CS 480/680
Introduction to Machine Learning

Lecture 0: Logistics & Introduction

Kathryn Simone

5 September 2024

UNIVERSITY OF WATERLOO | FACULTY OF MATHEMATICS

About Me

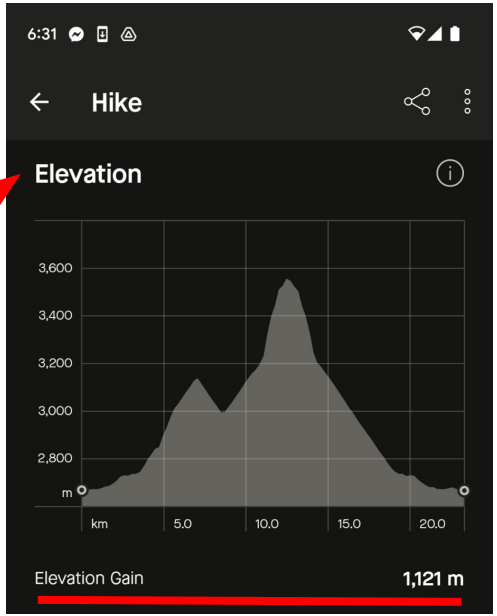
Postdoctoral Fellow

- Cheriton School of Computer Science and Center for Theoretical Neuroscience
- Principal Investigators:
  - Prof. Jeff Orchard (Faculty of Math)
  - Terrence C. Stewart (National Research Council of Canada
- Investigate the algorithms underlying natural intelligence, develop biologically-plausible algorithms, evaluate them for AI applications and on neuromorphic hardware

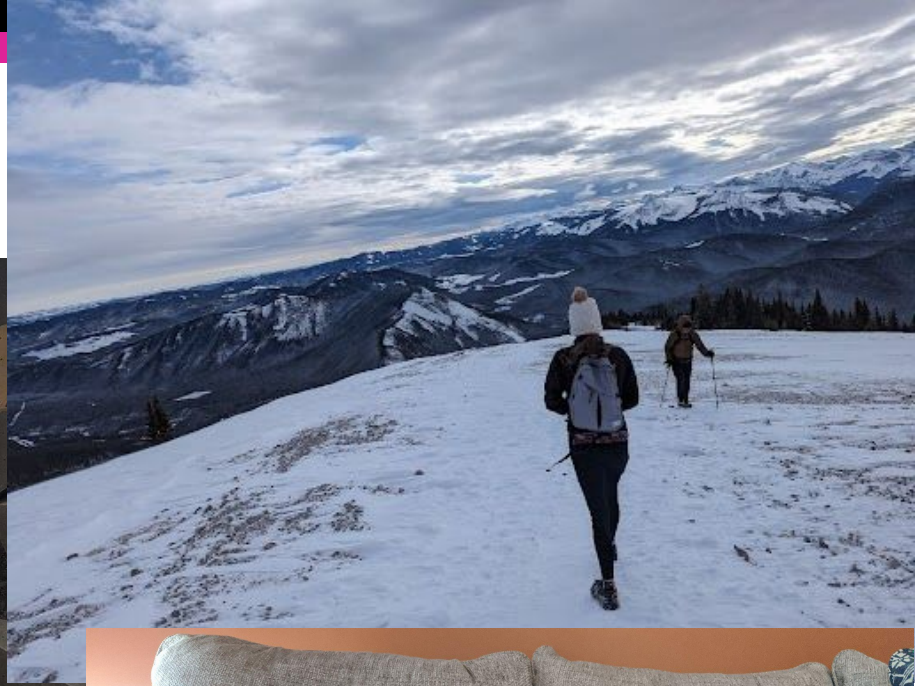
History

- Undergraduate: Electrical Engineering at Memorial University of Newfoundland
- Masters: Biomedical Engineering at the University of Calgary (Signal Processing)
- PhD: Computational and Systems Neuroscience (Stress)

Neuromorphic engineering community



In my free time...



Lecture Outline

I. **Logistics**
   How will the course run?
II. **Aims and Outcomes**
   What can I expect to be able to do?
III. **Definitions and Concepts**
   What is machine learning, anyways?
   What will we cover, and when?
IV. **Summary**
   What's next?

Lecture Outline

I. **Logistics**

How will the course run?

II. **Aims and Outcomes**

What can I expect to be able to do?

III. **Definitions and Concepts**

What is machine learning, anyways?

What will we cover, and when?

IV. **Summary**

What's next?

Course information

- **Times and Locations**
  - Section 001: TR 1:00pm - 2:20pm, MC 4021
  - Section 002: TR 8:30am - 9:50am, MC 2017
  - In-person attendance required. Class time will not be recorded.
- **Homepage:** github.com/kpc-simone/cs480-f24
  - Syllabus, slides, readings/resources, assignments
- **Piazza:** https://piazza.com/uwaterloo.ca/fall2024/cs480680
  - Announcements, questions, discussion
  - Approx 40 signed already -- go register now!
- **LEARN/Crowdmark:** https://learn.uwaterloo.ca/d2l/home/1046818
  - Assignment submission and grades

Learning Community

- Students: 159 enrolled
  - 126 undergraduate (CS 480)
  - 33 graduate (CS 680)
    - 15 waitlisted/auditing
- Instructor: Kathryn Simone (kpsimone@uwaterloo.ca)
  - Office Hours: by e-mail appointment
- Instructional Team:
  - Saber Malekmohammadi (s3malekm@uwaterloo.ca; A1)
  - Matina Mahdizadeh Sani (m3mahdiz@uwaterloo.ca; A2)
  - Carter Blair (cblair@uwaterloo.ca; A3, A4)
  - Evelien Riddell (eeboerst@uwaterloo.ca; Project + Piazza Czar)
  - Each TA will have their own office hours

There is no required textbook

Materials will be linked on the course home page

- *An Introduction to Statistical Learning*
  - Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani.
- *Elements of Statistical Learning*
  - Trevor Hastie, Robert Tibshirani and Jerome Friedman.
- *Understanding Machine Learning: From Theory to Algorithms*
  - Shai Shalev-Shwartz and Shai Ben-David.
- *Deep Learning*
  - Ian Goodfellow, Yoshua Bengio and Aaron Courville.
- *Dive into Deep Learning*
  - Aston Zhang, Zack C. Lipton, Mu Li and Alex J. Smola.

