Lecture 1

CS436/536: Introduction to Machine Learning

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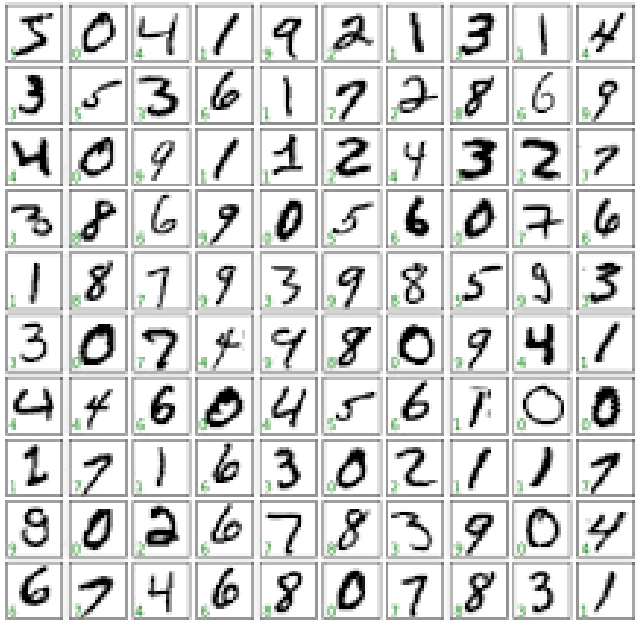
Why? Huh!? What is it good for?



Iris Versicolor

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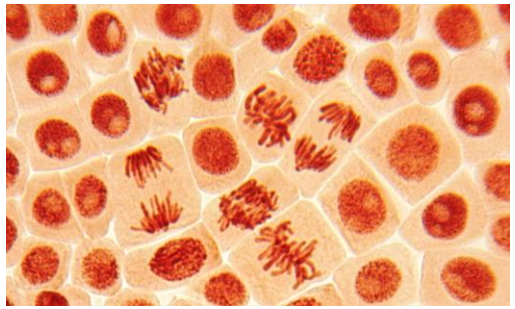
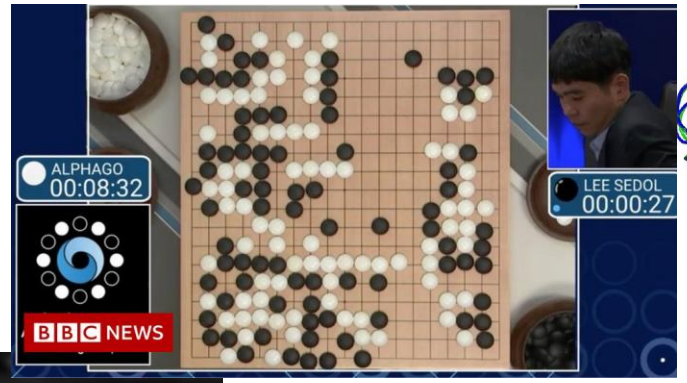
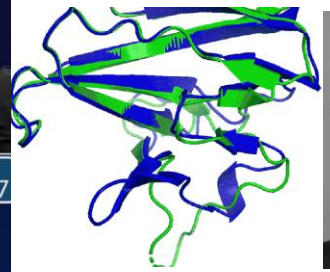
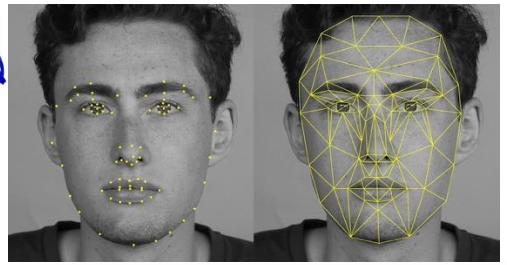
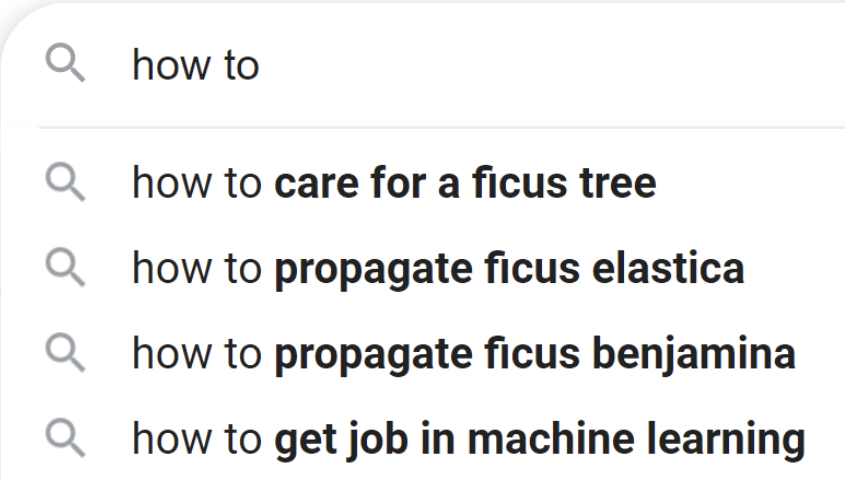










