

Lecture 1

Introduction to Machine Learning

Welcome to CS189/289

EECS 189/289, Fall 2026 @ UC Berkeley
Joseph E. Gonzalez and Narges Norouzi



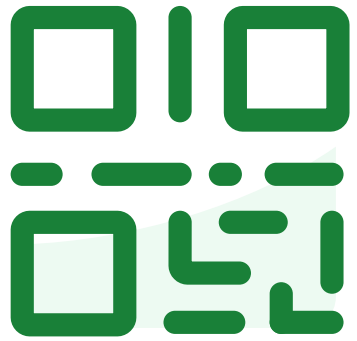
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Pre-Semester Survey

Take a minute to fill out the [pre-semester survey](#) now if you haven't already!



Do not edit
How to change the
design



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#1834846**

① The Slido app must be installed on every computer you're presenting from

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Roadmap

- Introductions
- CS 189/289 Goals and Plans
- What Is Machine Learning?
 - Definition
 - History
- The ML Process (Lifecycle)
- Logistics



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Introductions

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Narges Norouzi



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- **Associate Teaching Professor** at EECS UC Berkeley (2022-now).
 - A member of [BAIR](#) and [ACE](#).
- **Associate Dean** in the College of Computing Data Science, and Society!
- **Research:** ML and ML tools in education
 - Models to model and support complex human behavior
- Also taught ML, AI, Deep Learning + Data 100!
- This semester, I'm:
 - Teaching this course, advising my students, and leading the Student Services at CDSS!!!

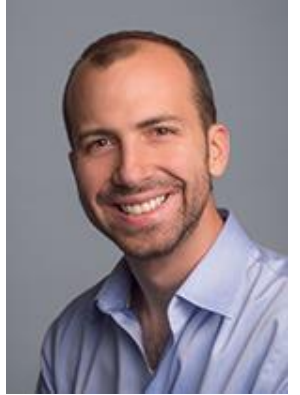


[Pronunciation
of my name](#)

Joey Gonzalez



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- **Associate Research Professor** at EECS UC Berkeley (2016-now).
 - Co-directory of the [Sky Computing Lab](#) and a member of [BAIR](#)
- **Research:** AI and AI-Systems
 - Training and Inference Systems (e.g., [Clipper](#), [vLLM](#), [SG-Lang](#))
 - Developing new LLMs and Agents (e.g., [Gorilla LLM](#), [MemGPT](#), and [Vicuña](#))
 - Evaluating LLMs (e.g., [Chatbot Arena](#) and [LLM-as-a-judge](#))
 - AI in the context of competitive negotiations (e.g., [C2C](#))
 - Robotics and Autonomous Driving Systems ([ERDOS](#))
 - Large-Scale Data Processing Systems (e.g., [Apache Spark](#), [GraphLab](#), [Ray](#))
- **I also teach:** Data-8, Data-100, and CS299-162 (Graduate AI Systems)
- This semester, I'm:
 - Teaching this course and launching a new GenAI systems lab (ask me in OH).
 - Vice Chair Grad Matters, UCB Division Council, and Chair campus GenAI working group
 - Advising a bunch of AI companies

CS 189/289 Goals and Plans



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Why Are We Excited to Teach CS189?

- **The field shifted under our feet** → we're redesigning now so we surf, not chase.
- **We listened to student pain points** → we're tightening the storyline to **math** → **code** → **experiments**, with unified notation and right-sized and reasonable prerequisites.
- **Classroom work should feed research** → projects will connect to live problems so **students** → **collaborators**.
- **Berkeley should set the bar** → we aim to produce a shareable resource that others can adopt and adapt.
- We are trying **MANY NEW THINGS** some things will break... but we hope you will enjoy this class.



Why are you excited to take CS189?

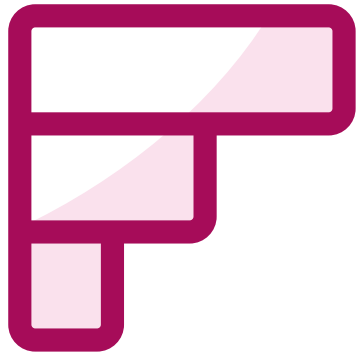


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By the End of CS189, You Should:

- Have a **rigorous foundation** in core ML concepts and algorithms, connecting the math to the methods we use.
- Be able to **implement, train, and debug** standard models in Python/PyTorch and move from data prep to experiments.
- Be able to **design sound evaluations** and document your work so results are **reproducible and responsible**.
- Be **prepared for advanced courses and research**.

These are ambitious goals!



Which topics are you most excited about learning this semester?



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Succeed in Advanced ML Courses

Advanced ML course:

- [Computer vision \(180/280\)](#), [NLP \(288\)](#), [RL \(285\)](#), [Statistical Learning Theory \(281\)](#), and Many Special Topics Courses on AI (194/294)

Require understanding of basic concepts:

- Model design
- Stochastic Gradient Descent
- Maximum Likelihood
- Loss Structure
- Supervised Learning
- Unsupervised Learning
- Classification
- Regression
- Regularization and the Bias/Variance Tradeoff
- Dimensionality Reduction
- Clustering and Density Estimation
- Experiment Design and Tracking
- ...

What Is Machine Learning?



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What Is Machine Learning (ML)?

Software systems that improve (learn) through data.

Classic Example: What is Spam?

- Difficult to define
- Easy to demonstrate

Classic Example: Face detection?

- Difficult to program
- Easy to demonstrate

Basic Recipe:

- Use examples (**data**) to teach (**fit**) a **model**.
- Use the **model** to **make decisions**.

What Is Artificial Intelligence?

Artificial intelligence (AI) refers to the capability of computational systems to perform tasks typically associated with human intelligence, such as learning, reasoning, problem-solving, perception, and decision-making.

-- Wikipedia (2025)

The primary technology behind modern AI is
Machine Learning (ML)

Artificial Intelligence Is the Goal Machine Learning Is the Method

Terms are often used interchangeably (even by experts).



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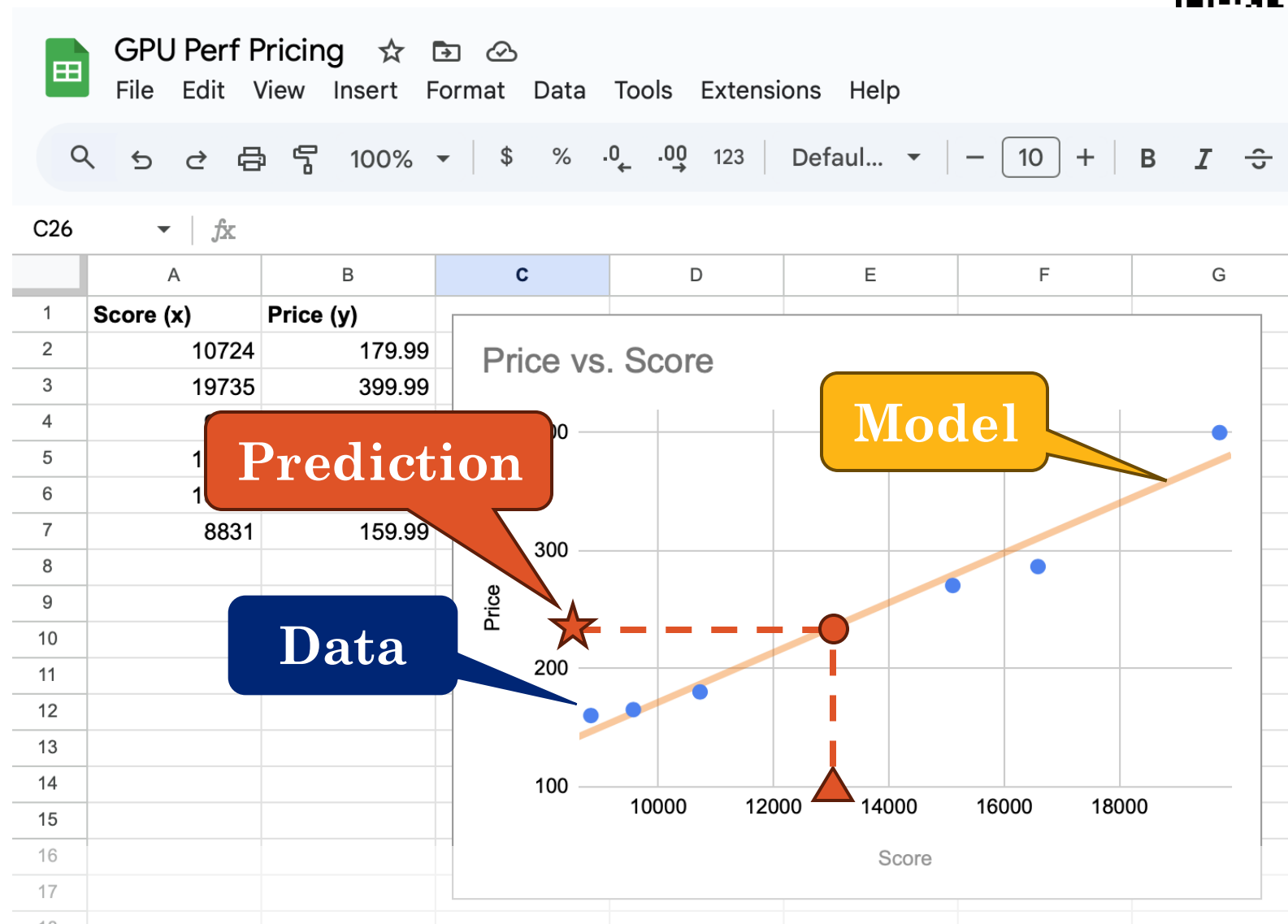
You have (probably) already
done **Machine Learning**

Linear Regression is Machine Learning

Basic Recipe:

Training: Use **data** to teach (fit) a **model**.

