as possible
- Minimise the errors in reproduction
- Make responses independent



What are Models in MBM?

- simplification
  - test or make measurements that are not possible on the real system
  - capture potentially interesting characteristics of the system
- abstraction
  - they are not a replication
  - implementations of a hypothesis
  - used to investigate a question or demonstrate a feature as it should

How are Models used in MBM?

- Phenomenon
- Implementation
- Simulation
- Report

- Lecture
- Workshop
- Assignment
- Submission

Lab

Max Di Luca

Mind, **B**rain, and **M**odels 2022/23 08/02/2023

Psychophysics experiment

- 2AFC
- constant stimuli
- psychometric function
- judgment noise