Learning to Solve Hard Problems with Data

When is Machine Learning Useful?

- Human expertise does not exist or cannot be conveniently translated into an algorithm (navigating on Mars, protein structure)
- Humans can’t explain their expertise (speech / face recognition)
- Models must be customized (personalized medicine)
- Models are based on huge amounts of data (genomics)
- No “analytical” solution

Some Other Applications

- Recognizing patterns
  - Facial identities or facial expressions
  - Handwritten or spoken words
  - Medical images
- Generating patterns
  - Generating images or motion sequences
- Recognizing anomalies
  - Unusual credit card transactions
  - Unusual patterns of sensor readings in a nuclear power plant
- Prediction
  - Future stock prices or currency exchange rates

Central to

- Natural language processing (NLP)
- Computer vision
- Computational biology
- Robotics

…

Example: Credit Approval

- Using salary, debt, years in residence, etc., approve for credit or not
- Nobody has an optimal credit approval formula
- But banks have data
  - Customer information
  - Credit history

age	33 years
salary	50,000
debt	27,500
years employed	1
years at residence	2
…	…

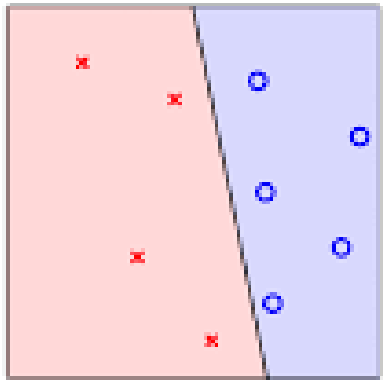
Approve for credit?

Outline

1. What is Learning?

   "Learning is a process by which a system improves performance from experience"

   - Herbert Simon
2. Can we Learn?
3. How to Learn?
4. How to Learn well?
5. Advanced Techniques.
6. Other Learning Paradigms.



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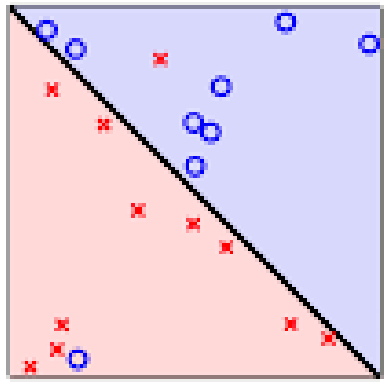

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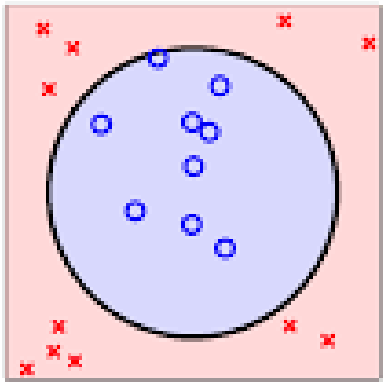