Required and Useful Knowledge

Official Course Prerequisites

- Algorithms: CS 341
- Statistics: STAT 206 or STAT 231 or STAT 241

Useful

- Linear algebra: inner products, norms, matrix properties, etc.
- Calculus: partial derivatives
- Python

Work Load and Grading Scheme

Table 2: Grading Scheme

Assessment	Assessment Date	Weighting (CS480)	Weighting (CS680)
Assignment 1	September 27	7.5%	7.5%
Assignment 2	October 14	7.5%	7.5%
Assignment 3	November 8	7.5%	7.5%
Assignment 4	November 22	7.5%	7.5%
Exams			
Midterm	October 29	30%	15%
Final	TBD	40%	30%
Project (CS 680 only)			
Pitch	September 19	N/A	2%
Proposal	October 8	N/A	8%
Report	December 3	N/A	15%
Total		100%	100%

Policies

- You must do your own assignments
  - Copying others' code is not permitted
  - Using Generative AI is not permitted
- Office hours
  - By email appointment. Please refer to my calendar linked in the syllabus.
  - Office hours for assignments will be announced on the posting date
- Late work
  - Two 48-hour extensions for assignments per student, no questions asked
  - Email the TA 48 hours before the deadline
  - Further extensions require justification and documentation
- Regrade requests
  - Considered within 1 week of grades released
- Communication
  - Piazza for all course content and conceptual discussions with other students
  - Email for all logistical matters: extension request, meeting request
  - Email: expect a response within 8 working hours

Questions?

Lecture Outline

I. **Logistics**
   How will the course run?

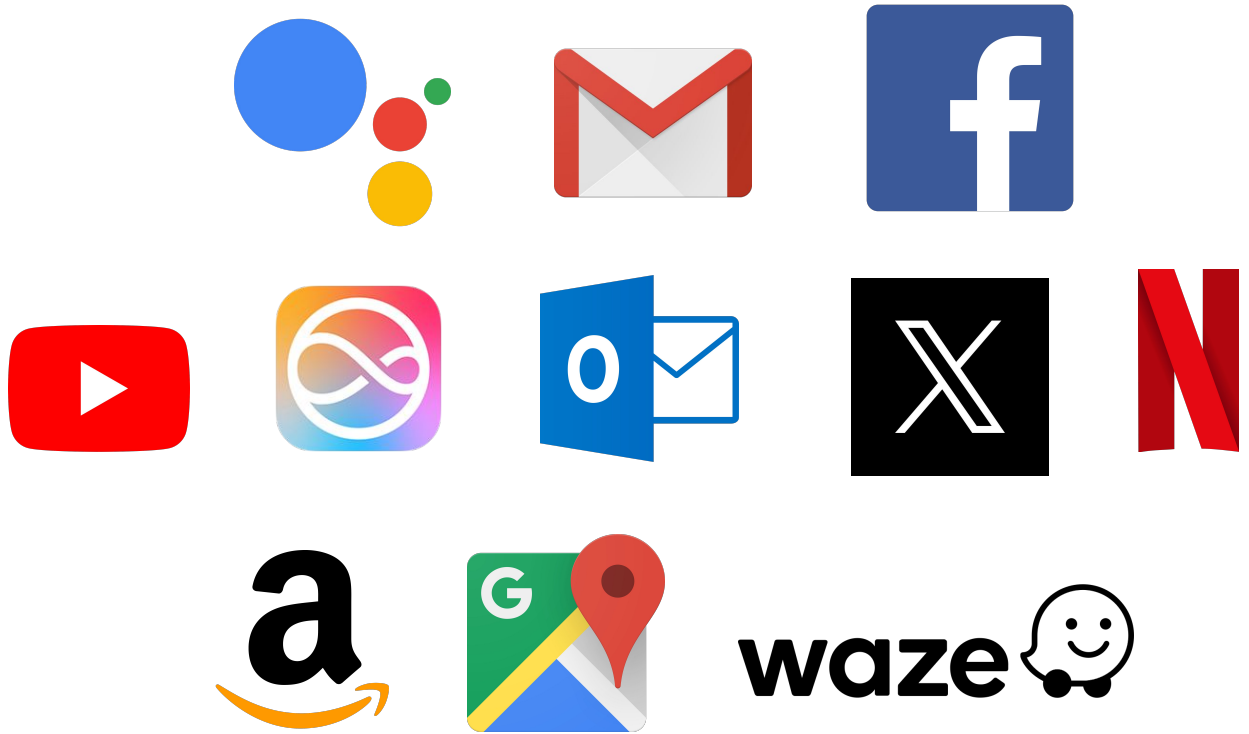
II. **Aims and Outcomes**
   What can I expect to be able to do?

III. **Definitions and Concepts**
   What is machine learning, anyways?
   What will we cover, and when?

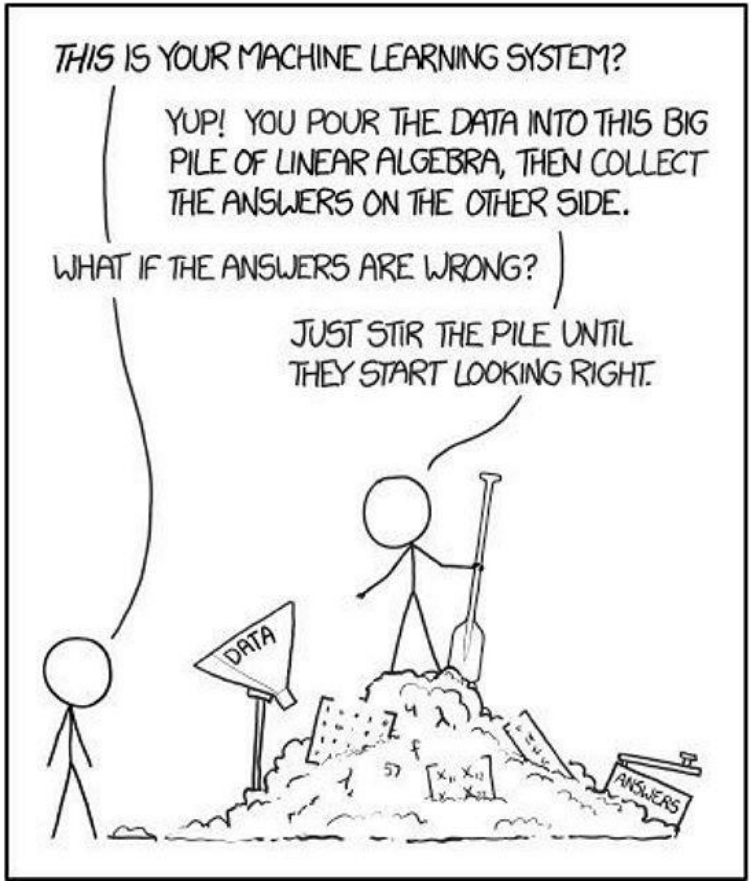
IV. **Summary**
   What's next?