Inference: Use the **model** to make **predictions** (decisions).



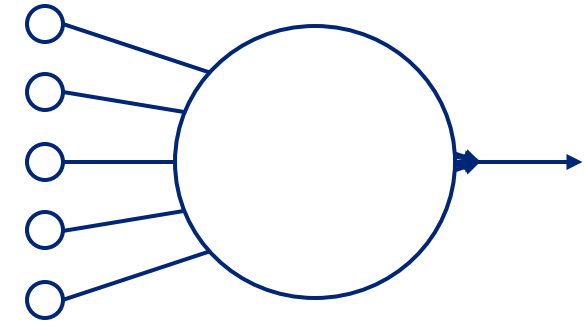
Machine Learning



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Training

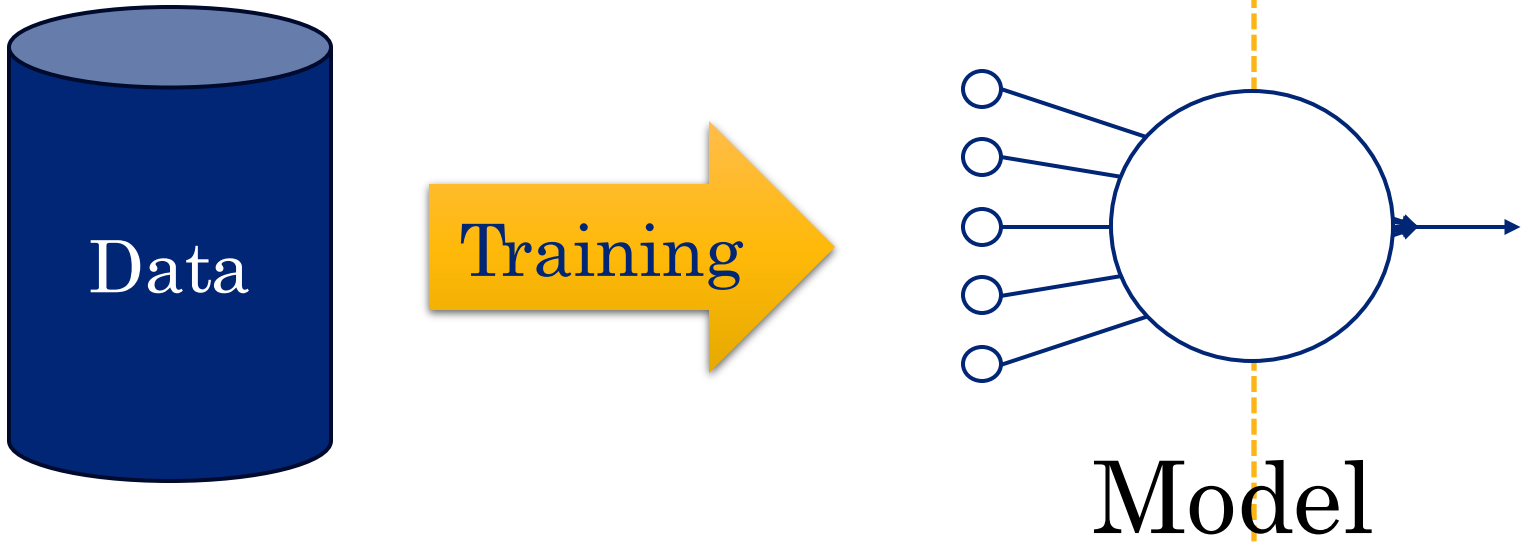


Big Model



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Training

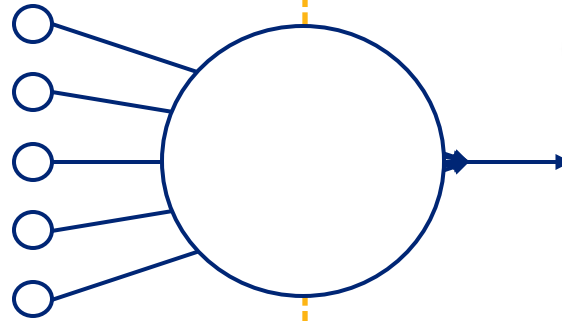


Training

Inference



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Model



Application

When should I use Machine Learning?

What kinds of problems are
Machine Learning Problems?



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A Machine Learning Problem

A problem for which it is **easy to demonstrate** or **evaluate the solution** but **difficult to directly implement**.

Machine Learning Solution:

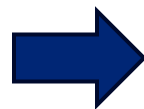
The system **learns the desired behavior** (e.g., prediction, representation, or a policy) through **demonstration** or **experience**.

Example:

Determine if a text message is spam

How do you
define Spam?

Spam is **difficult to define** and
depends on the receiver.