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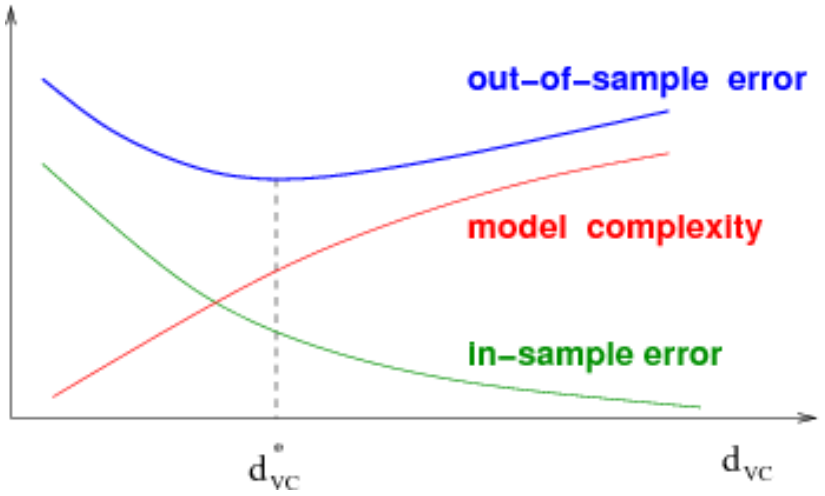
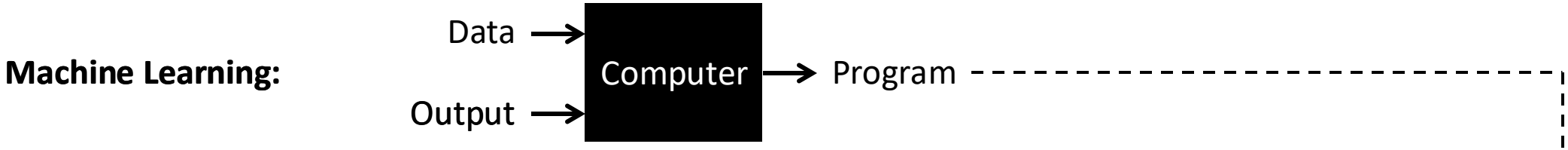
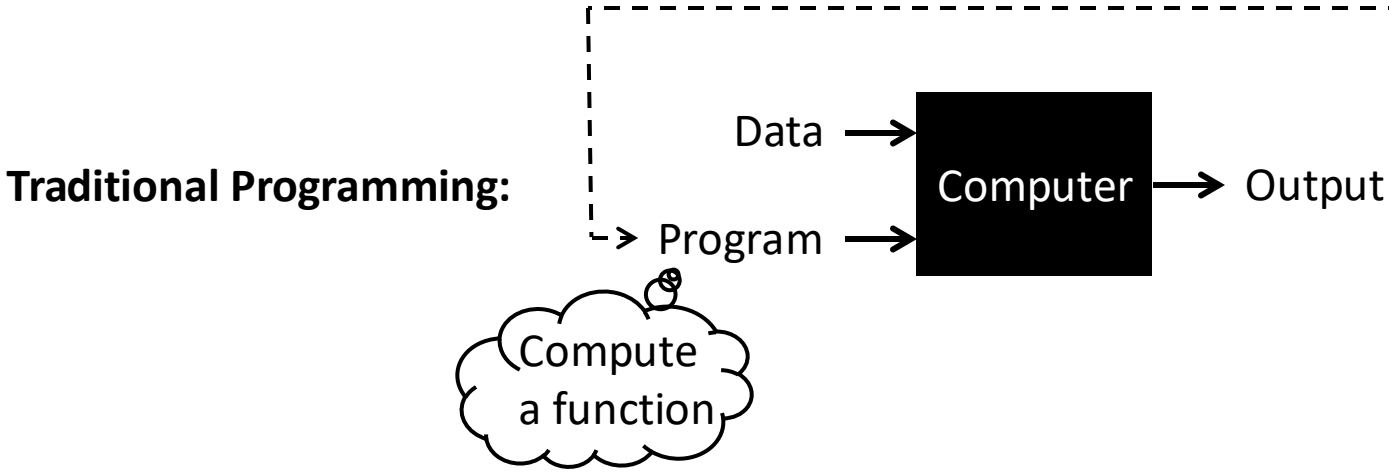