Machine learning is everywhere

Machine learning is everywhere



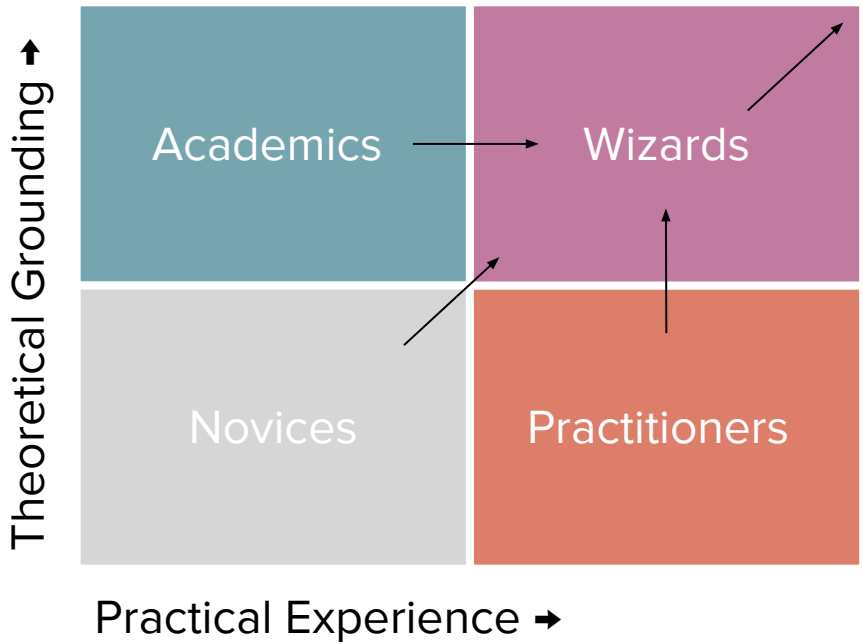
Goal: Demystify ML



https://xkcd.com/1838/

This course attracts learners with different backgrounds

Approach: Understand ML algorithms, from equations to code



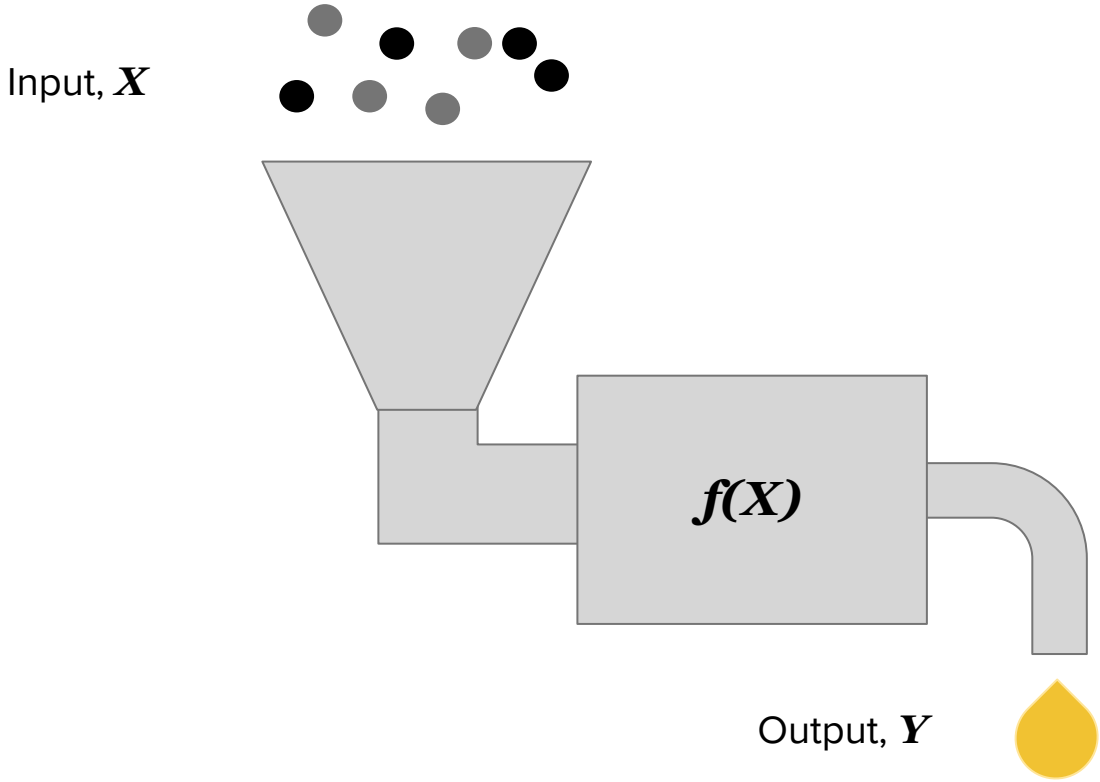
Intended Learning Outcomes

- Recognize and formulate a task as a ML problem;
- Identify and recommend suitable algorithms to tackle different ML problems;
- Implement foundational ML algorithms;
- Apply and evaluate ML algorithms on real datasets;
- Justify and critique choices in terms of ML principles;
- Describe ethical and safety issues of ML on society.

Lecture Outline

I. **Logistics**
   How will the course run?
II. **Aims and Outcomes**
   What can I expect to be able to do?
III. **Definitions and Concepts**
   What is machine learning, anyways?
   What will we cover, and when?
IV. **Summary**
   What's next?

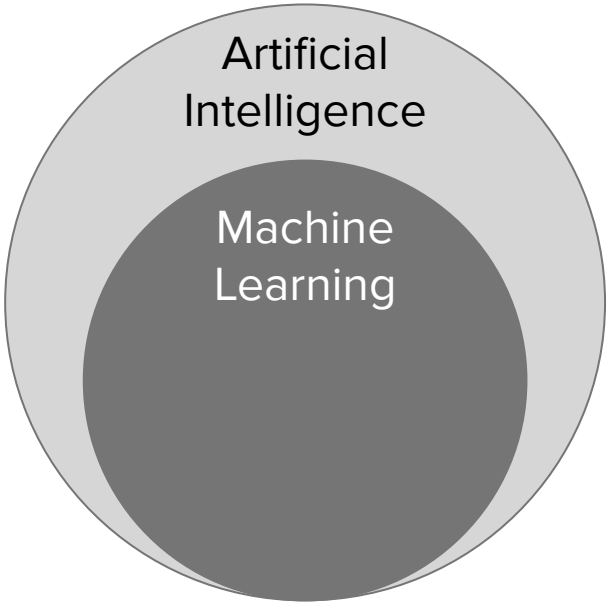
What is machine learning (ML)?