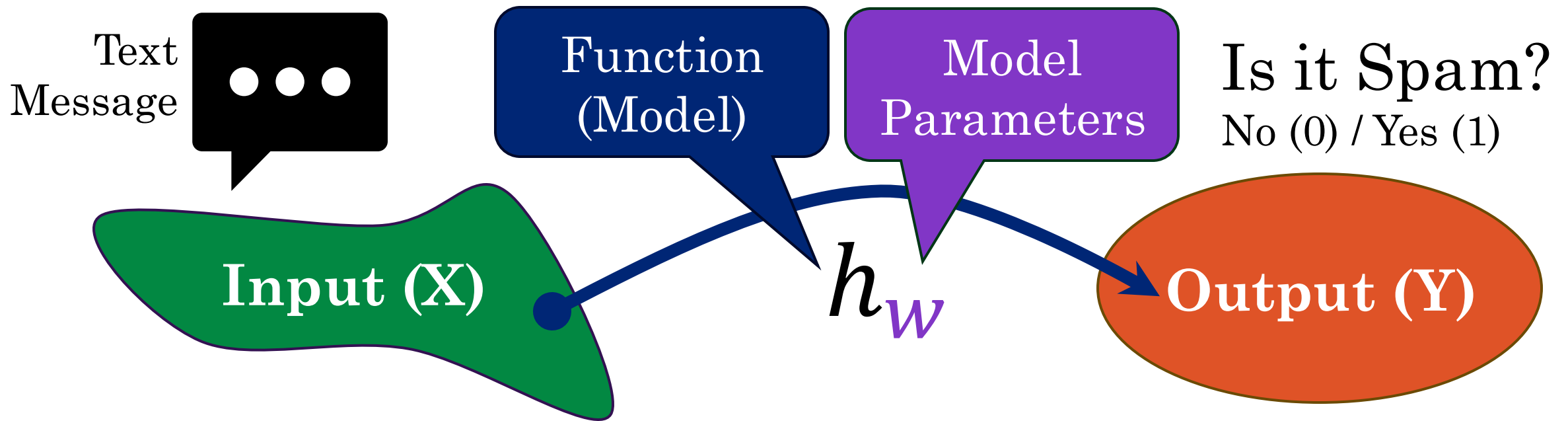


Easier to **demonstrate examples**
and **learn a function** to detect

Machine Learning as Learned Function Approximation



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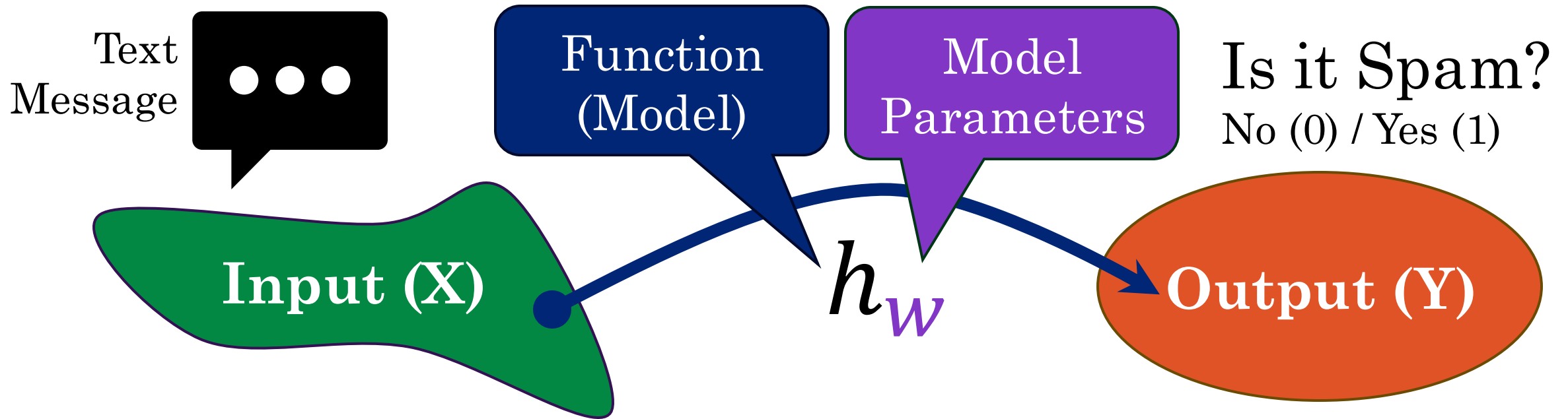


Machine learning becomes the process of “**learning**” the **model parameters** from data or interaction with the world.

Machine Learning as an Optimization Problem

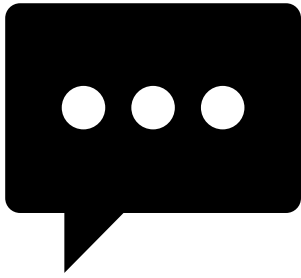


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$$\text{Goal: } \arg \min_w \mathbb{E}_X [\text{Loss}(h_w(X))]$$

Text
Message



Function
(Model)

Model
Parameters

Is it Spam?
No (0) / Yes (1)



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Learning Settings

Supervised
(Demonstration)

Unsupervised

Reinforcement
(Reward)

Observe:

$\{(\mathbf{X}, \mathbf{Y})\}$

$\{\mathbf{X}\}$

$\mathbf{X}$, reward(.)

Supervised Learning



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Trying to learn a relationship between observed $\{(\mathbf{X}, \mathbf{Y})\}$ pairs.

Classification

Regression

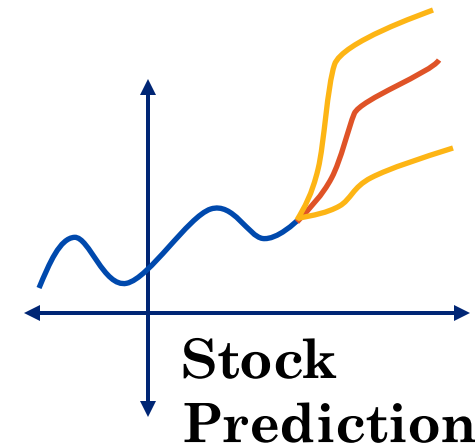


Image Labeling

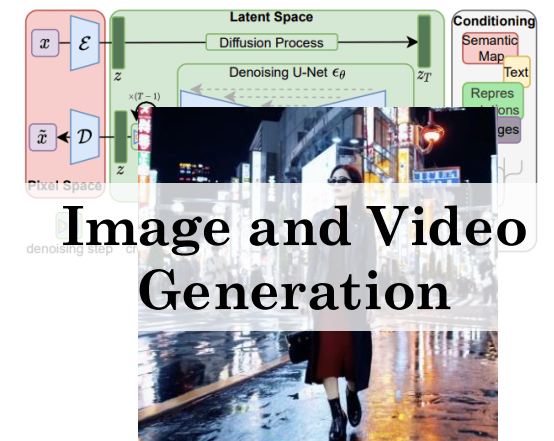
$\mathbf{X}$: Image
 $\mathbf{Y}$: {Hot Dog, ...}



$\mathbf{X}$: Prompt
 $\mathbf{Y}$: Next Word



$\mathbf{X}$: History
 $\mathbf{Y}$: Next Value



$\mathbf{X}$: Prompt+Noise
 $\mathbf{Y}$: Pixel Values

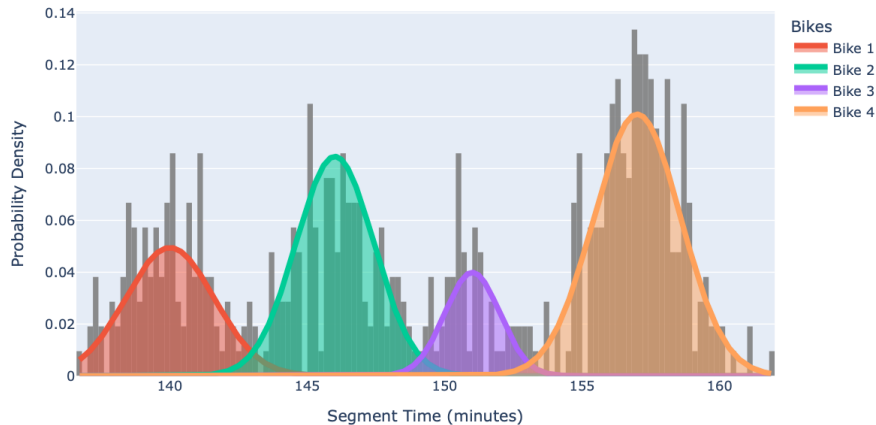


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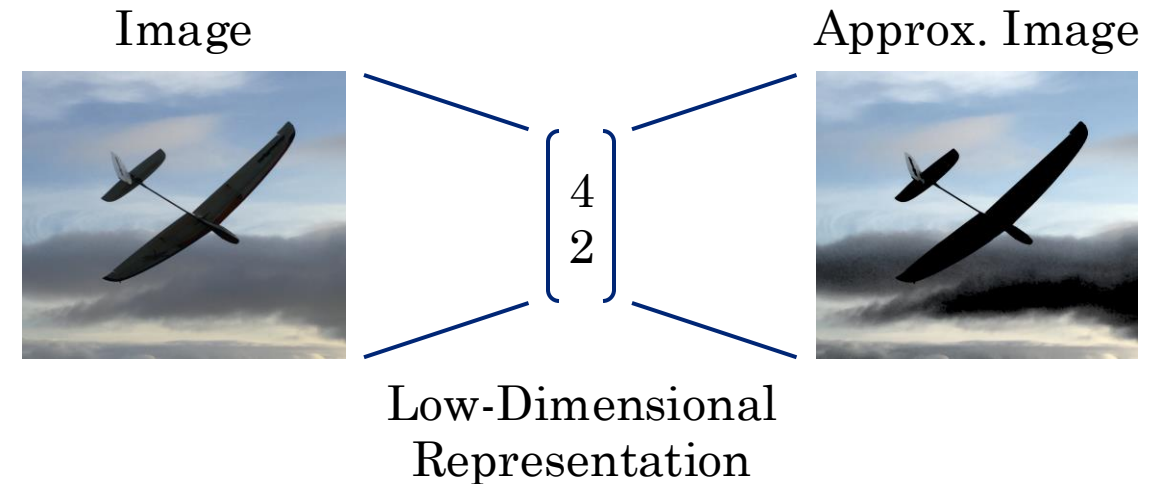
Unsupervised Learning

Trying to **model** the **data** in the **absence** of **explicit labels**.

Clustering & Density Estimation



Dimensionality Reduction



Used for **visualization** and as a step in **other ML tasks**.

