

What is Machine Learning?

- How can we solve a specific problem?
 - ▶ As computer scientists we **write a program** that encodes a set of rules that are useful to solve the problem



Figure : How can we make a robot cook?

Tasks that requires machine learning: What makes a 2?

0 0 0 1 1 (1 1 1 2

2 2 2 2 2 2 3 3 3

3 4 4 4 4 4 5 5 5

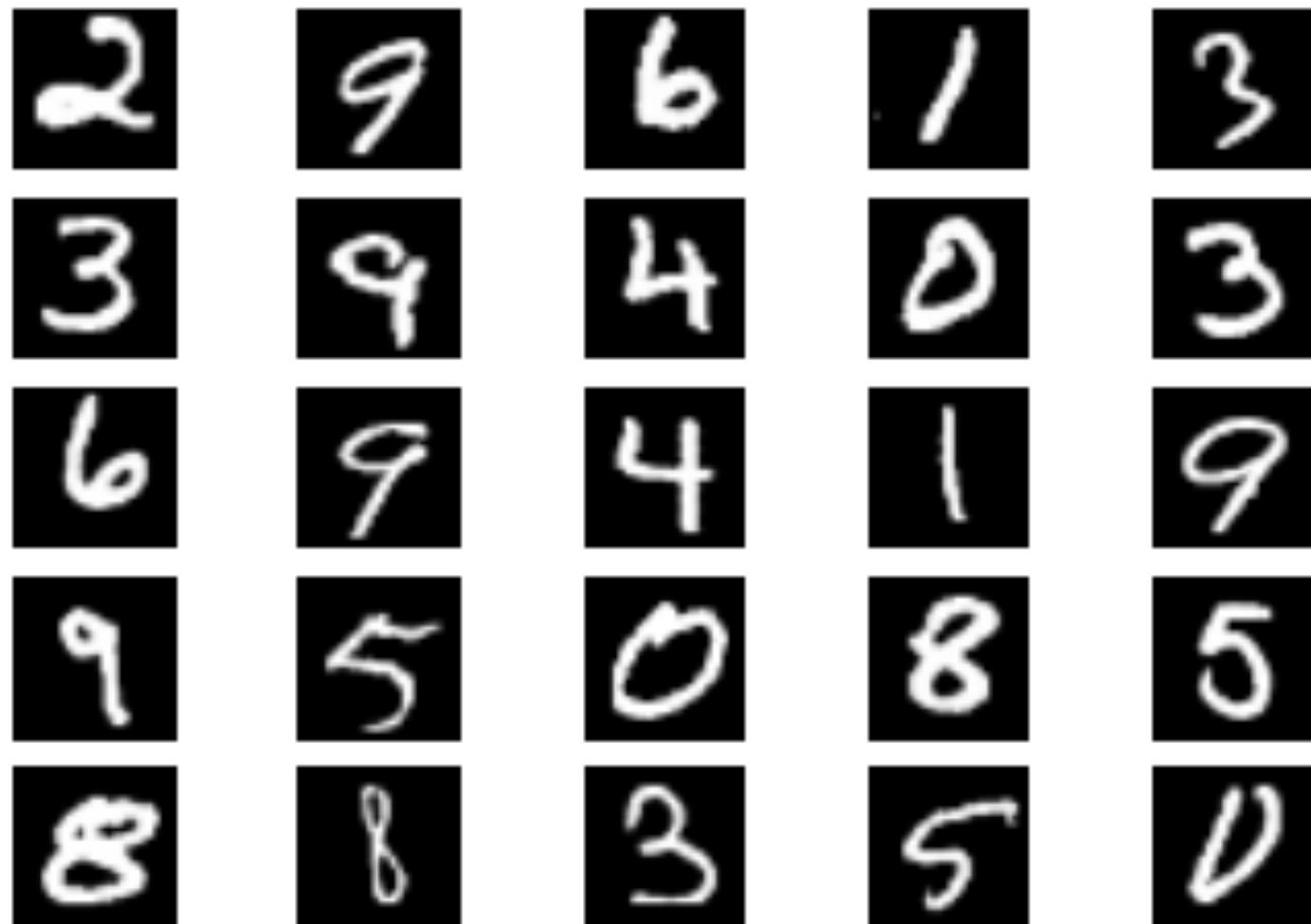
6 6 7 7 7 7 1 8 8

8 8 8 7 9 4 9 9 9

Learning algorithms are useful in many tasks

1. Classification: Determine which discrete category the example is

Examples of Classification



Learning algorithms are useful in many tasks

1. Classification: Determine which discrete category the example is
2. Recognizing patterns: Speech Recognition, facial identity, etc

Examples of Recognizing patterns



Figure : Siri: <https://www.youtube.com/watch?v=8ciagGASro0>

Learning algorithms are useful in other tasks

1. Classification: Determine which discrete category the example is
2. Recognizing patterns: Speech Recognition, facial identity, etc
3. Recommender Systems: Noisy data, commercial pay-off (e.g., Amazon, Netflix).

Examples of Recommendation systems

The screenshot shows the Netflix website interface. At the top, the Netflix logo is on the left, followed by a 'Browse' dropdown menu, a 'DVD' link, and a search bar containing the text 'despi'. To the right of the search bar are icons for notifications and a user profile named 'Raquel'. Below the header, the movie poster for 'Despicable Me' is displayed, featuring Gru and the Minions. The title 'Despicable Me' is prominently shown below the poster. To the right of the title is a large play button icon. The movie's rating (4 stars), release year (2010), and runtime (1h 34m) are listed. A brief plot summary follows: 'Villainous Gru hatches a plan to steal the moon from the sky. But he has a tough time staying on task after three orphans land in his care.' Below the plot summary, the cast (Steve Carell, Jason Segel, Russell Brand) and genres (Children & Family Movies, Movies for ages 5 to 7, Movies for ages 8 to 10) are listed. A note indicates that Steve Carell, Jason Segel, Russell Brand and Kristen Wiig lend their voices to this animated box office hit. A 'MY LIST' button is located at the bottom left. At the very bottom of the page, there are navigation links for 'OVERVIEW', 'MORE LIKE THIS', and 'DETAILS'.