Machine Learning

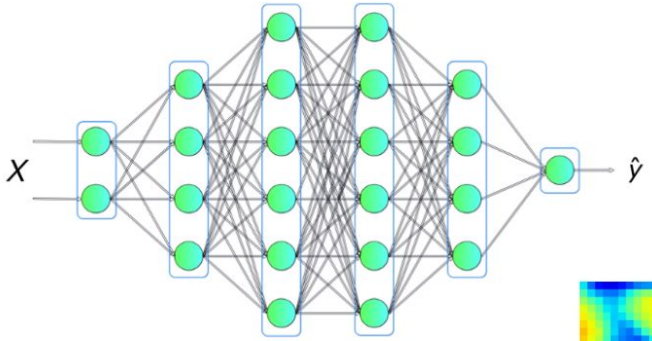
ML is a field within Artificial Intelligence (AI)

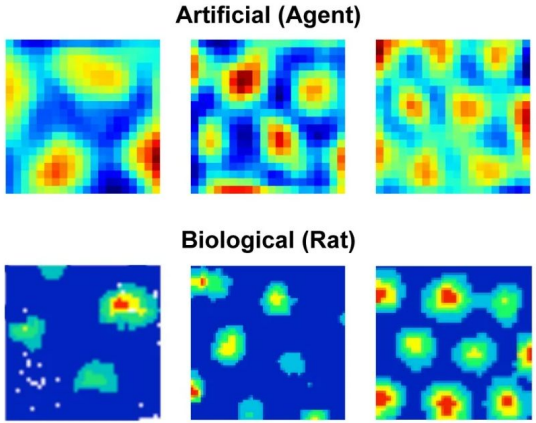
Thanks to machine-learning algorithms, the robot apocalypse was short-lived.

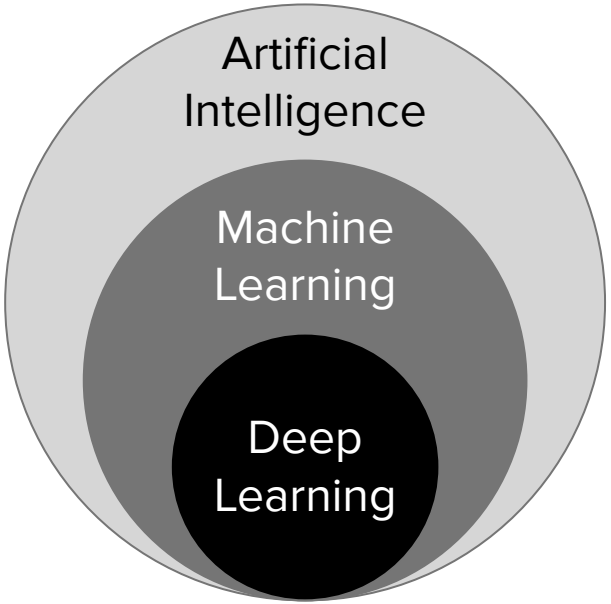


https://www.smbc-comics.com/comic/rise-of-the-machines

Deep learning (DL) is a subtopic of ML



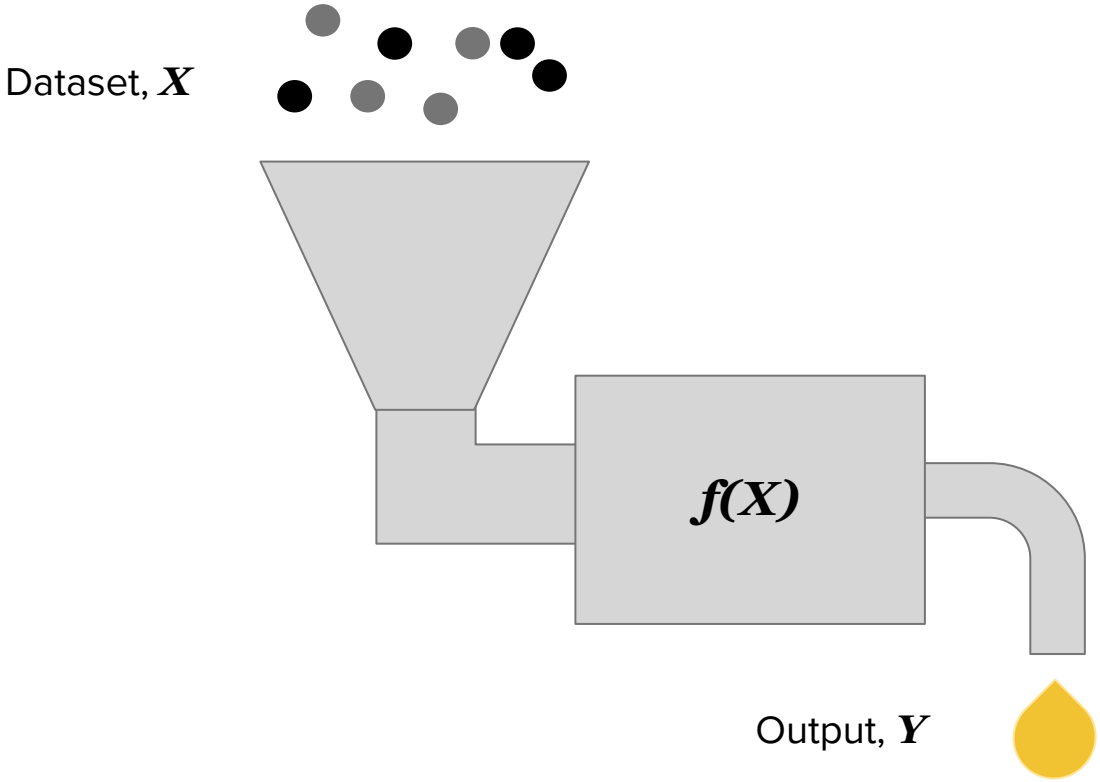




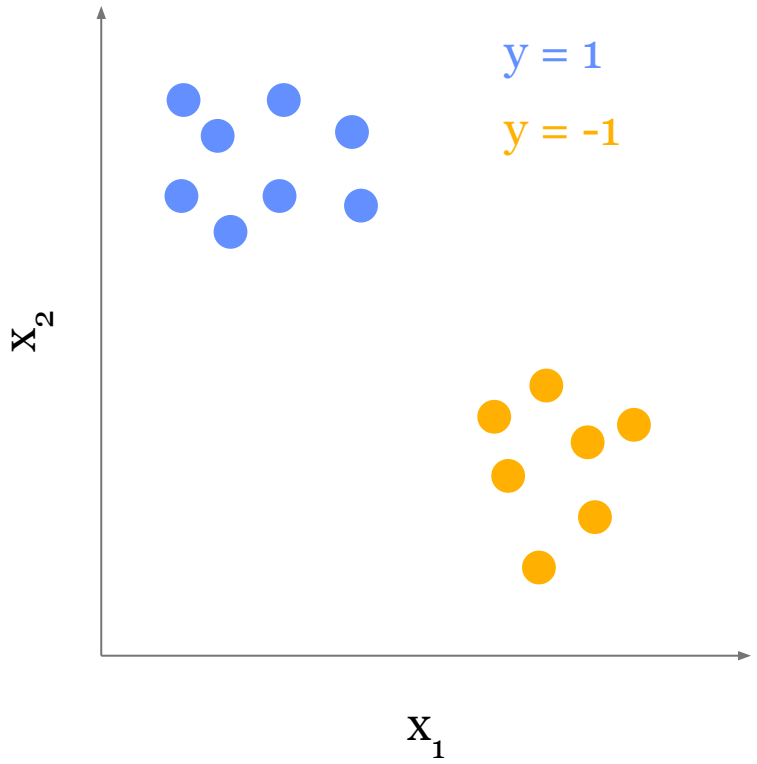
Clockwise from top:

1. Skalski, Piotr. “Deep Dive Into Math Behind Deep Networks - Towards Data Science.” Medium, 16 Feb. 2020, towardsdatascience.com/https-medium-com-piotr-skalski92-deep-dive-into-deep-networks-math-17660bc376ba.
2. Banino, Andrea, et al. "Vector-based navigation using grid-like representations in artificial agents." *Nature* 557.7705 (2018): 429-433.