Reinforcement Learning

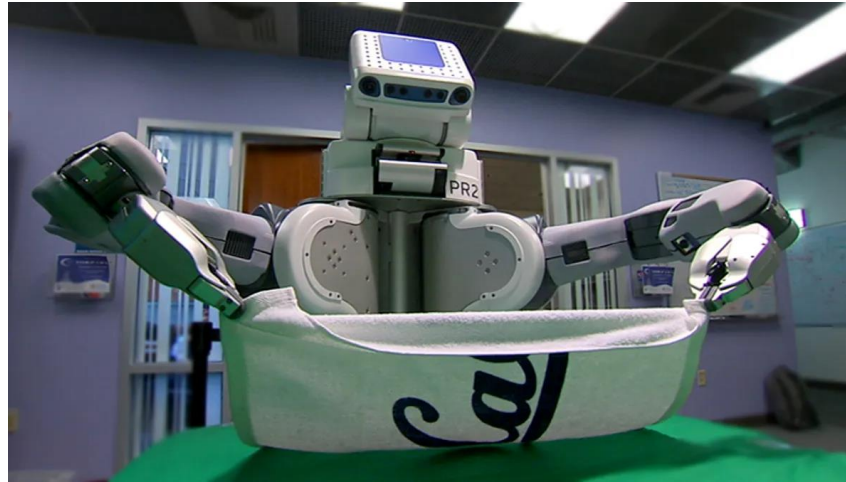


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Learning from **reward signals** often with complex **multi-step** (discrete or continuous) **action** sequences.



Action: next move,
Reward: Win/Lose



Action: change in joint angles
Reward: Fold quality

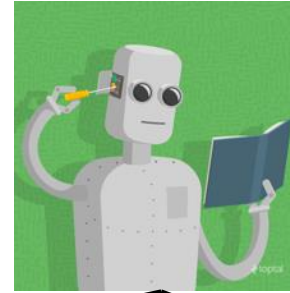


ChatGPT

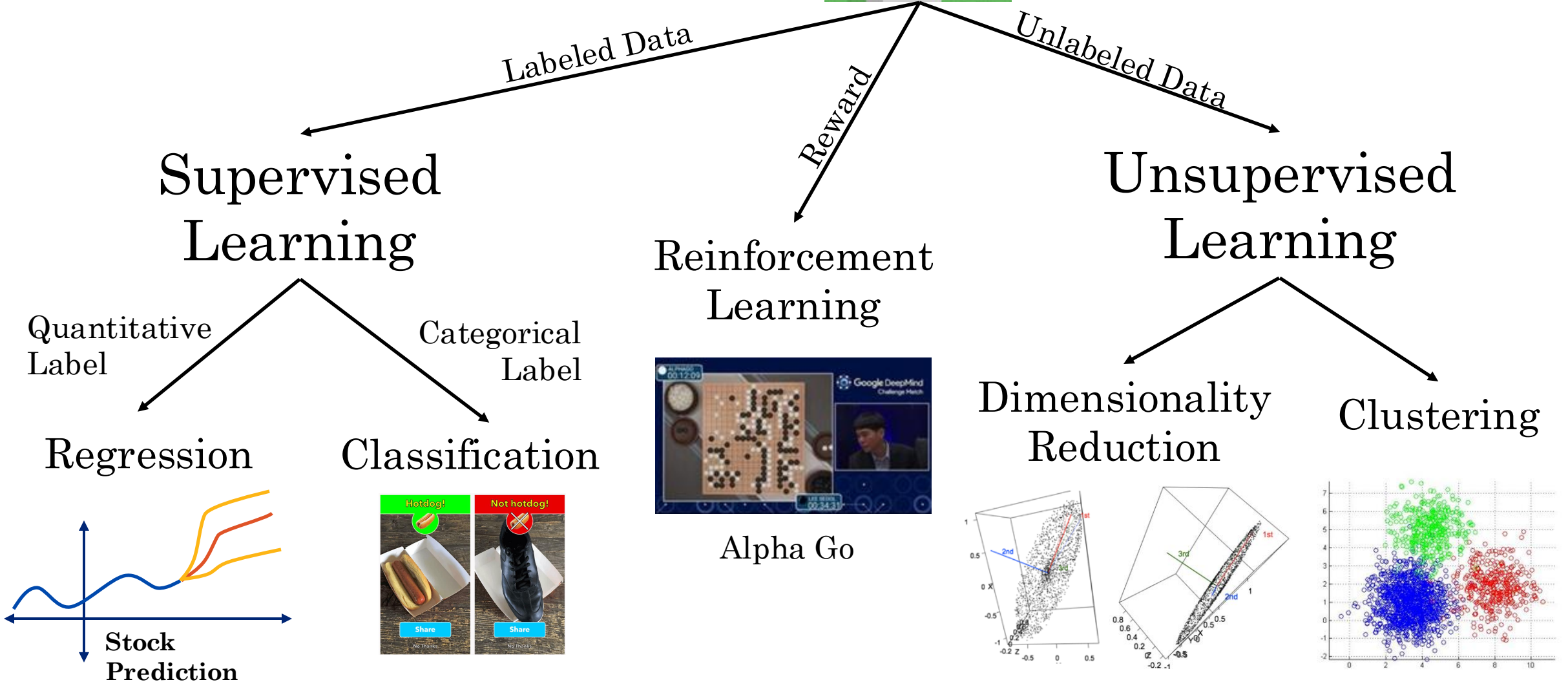
Action: next token
Reward: answer quality

This semester we plan to introduce basic RL (Policy Gradient).

Taxonomy of Machine Learning



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History of Machine Learning



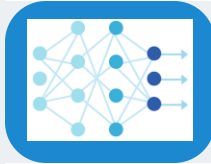
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History of ML



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1950s–60s Early Days	1970s–80s Challenges and Advances	1990s Rise of Statistical ML	2000s Big Data Era	2010s Deep Learning Revolution	Present
Self-learning checkers program (1959) Perceptron (1957)	Decision trees, RL basics, and the rediscovery of NNs	Probabilistic models & statistical learning. Focus on math foundations.	Datasets grew & computation became cheaper Rise of Data Mining & Data Science	Deep learning (2012)	Generative models and Large Language/Large Vision Models
					

Today – GenAI



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What does it mean?

Models that can
generate the data.

Why is it important?

Unlocking new advanced
general AI abilities.

Will we cover it?

Yes!

UC Berkeley is at the center of the AI revolution:



Discover BAIR, the world's most
advanced academic AI research lab.

[Vicuna](#)
[AdaGrad](#)
[TRPO](#)
[NeRF](#)
[LLM-as-a-Judge](#)
[MMLU](#)

[Spark](#)
[Caffe](#)
[vLLM](#)
[Diffusion Models](#)
[Chatbot Arena](#)
[Gorilla/BFCL](#)

[MemGPT](#)
[Sleep-time Compute](#)
[Test-time Compute](#)
[Perplexity.ai](#)
[Everybody Dance Now](#)
...



Get Involved in
Research!

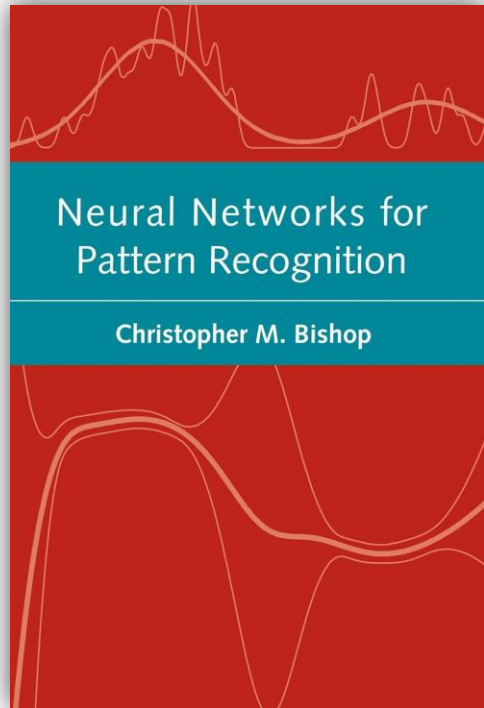
How We teach ML is *Evolving*



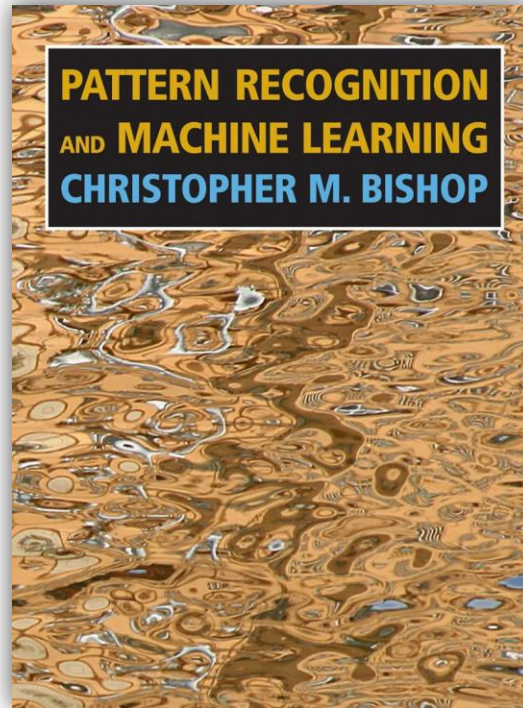
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Probability and Linear Algebra