What is Machine Learning?

"*computer programs that automatically improve their performance through experience*" – Herbert Simon



"… the ability to learn without being explicitly programmed" – Arthur Samuel



What it is not:

The *design* approach

How to Learn?

- Memorization
  - Accumulate all the facts in a large lookup table

- Generalization
  - Deduce new facts from old facts
  - Recognize a pattern and use it to *make a prediction*

  - A pattern exists
  - The pattern is **UNKNOWN**
  - But we have data

Credit Approval

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age	33 years
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…	…

Approve for credit?

Components of the **Learning Problem**

- age, salary, debt, years employed, …
- Approve credit or not
- **True** relationship between $\boldsymbol{x}$ and y
- Data on customers

input $\boldsymbol{x} \in \mathbb{R}^d = \mathcal{X}$

output $y \in \{-1, +1\} = \mathcal{Y}$

target function $f: \mathcal{X} \to \mathcal{Y}$ [unknown]

Optimal credit approval function

data set $\mathcal{D}_N = (x_1, y_1), \ldots (x_N, y_N)$ $[y_n = f(x_n)]$

$\mathcal{X}, \mathcal{Y}$ and $\mathcal{D}$ are *given* by the learning problem

The target function f is fixed but unknown

Learn the target function f from the data $\mathcal{D}$

What is Learning?