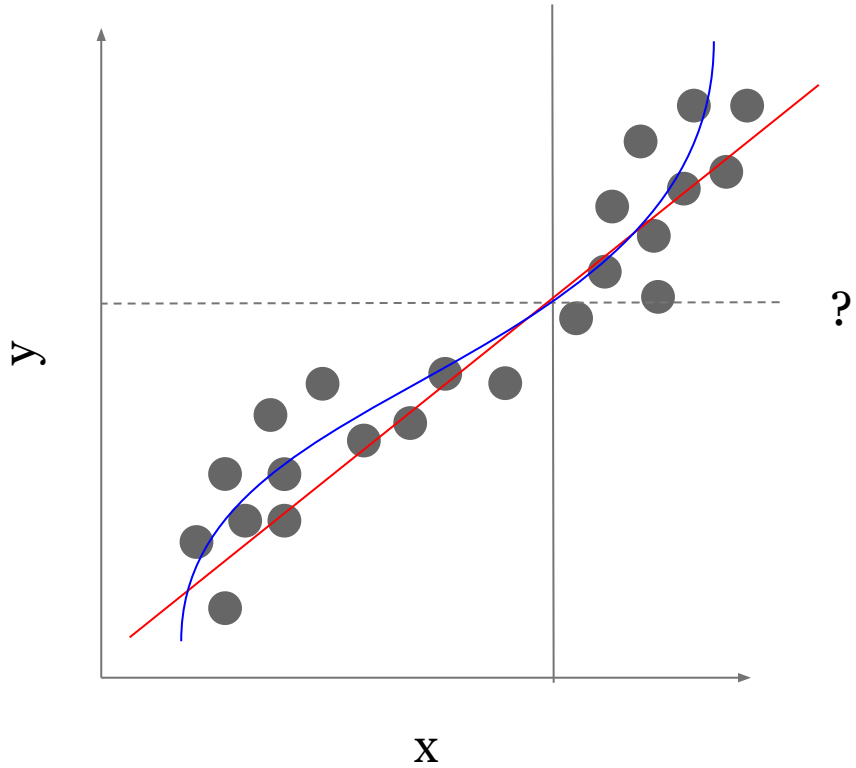
What kinds of functions?



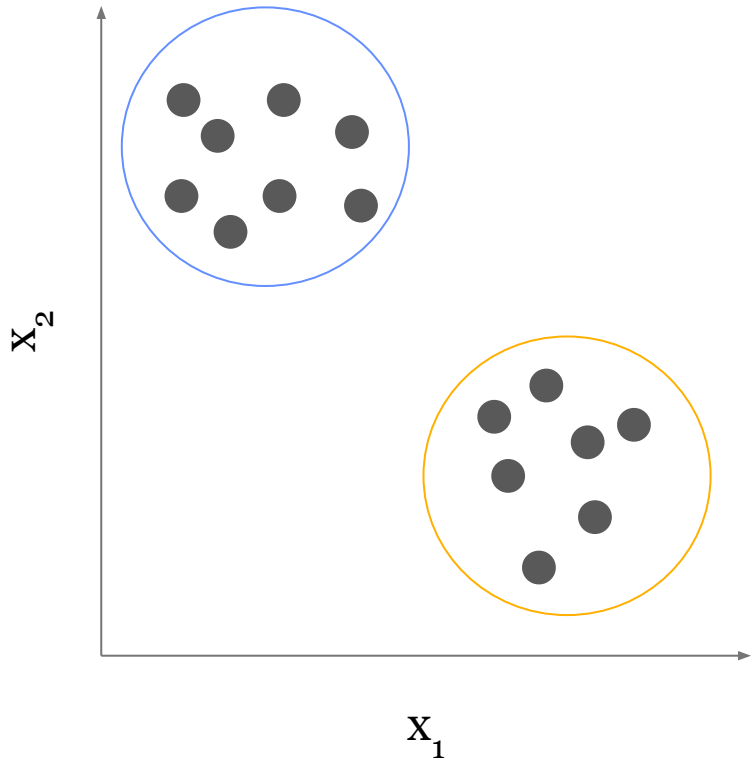
Tasks: Classification



Tasks: Regression



Tasks: Clustering



(Tentative) schedule

Mathematical Foundations

Classical ML Algorithms

Neural Networks

Modern Trends

Ethics

Lecture	Date	Topics
0	05/09/2024	Introduction + Administrative Remarks
1	10/09/2024	Halfspaces the Perceptron Algorithm
2	12/09/2024	Linear Regression and Convexity
3	17/09/2024	Maximum Likelihood Estimation
4	19/09/2024	k-means Clustering
5	24/09/2024	k-NN Classification and Logistic Regression
6	26/09/2024	Hard-margin SVM
7	01/10/2024	Soft-margin SVM
8	03/10/2024	Kernel methods
9	08/10/2024	Decision Trees
10	10/10/2024	Bagging and Boosting
	15/10/2024	NO LECTURE - MIDTERM BREAK
	17/10/2024	NO LECTURE- MIDTERM BREAK
11	22/10/2024	Expectation Maximization Algorithm
12	24/10/2024	MLPs and Fully-Connected NNs
	29/10/2024	NO LECTURE - MIDTERM EXAM
13	31/10/2024	Convolutional Neural Networks
14	05/11/2024	Recurrent Neural Networks
15	07/11/2024	Attention and Transformers
16	12/11/2024	Graph Neural Networks (Time permitting)
17	14/11/2024	VAEs and GANs
18	19/11/2024	Flows
19	21/11/2024	Contrastive Learning (Time permitting)
20	26/11/2024	Robustness
21	28/11/2024	Privacy (Saber Malekmohammadi)
22	03/12/2024	Fairness

If a picture is worth a thousand words, then …

Mathematical Foundations

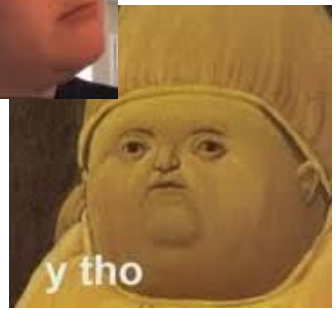
"Learn functions from data."

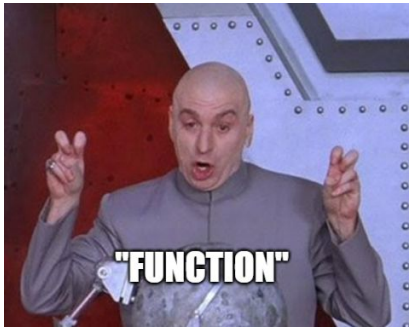
Classical ML

"Learn functions from *designed features* of data."