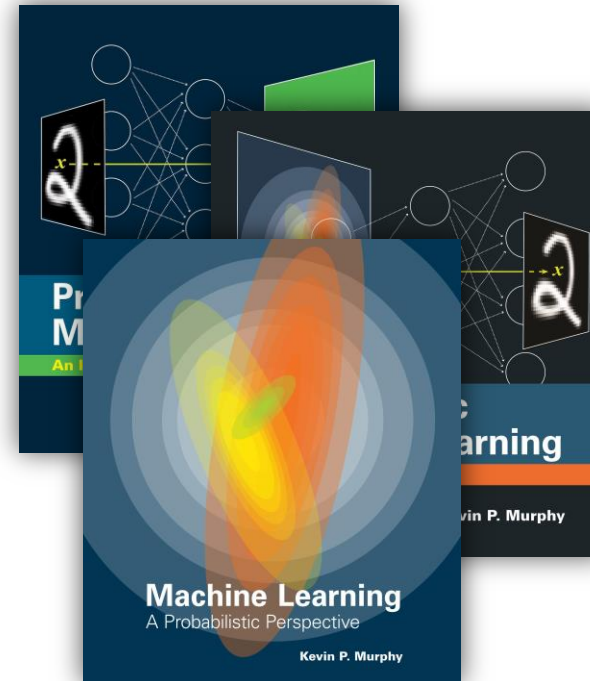
Deep Learning
(NN + Prob + Lin Alg.)



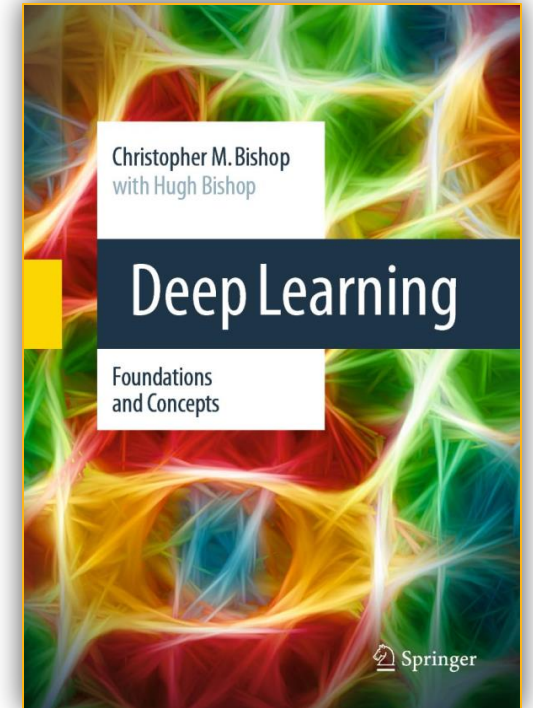
1996



2006



2013-2022



2023

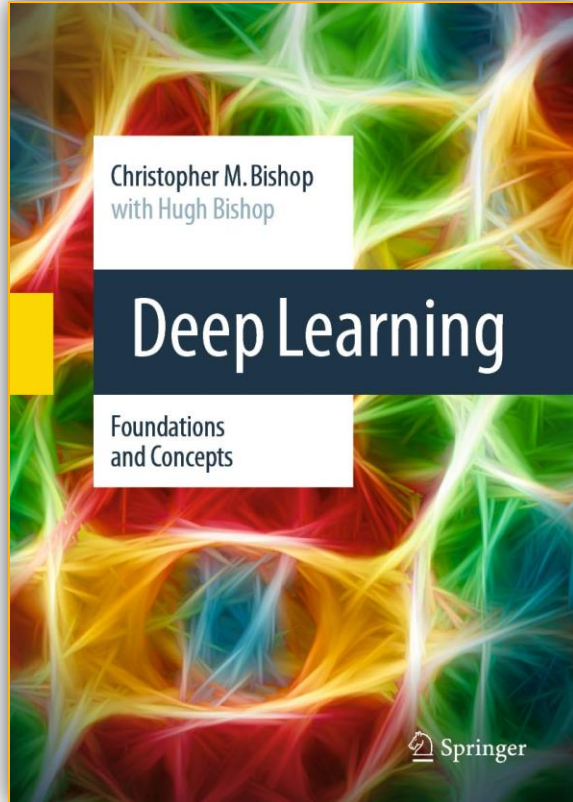


Click on the books to get free PDF versions of all of them!

Teaching CS189 w/ Bishop's Latest Book



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We will follow the books **notation** and **concepts**

- Book should be a helpful resource

Issues with the book (for this class):

- Heavy emphasis on **probabilistic** framing
- Some material is **out-of-scope for this class**
- Doesn't cover **coding related activities**

*Each lecture will have a list of textbook sections that we covered and you are **STRONGLY** encouraged to read the textbook!*



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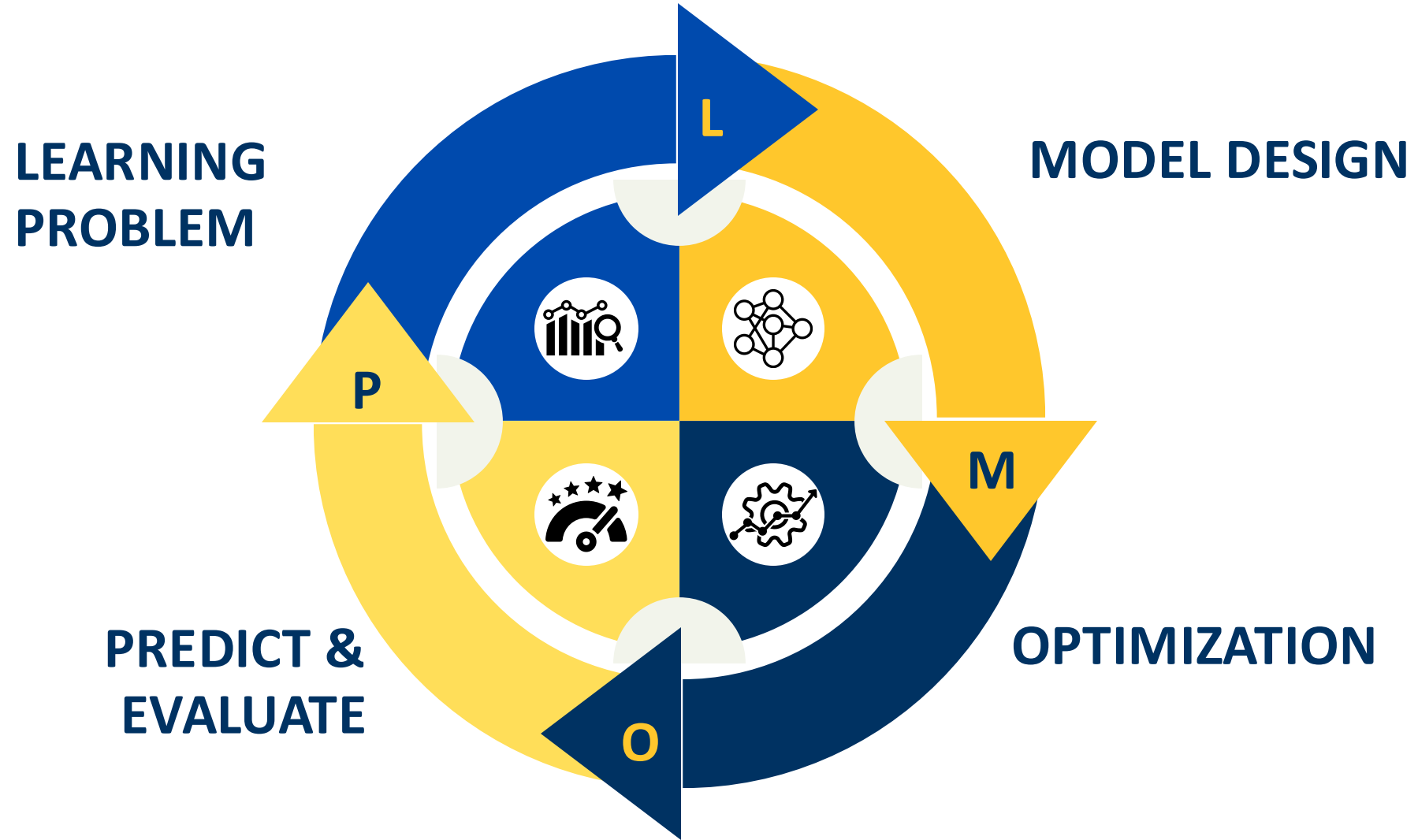
The ML Process (Lifecycle)

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ML Lifecycle



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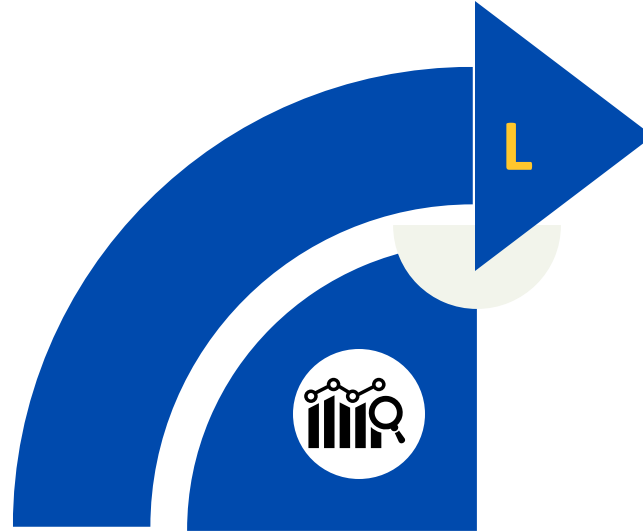
ML Lifecycle

This stage is about framing the real-world question into something a machine learning model can answer.