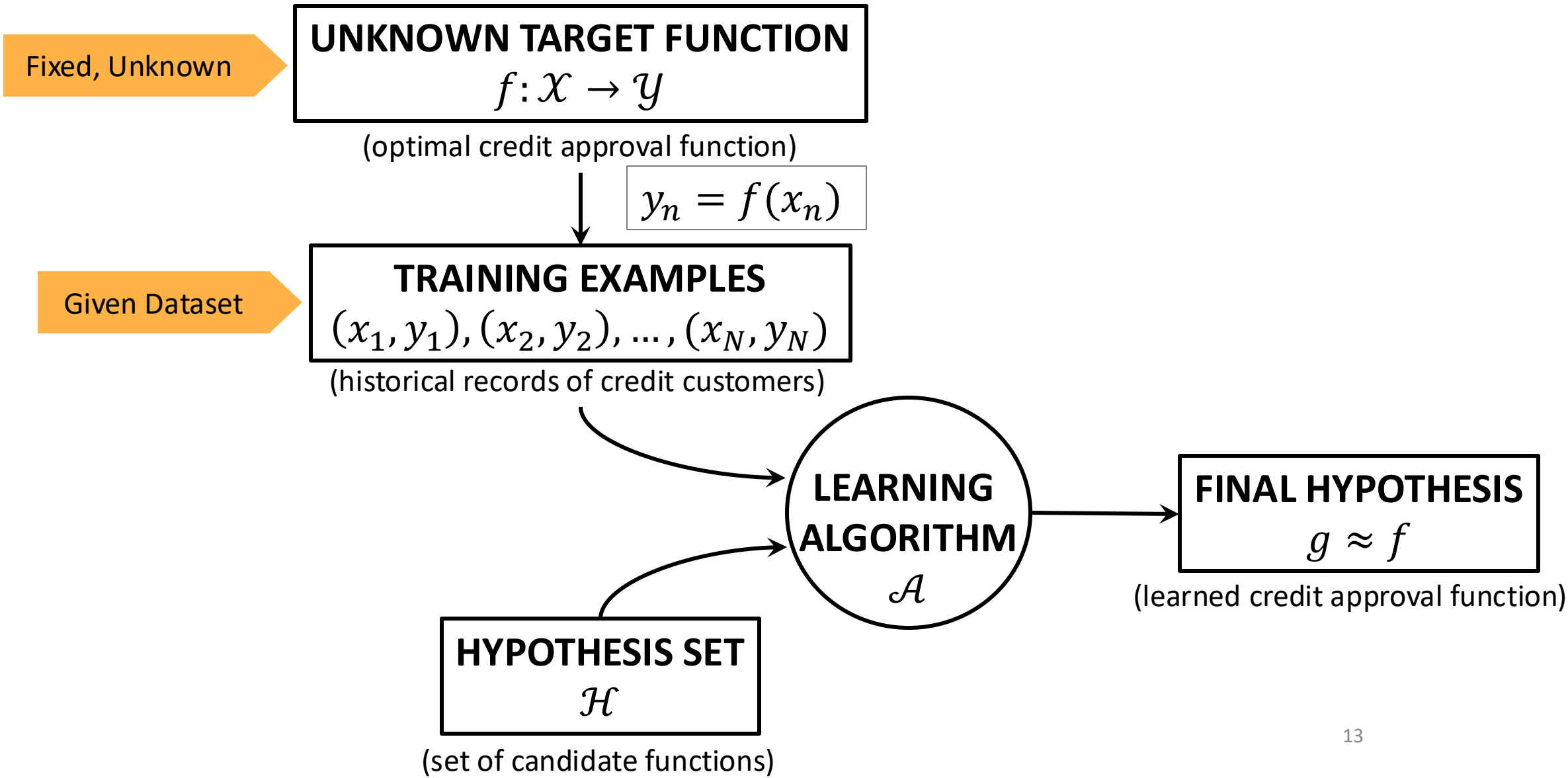
- Obtaining f
- Result of learning is an approximation of f

$$g: \mathcal{X} \to \mathcal{Y}$$

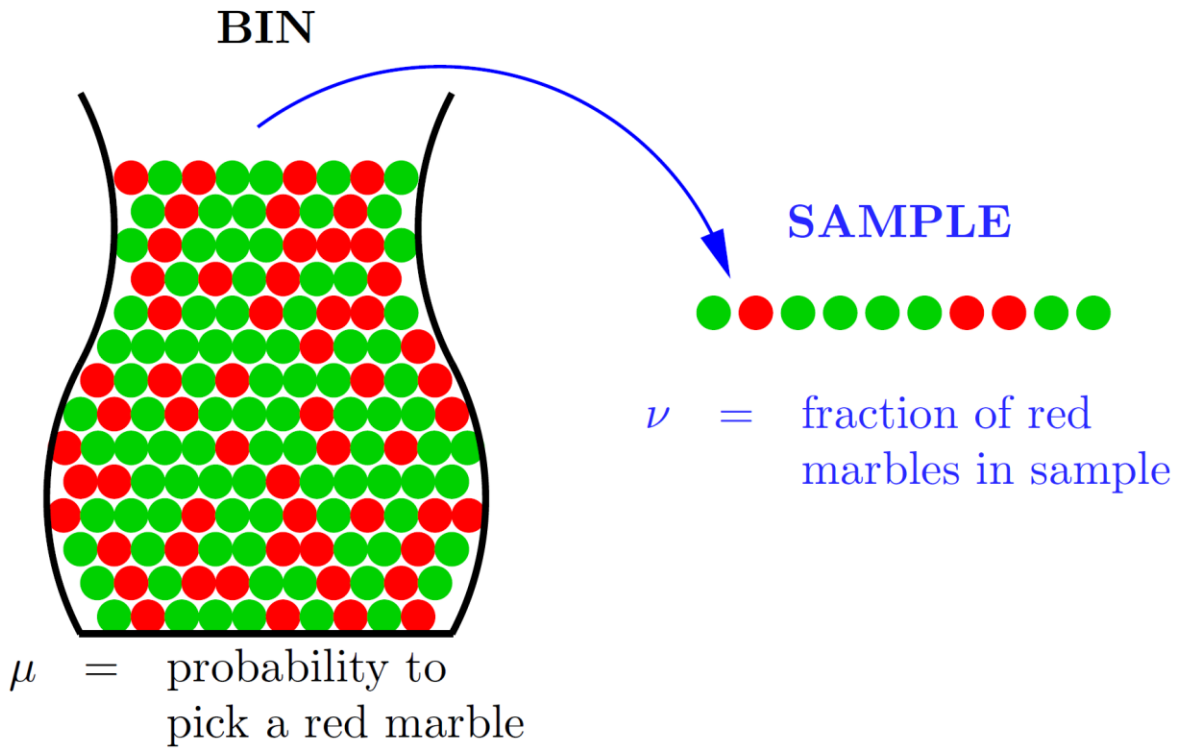
- Want:

$g \approx f$ i.e. $g(\boldsymbol{x}_*) \approx f(\boldsymbol{x}_*)$ where $\boldsymbol{x}_*$ is the next *test data point*

Learning Problem Setup



Estimating Population Mean from Sample Mean



Pick a *random* sample of N marbles with replacement *independently*

Observe the fraction of red marbles ν

Note: the only random quantity here is ν. μ is fixed (albeit unknown)

What does ν tell us about μ?
Nothing for sure.
But…

Estimating Population Mean from Sample Mean

Can we say anything **<u>for certain</u>** about μ (outside the data)
having observed ν (the data)?

- No.

It is *possible* to pick only red marbles while the bin has mostly green marbles

But not probable

- See the binomial distribution

- What is the relationship between ν and μ?

Learning

- Start with a set of candidate hypotheses $\mathcal{H}$ which likely represent f

$\mathcal{H} = \{h_1, h_2, \dots\}$ The hypothesis set or *model*

- Select a hypothesis g from $\mathcal{H}$

Using a *learning algorithm*

- Use g for new customers

Hope that $g \approx f$

$\mathcal{X}, \mathcal{Y}$ and $\mathcal{D}$ are ***given*** by the learning problem

The target function f is **fixed but unknown**

We choose $\mathcal{H}$ and the learning algorithm

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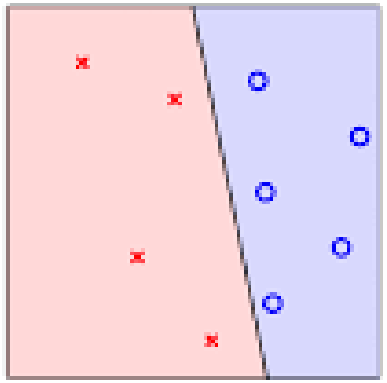

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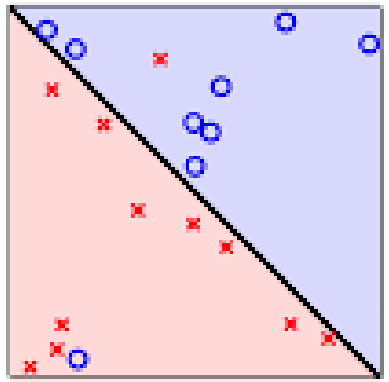

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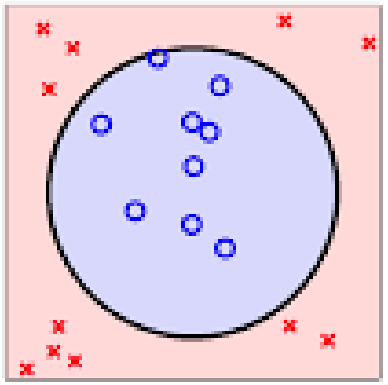