Neural Networks:

"Learn the features *and* the function."



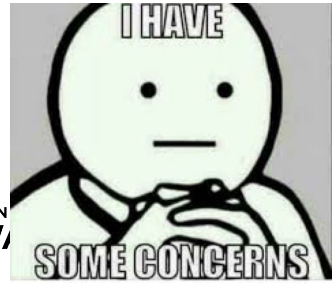


Modern Trends:

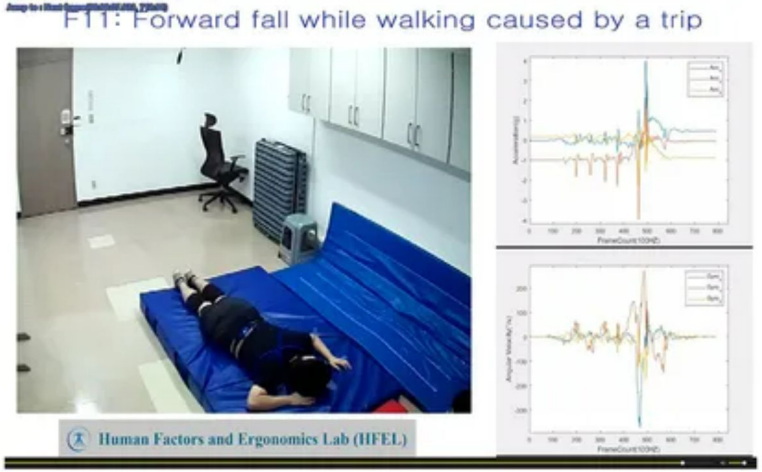
"Function?"

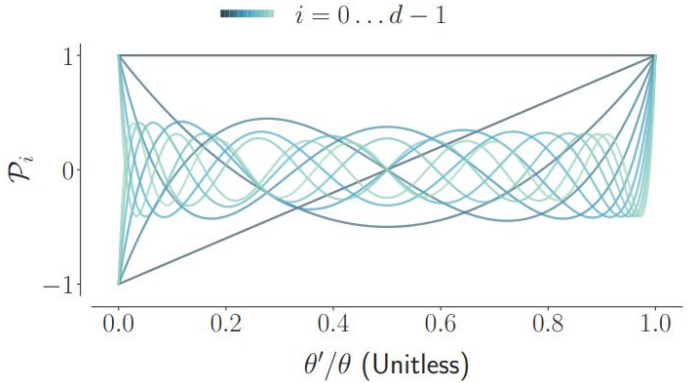
Ethics:

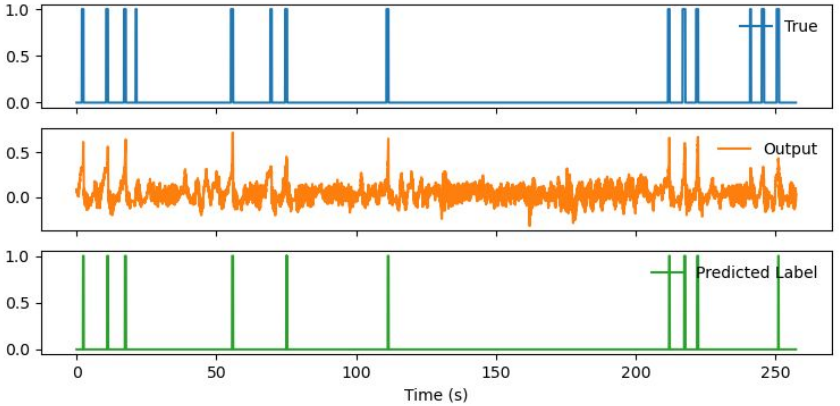
"This isn't necessarily reliable, safe, or good for society."



Classification Example:
Fall detection from accelerometer data

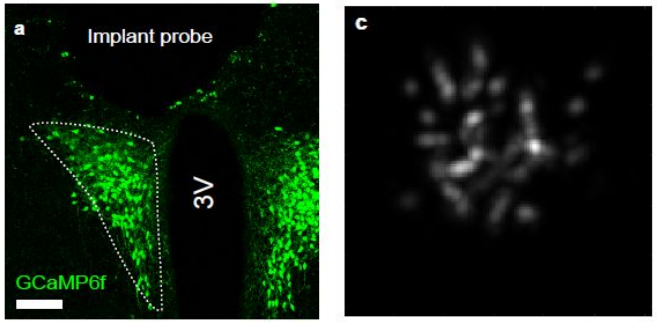


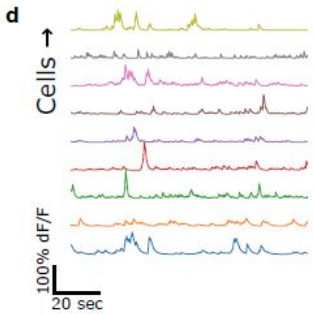


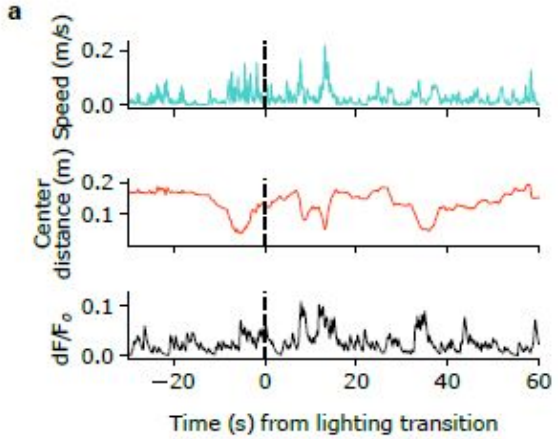


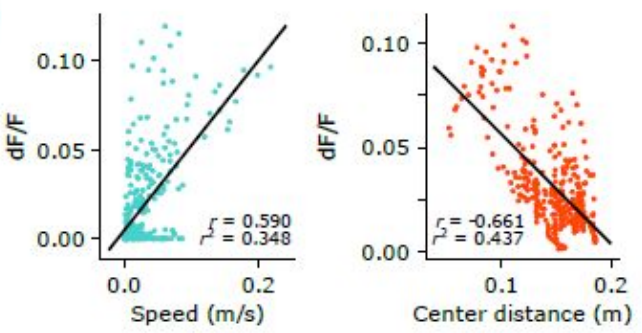
Clockwise from top:
Yu, Xiaoqun, Jaehyuk Jang, and Shuping Xiong. *Frontiers in Aging Neuroscience* 13 (2021): 692865.
Voelker, Aaron, Ivana Kajić, and Chris Eliasmith. *Advances in neural information processing systems* 32 (2019).
Barkley and Simone 2023, Unpublished