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LEARNING PROBLEM



- **Target:**
 - What do I want to **predict**? What is the machine learning task?
- **Objective:**
 - How would I **evaluate success**? What loss should I use?
- **Data:**
 - What **data** do I have?
 - Data representation? Feature Engineering?
 - Training/Test split

ML Lifecycle

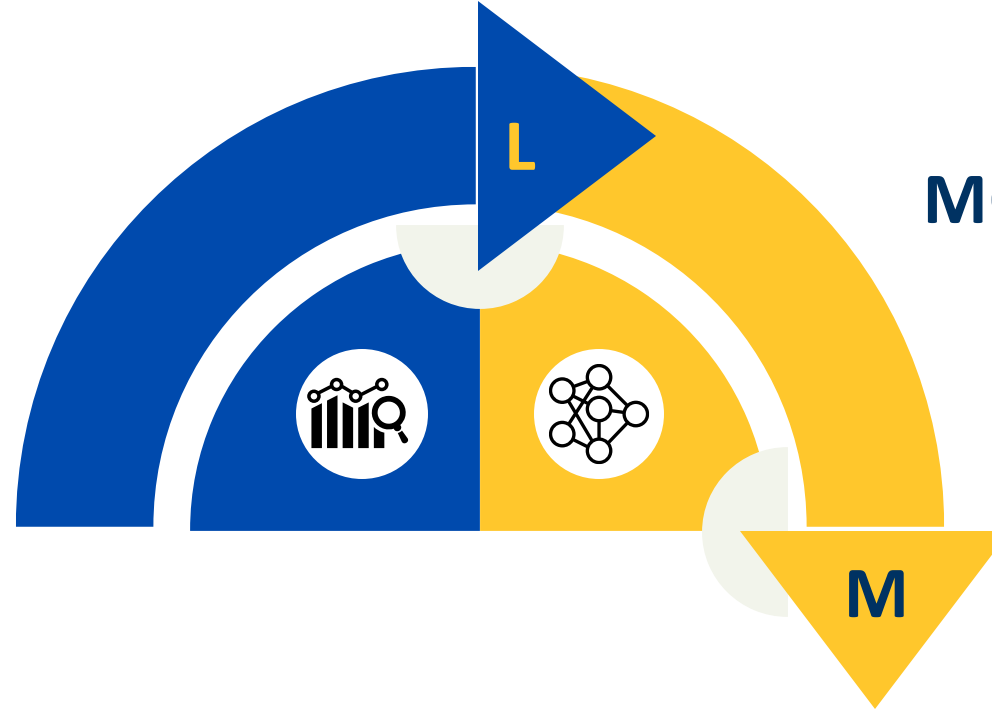
Choose and design an appropriate model.



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LEARNING PROBLEM

- Target
- Objective
- Data



MODEL DESIGN

- Feature Engineering
- Model family/Architecture
- Hypothesis space
- Inductive biases / Assumptions

ML Lifecycle

Adjusting the model's parameters to minimize error using optimization algorithms.

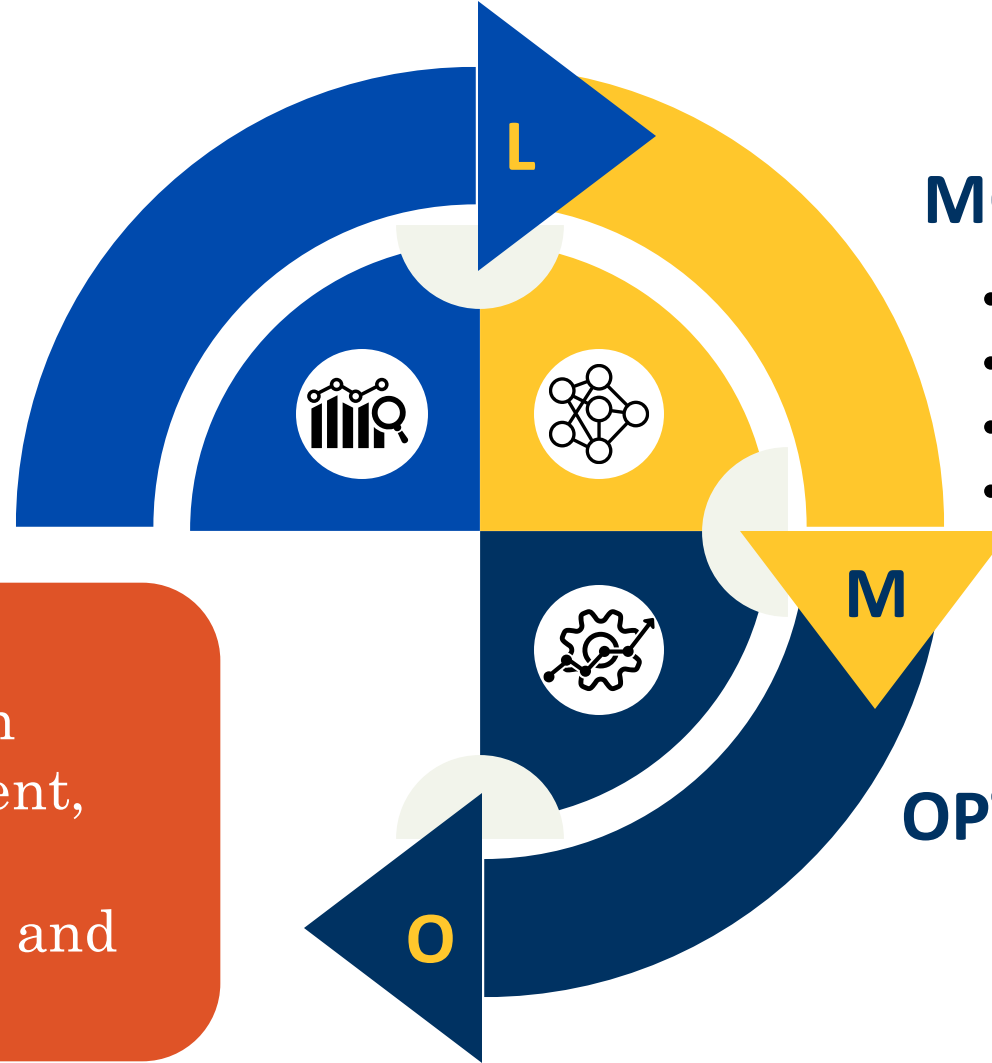


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LEARNING PROBLEM

- Target
- Objective
- Data

- Define a loss
- Choose an optimization method (gradient descent, etc.)
- Manage regularization and overfitting



MODEL DESIGN

- Feature Engineering
- Model family/Architecture
- Hypothesis space
- Inductive biases / Assumptions

OPTIMIZATION

ML Lifecycle

Test how well the model performs.



