Course Overview

- Statistical methods
- Neural networks
- Advanced topics
- Applications to cognitive science
Three Types of Learning

Imagine an agent observes a sequence of inputs: $x_1, x_2, x_3, \ldots$

**Supervised learning**

The agent also observes a sequence of labels or outputs $y_1, y_2, \ldots$, and the goal is to learn the mapping $f: x \rightarrow y$.

**Unsupervised learning**

The agent’s goal is to learn a statistical model for the inputs, $p(x)$, to be used for prediction, compact representation, decisions, \ldots

**Reinforcement learning**

The agent can perform actions $a_1, a_2, a_3, \ldots$, which affect the state of the world, and receives rewards $r_1, r_2, r_3, \ldots$. Its goal is to learn a policy $\pi$: $\{x_1, x_2, \ldots, x_t\} \rightarrow a_t$ that maximizes rewards.
Supervised Learning

**Classification:** the outputs $y_1, y_2, \ldots$ are **discrete** labels

Dog

Cat

**Regression:** the outputs $y_1, y_2, \ldots$ are **continuously** valued

![Graph](image)
Applications: Cognitive Science

Object Categorization

Speech Recognition

Face Recognition

Motor Learning
Challenges

• Noisy sensory inputs
• Incomplete information
• Changing environment
• Many variables (mostly irrelevant)
• No (one) right answer
• Prior knowledge
• Inductive inference (open-ended)
• Uncertainty, not deterministic
An Example: Curve-Fitting
Polynomial Curve-Fitting

Linear model

\[ y(x; \mathbf{w}) = w_0 + w_1 x + w_2 x^2 + \ldots + w_n x^n = \sum_{j=0}^{n} w_j x^j \]

Error function (root-mean-square)

\[
E(\mathbf{w}) = \sqrt{\frac{\sum_{j=0}^{n} (y(x_i, \mathbf{w}) - y_j)^2}{N}}
\]
Linear Fit?
Quadratic Fit?
5th-Order Polynomial Fit?
10th-Order Polynomial Fit?
And the Answer is...

Quadratic
Training Error vs. Test Error

1st-order

2nd-order

5th-order

10th-order
What Did We Learn?

- Model complexity important
- Minimizing training error → overtraining
- A better error metric: test error
- But test error costs extra data (precious)
- Fix 1: regularization (3.1)
- Fix 2: Bayesian model comparison (3.3)