Regression Example:
Identifying representations in the mammalian hypothalamus



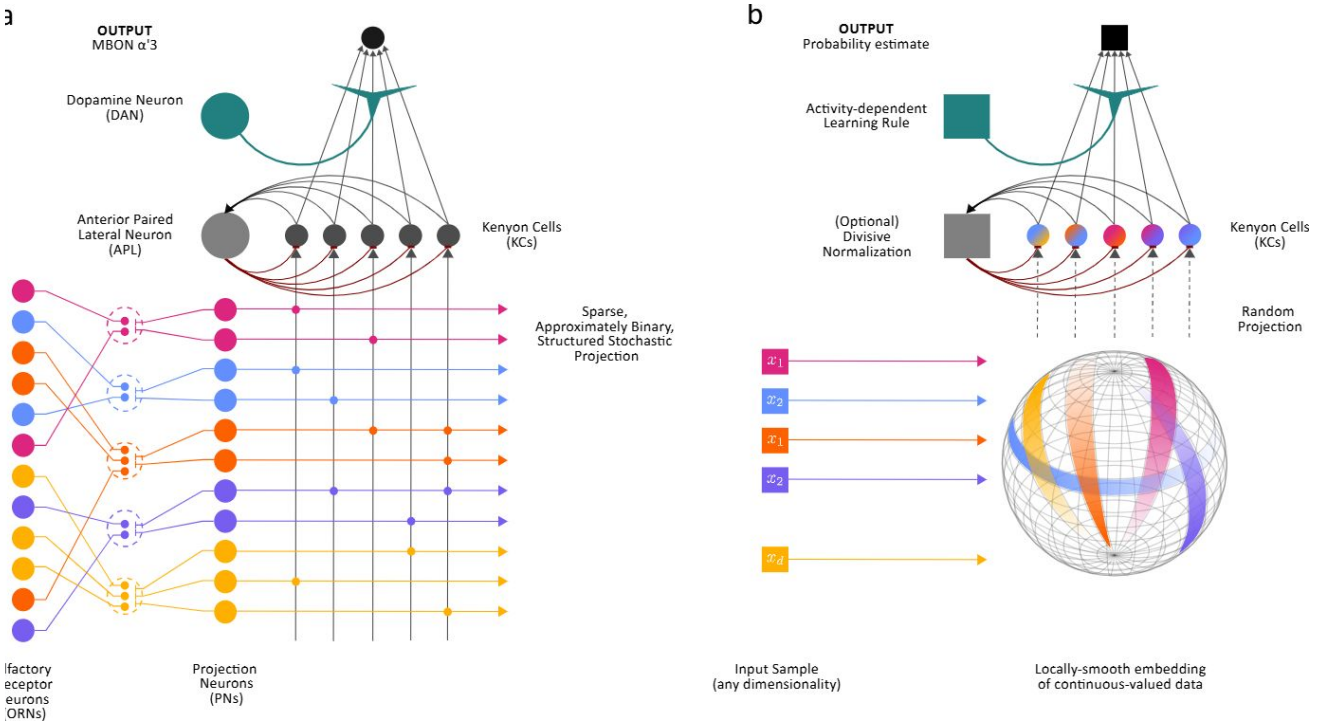






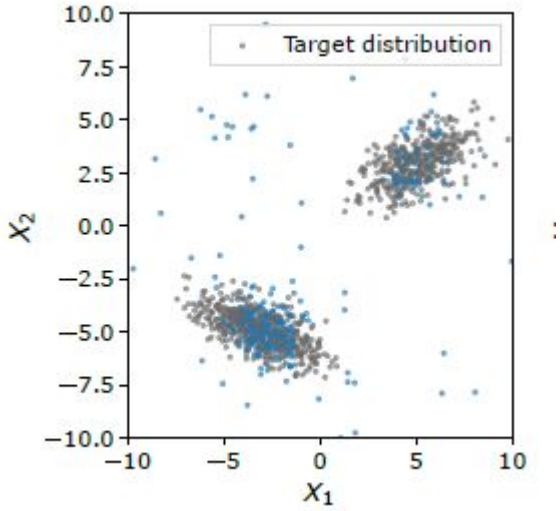
Simone et al, 2022

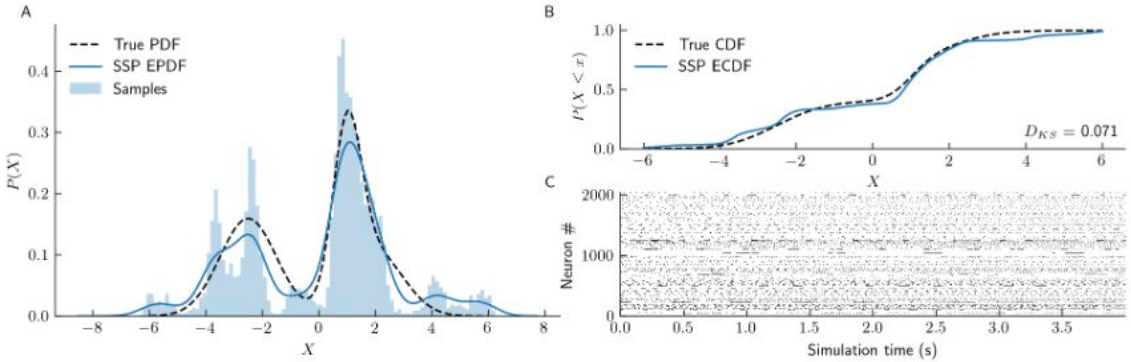
Unsupervised learning example: Distribution learning



Simone et al, 2024 (In preparation)

Generation example:
Biologically-plausible cognitive-inspired sampling





Furlong, P. Michael, et al. "Biologically-plausible Markov Chain Monte Carlo Sampling from Vector Symbolic Algebra-encoded Distributions."

For some topics, I'm at the edge of my expertise

Lecture	Date	Topics
0	05/09/2024	Introduction + Administrative Remarks
1	10/09/2024	Halfspaces the Perceptron Algorithm
2	12/09/2024	Linear Regression and Convexity
3	17/09/2024	Maximum Likelihood Estimation
4	19/09/2024	k-means Clustering
5	24/09/2024	k-NN Classification and Logistic Regression
6	26/09/2024	Hard-margin SVM
7	01/10/2024	Soft-margin SVM
8	03/10/2024	Kernel methods
9	08/10/2024	Decision Trees
10	10/10/2024	Bagging and Boosting
	15/10/2024	NO LECTURE - MIDTERM BREAK
	17/10/2024	NO LECTURE- MIDTERM BREAK
11	22/10/2024	Expectation Maximization Algorithm
12	24/10/2024	MLPs and Fully-Connected NNs
	29/10/2024	NO LECTURE - MIDTERM EXAM
13	31/10/2024	Convolutional Neural Networks
14	05/11/2024	Recurrent Neural Networks
15	07/11/2024	Attention and Transformers
16	12/11/2024	Graph Neural Networks (Time permitting)
17	14/11/2024	VAEs and GANs
18	19/11/2024	Flows
19	21/11/2024	Contrastive Learning (Time permitting)
20	26/11/2024	Robustness
21	28/11/2024	Privacy (Saber Malekmohammadi)
22	03/12/2024	Fairness

Lecture Outline

I. **Logistics**
   How will the course run?
II. **Aims and Outcomes**
   What can I expect to be able to do?
III. **Definitions and Concepts**
   What is machine learning, anyways?
   What will we cover, and when?
IV. **Summary**
   What's next?