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LEARNING PROBLEM

- Target
- Objective
- Data

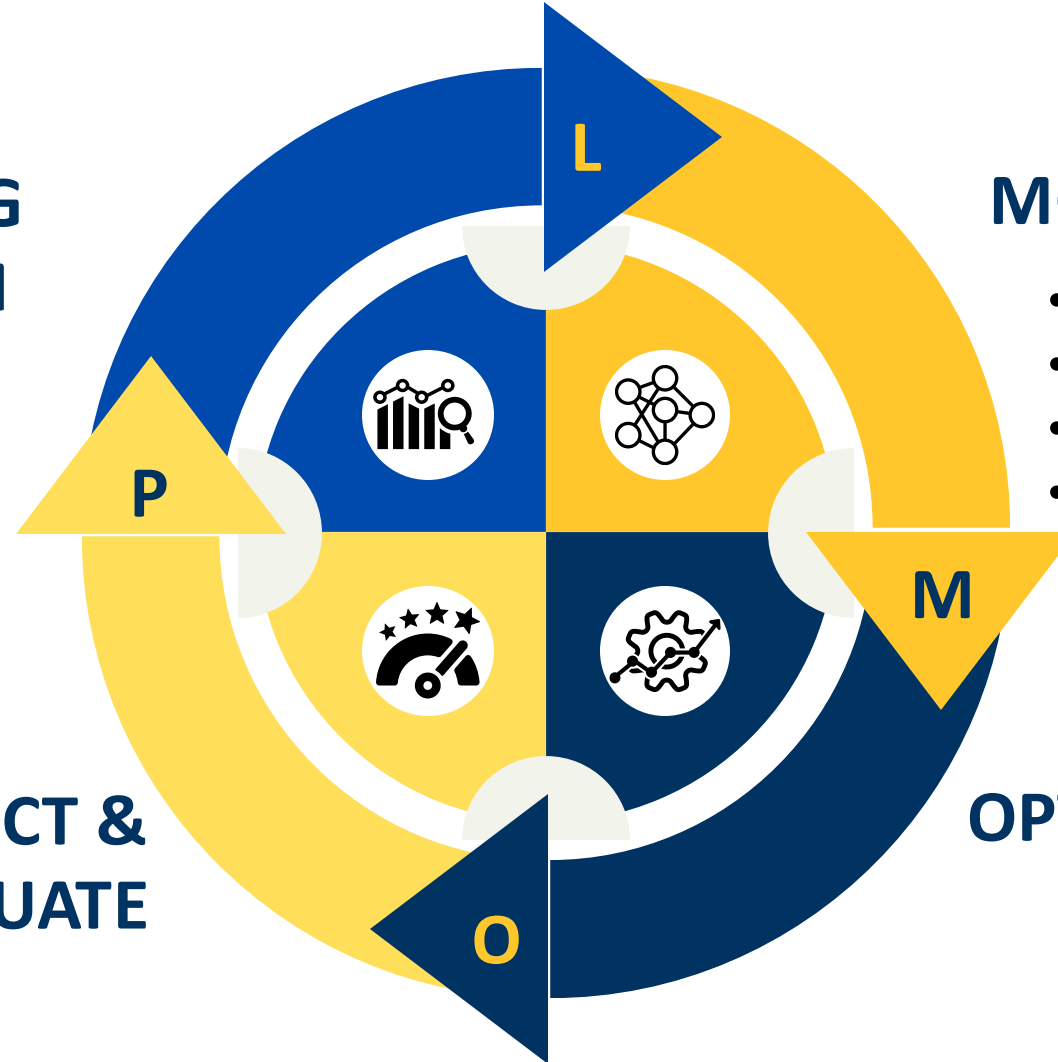
MODEL DESIGN

- Feature Engineering
- Model family/Architecture
- Hypothesis space
- Inductive biases / Assumptions

PREDICT & EVALUATE

Evaluate predictions based on evaluation metrics

OPTIMIZATION



We are going to ...

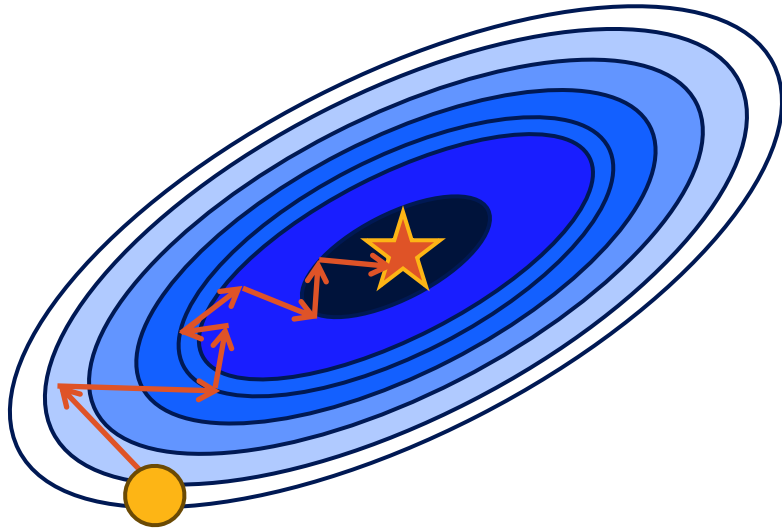
Teach ML “Backwards”

Classic Machine Learning Classes

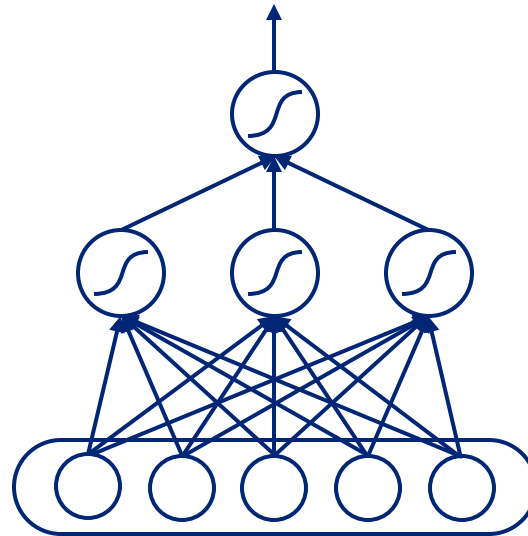


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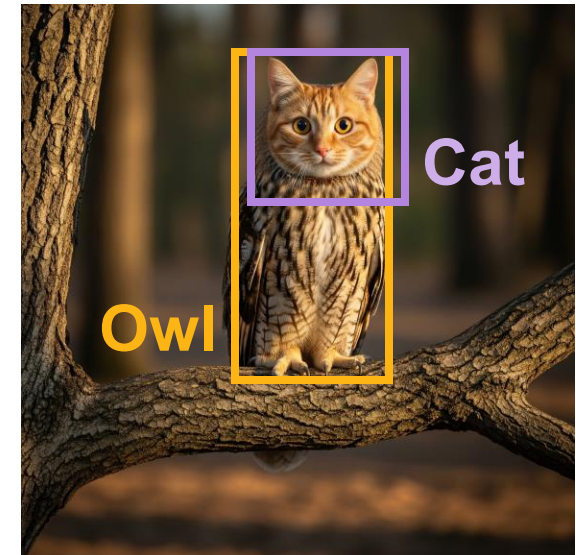
Algorithm



Model



Application



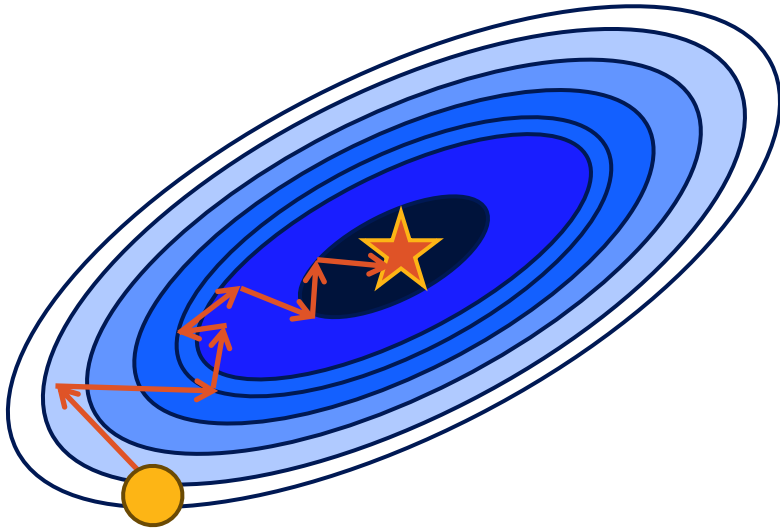
Classic Machine Learning Class

Teaching Machine Learning Differently

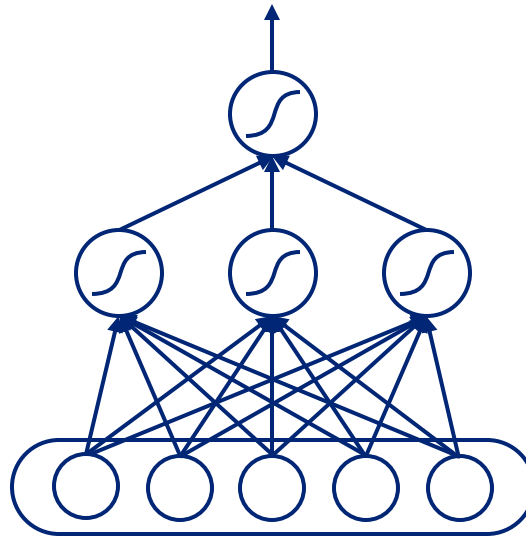


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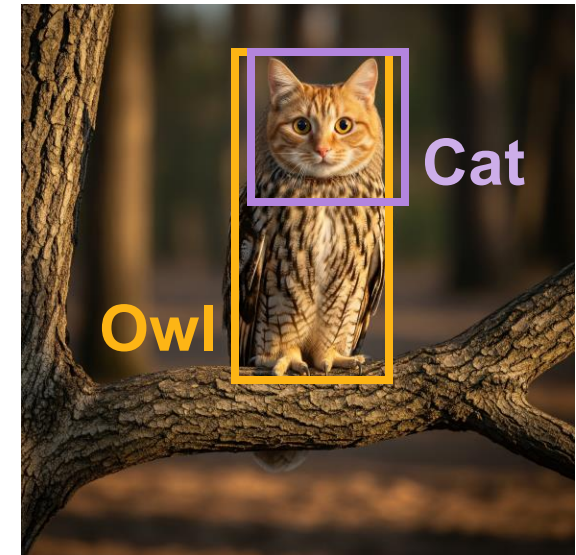
Algorithm