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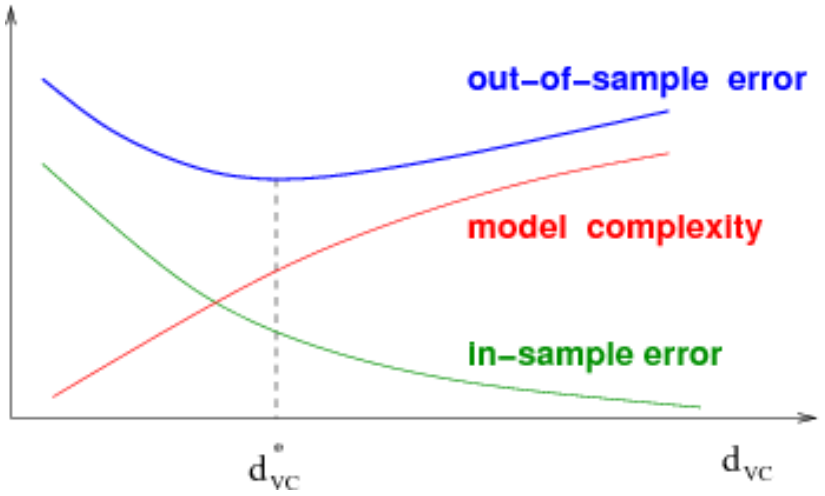


Prerequisites

- CS 375 Design and Analysis of Algorithms or equivalent
- MATH 327 Probability with Statistics Methods

- Comfort with Linear Algebra, Calculus

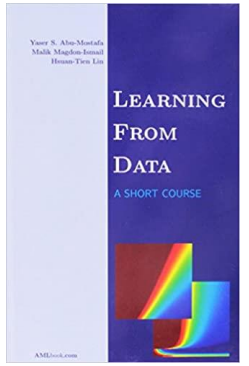
- Proficiency with at least one of the following high level programming language:

Python, Matlab, Java, C++

Textbooks

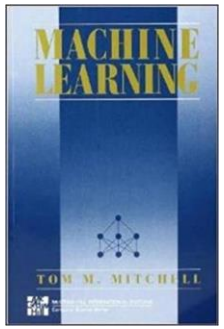
- *Learning from Data*

by Yaser S. Abu-Mostafa, Malik Magdon-Ismail, Hsuan-Tien Lin



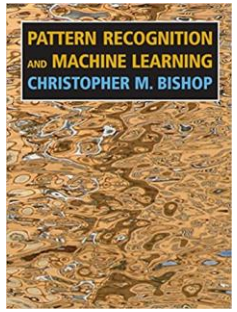
- *Machine Learning*

by Tom Mitchell



- *Pattern Recognition and Machine Learning*

by Christopher M. Bishop



Grading

- (70 points) 7-10 Take-home Homework and Programming Assignments
- (5 points) 4 In-class Quizzes
  - Open book, open notes, NO electronics
- (30 points) Two Exams (open-book)

- Please talk to each other
- Write solutions / implement program yourself

- Check Brightspace for all announcements and course content

Grading

- A/A-: 100-90
- B+/B/B-: 75-90
- C+/C/C-: 65-75
- D: 55-65

Office hours

Zhaohan Xi

Tuesday & Thursday

1:00PM – 2:50PM

EB G06

Taoyue Wang

Friday

2:00PM – 4:00PM

EB N00

Additional appointments arranged by email:

zxi1@binghamton.edu

twang61@binghamton.edu

Syllabus available on Brightspace

- Please review the syllabus
- Please read the CS department Academic Honesty letter to students
- Please review Watson College and University Academic Integrity policy

Academic Integrity/Honesty

- The Watson College Student Academic Honesty Code
- Student Academic Honesty Code

Today’s Tasks

- Say hello
- Please talk to each other
- Find some people to work on homework with
- Form some initial agreements to work in pairs