The syllabus affirms everything said today

CS 480/680:
Introduction to Machine Learning
Fall 2024

Time and Location
480/680 Sec. 001: TR 1:00 - 2:20 PM MC 4021
480/680 Sec. 002: TR 8:30 - 9:50 AM MC 2017

Links
Homepage: github.com/kpc-simone/cs480680-f24
Submissions (LEARN/CrowdMark): learn.uwaterloo.ca/d2l/home/1046818
Discussions (Piazza): piazza.com/uwaterloo.ca/fall2024/cs480680

Syllabus

Instructional Team

Instructor: Kathryn Simone
Office: DC 2126
Office Hours: See **Policies**.
Email: kpsimone@uwaterloo.ca

T.A.	Carter Blair	Matina Mahdizadeh Sani	Saber Malekmohammadi	Evelien Riddell
Email (@uwaterloo.ca)	cblair	m3mahdiz	s3malekm	eeboerst

Course Information

Course Description

Introduction to modeling and algorithmic techniques for machines to learn concepts from data. Generalization: underfitting overfitting, cross-validation. Tasks: classification, regression, clustering. Optimization-based learning: loss minimization. regularization. Statistical learning: maximum likelihood, Bayesian learning. Algorithms: nearest neighbour, (generalized) linear regression, mixtures of Gaussians, Gaussian processes, kernel methods, support vector machines, deep learning, sequence learning, ensemble techniques. Large scale learning: distributed learning and stream learning. Applications: Natural language processing, computer vision, data mining, human computer interaction, information retrieval. [Note: Lab i not scheduled and students are expected to find time in open hours to complete their work.]

Links

- **Course Materials**
  - github.com/kpc-simone/cs480680-f24
  - Syllabus, slides, video lectures, assignments
- **Submissions: Waterloo LEARN (D2L)**
  - https://learn.uwaterloo.ca/d2l/home/1046818
- **Questions, discussion, announcements**
  - https://piazza.com/uwaterloo.ca/fall2024/cs480680

Next Lecture

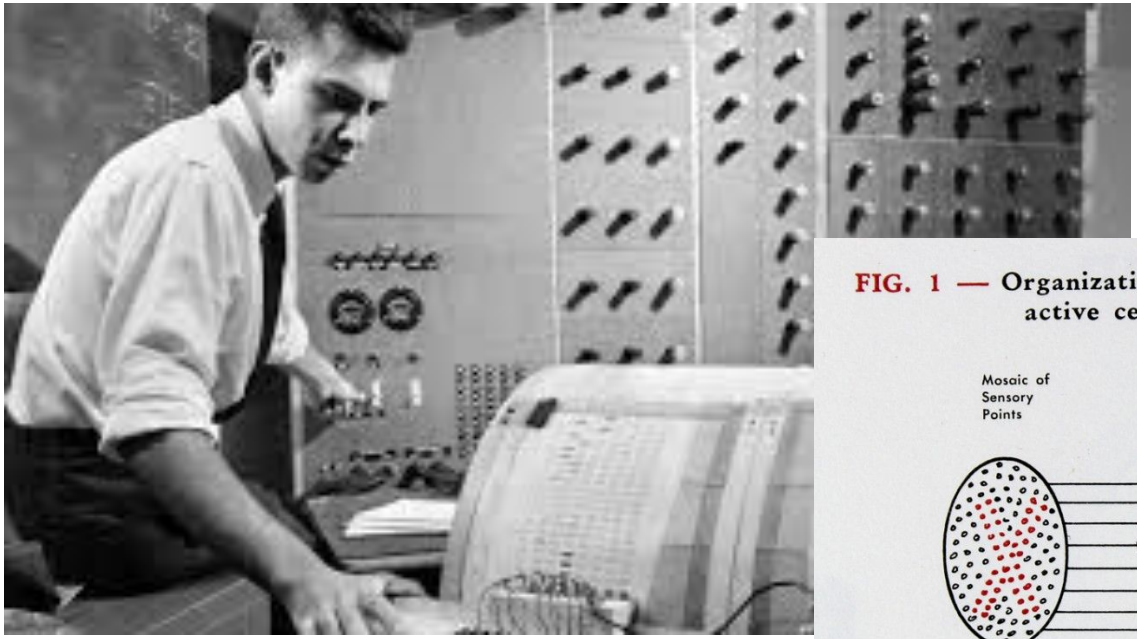


FIG. 1 — Organization of a biological brain. (Red areas indicate active cells, responding to the letter X.)

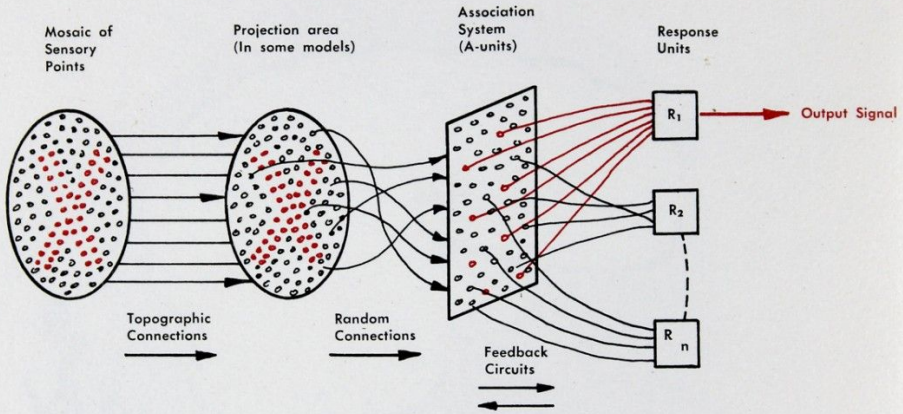


FIG. 2 — Organization of a perceptron.

On the horizon

Table 2: Grading Scheme

Assessment	Assessment Date	Weighting (CS480)	Weighting (CS680)
Assignment 1	September 27	7.5%	7.5%
Assignment 2	October 14	7.5%	7.5%
Assignment 3	November 8	7.5%	7.5%
Assignment 4	November 22	7.5%	7.5%
Exams			
Midterm	October 29	30%	15%
Final	TBD	40%	30%
Project (CS 680 only)			
Pitch	September 19	N/A	2%
Proposal	October 8	N/A	8%
Report	December 3	N/A	15%
Total		100%	100%

Questions?