Model



Application



This Machine Learning Class



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Greater Focus on ML Engineering

You will learn to use **tools for ML**:

- **pandas** (<https://pandas.pydata.org/>) for data manipulation.
- **Plotly** (<https://plotly.com/>) and **Matplotlib** (<https://matplotlib.org/>) for data visualization.
- **Scikit-learn** (<https://scikit-learn.org/stable/>) for classic machine learning tasks.
- **PyTorch** (<https://pytorch.org/>) and **HuggingFace** (<https://huggingface.co/>) for neural network development.
- **Weights-and-Biases** (<https://wandb.ai/site/>) for experiment management.



We will work in the **Google Colab environment or Databricks**, but you will also be able to use your own tools if you prefer.

Logistics

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Course Map at a Glance

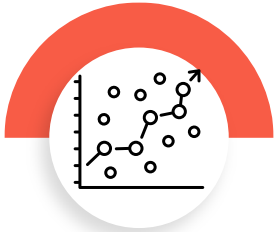


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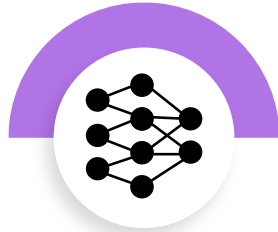
1-2



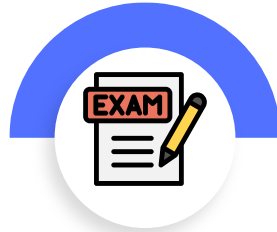
3-6



7-8



9



10-11



12-14



15-16



Introduction and
ML Mechanics

**Supervised
Core**

k-means/EM;
regression →
classification;
GD

**Neural
Networks**

NN Fundamentals:
backprop
non-linearity
regularization

**Midterm
Week**

**Advanced
Architectures**

CNN
Transformer
LLM

**Advanced
Topics**

Attention models
RL
Post-training

Applications

Diffusion
More advanced
applications

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
09:00	Narges OH		OH				
10:00							
11:00					HW RELEASE		
12:00	Discussion			OH			
1:00					OH		
2:00							
3:00	Disc	Joey OH					
4:00			OH				
5:00		Lecture		Lecture			
6:00							
7:00			Discussion				
11:59					HW DUE		

Weekly
Beat

Assessment Cadence



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- **5 Homeworks**, each spans **~3 weeks**, with **two parts** released together:
 - **Part 1 (Warmup)** → introduces tools;
 - **Part 2 (Main)** → deeper application.
- **Mix of written + coding**;
 - Some **public** sanity tests and **hidden** correctness tests.
 - Collaboration = discuss ideas, but **write/code individually**.
 - Open use of GenAI
 - No Vibe Coding/Writing!! You must understand everything you submit!
- **Due 11:59 pm**
 - **No HW drops.**
 - You get **10 total slip days** across the **10 HW deadlines**;
 - **max 4** per HW; slip days **auto-apply** (1 minute late = 1 day).

CS189

Prerequisites

Prerequisites



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- Official Prerequisite:
 - MATH 53 and MATH 54; and COMPSCI 70 (or equivalent).
- What you need:
 - Good programming skills in Python
 - Implement functions and classes
 - Debug programs
 - Probability and statistics
 - Work with conditional probabilities and Bayes rule and compute expectations
 - Familiarity with uniform, Bernoulli, and Gaussian distributions
 - Linear algebra and Calculus
 - Understand eigenvectors and eigenvalues
 - Compute gradients, apply the chain rule

CS189

Course Staff



Ozan Bayiz
Head



Alan Zhu
Head Content

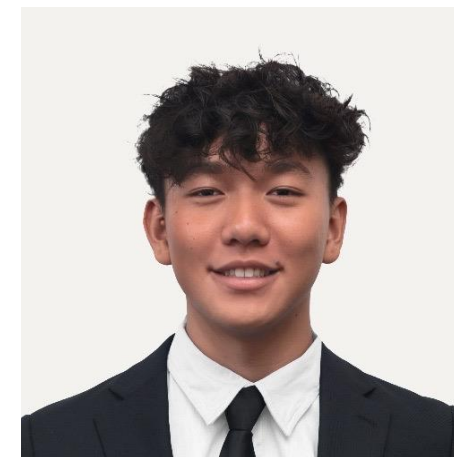
UCS2s (TAs)



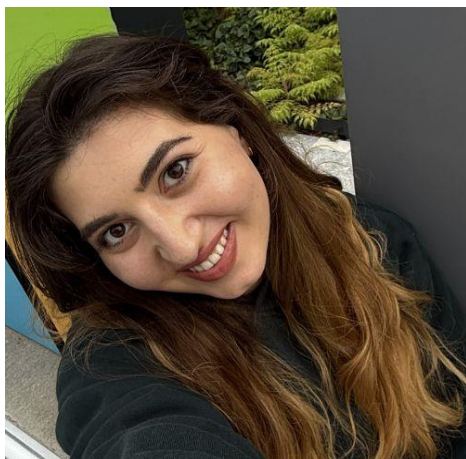
Carolyn Wang
Logistics



Deena Sun
Content



Andrew Zhou
Exams



Susanna Atanessian
AI Tools



Kenneth Llontop
Student Support



Celine Tan
Infrastructure



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UCS1s (Tutors)



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Adelina Chau
Content Review



Deepinder Mann
Content Review



Jason Trinh
Content Review



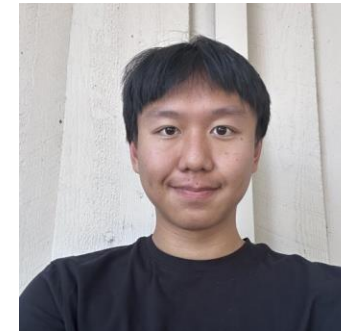
Avyukth Harish
Student Support



Sahir Tandon
Grading + AI Tools



Nikhil Mathihalli
Grading + AI Tools



Jermaine Li
Lecture Support



Aniket Samet
Lecture Support

CS189

Course Platforms



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Course Platforms

- Website <https://eecs189.org/fa26/>
- Official programming environment on Google Colab or Databricks platform
- You may use your own tools (vscode, cursor, jupyterlab, ... vim?)
 - We won't be able to officially support you
- Ed <https://edstem.org/us/courses/100913/>

Course Platforms - Askademia



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Login

Contact Us

Learn smarter. Understand deeper.

Turn educational videos into interactive learning.

 Best Overall Paper at AIED 2025

Built at UC Berkeley. Answered **13,746** questions and counting.

Student Login

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CHEM 3A: Midterm Review

Cellular Respiration: ATP Yield

Most ATP comes from oxidative phosphorylation in the inner mitochondrial membrane.

Stage	ATP
Glycolysis	2
Krebs Cycle	2
ETC	~26-28

Gly

Krebs

ETC

Key idea

ETC uses a proton gradient to drive ATP synthase, producing most ATP.

Chat Quiz Notes

Which stage of cellular respiration produces the most ATP?

A) Glycolysis

B) Krebs cycle

C) Electron transport chain

Incorrect: you selected A) Glycolysis. Correct answer: C) Electron transport chain, which produces most ATP via oxidative phosphorylation.



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Let's Review Syllabus on the Website

Lecture 1

Introduction to Machine Learning

Credit: Joseph E. Gonzalez and Narges Norouzi

Reference Book Chapters: Chapter 1 (Section 1.1)