NETFLIX Explore titles related to: Despicable Me 2

Browse ▾ DVD

despi

Raquel

Despicable Me

★★★★★ 2010 [G] 1h 34m

Villainous Gru hatches a plan to steal the moon from the sky. But he has a tough time staying on task after three orphans land in his care.

Starring: Steve Carell, Jason Segel, Russell Brand
Genres: Children & Family Movies, Movies for ages 5 to 7, Movies for ages 8 to 10
This movie is: Goofy

Steve Carell, Jason Segel, Russell Brand and Kristen Wiig lend their voices to this animated box office hit.

MY LIST

OVERVIEW MORE LIKE THIS DETAILS

Urtasun, Zemel, Fidler (UofT)

CSC 411: 01-Introduction

25 / 44

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4. **Information retrieval:** Find documents or images with similar content

Examples of Information Retrieval

Google search results for "csc411":

Web Maps Videos News Images More ▾ Search tools

About 24,500 results (0.52 seconds)

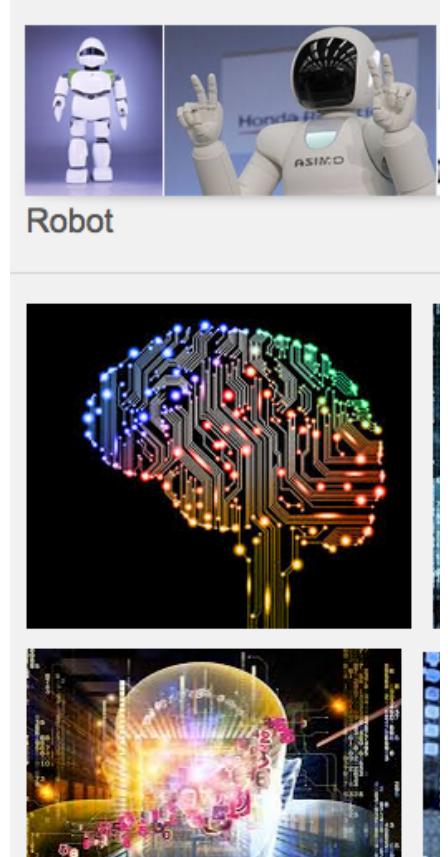
[PDF] CSC 411 MACHINE LEARNING and DATA MINING ...
www.cs.toronto.edu/~zemel/documents/411/syl.pdf ▾
CSC 411. MACHINE LEARNING and DATA MINING. Lectures: Monday, Wednesday 12-1 (section 1), 3-4 (section 2). Lecture Room: MP 134 (section 1); Bahen ...

Professor Richard Zemel - Department of Computer Science
www.cs.toronto.edu/~zemel/ ▾
Image Question Answering: A Visual Semantic Embedding Model and a New Dataset . Mengye Ren, Ryan Kiros, Richard Zemel. ICML 2015 Deep Learning ... Course Offerings - Research Interests - Students & Post Docs - Contact Info

UofT Machine Learning | Course
learning.cs.toronto.edu/courses ▾
CSC 411, Machine Learning and Data Mining (Raquel Urtasun and Richard Zemel); STA 4513, Statistical models of networks, graphs, and other relational ...

CSC 411: Machine Learning and Data Mining
www.cs.utoronto.ca/~radford/csc411.F06/ ▾
CSC 411: Machine Learning and Data Mining (Sept-Dec 2006). Note: The test on December 8 at 3pm will be held in BA B024, not the usual lecture/tutorial room.

Worth taking CSC321 before CSC411? : UofT - Reddit



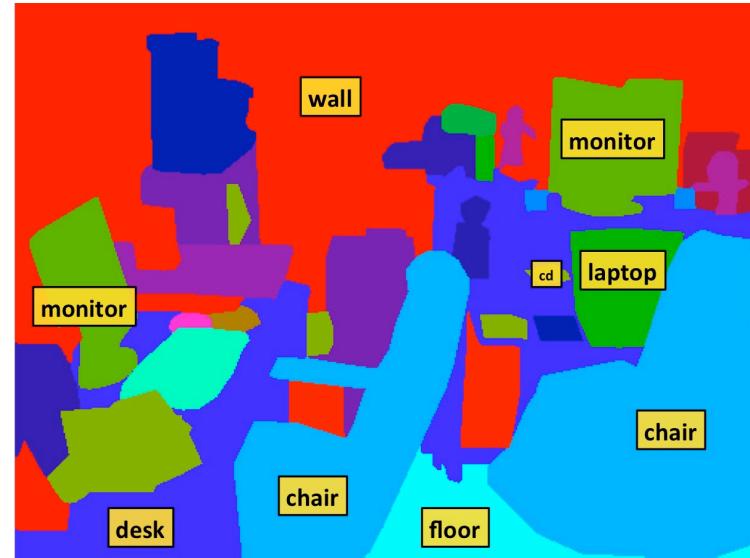
Google search results for "artificial intelligence":

Web News

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Computer Vision



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Autonomous Driving



Flying Robots

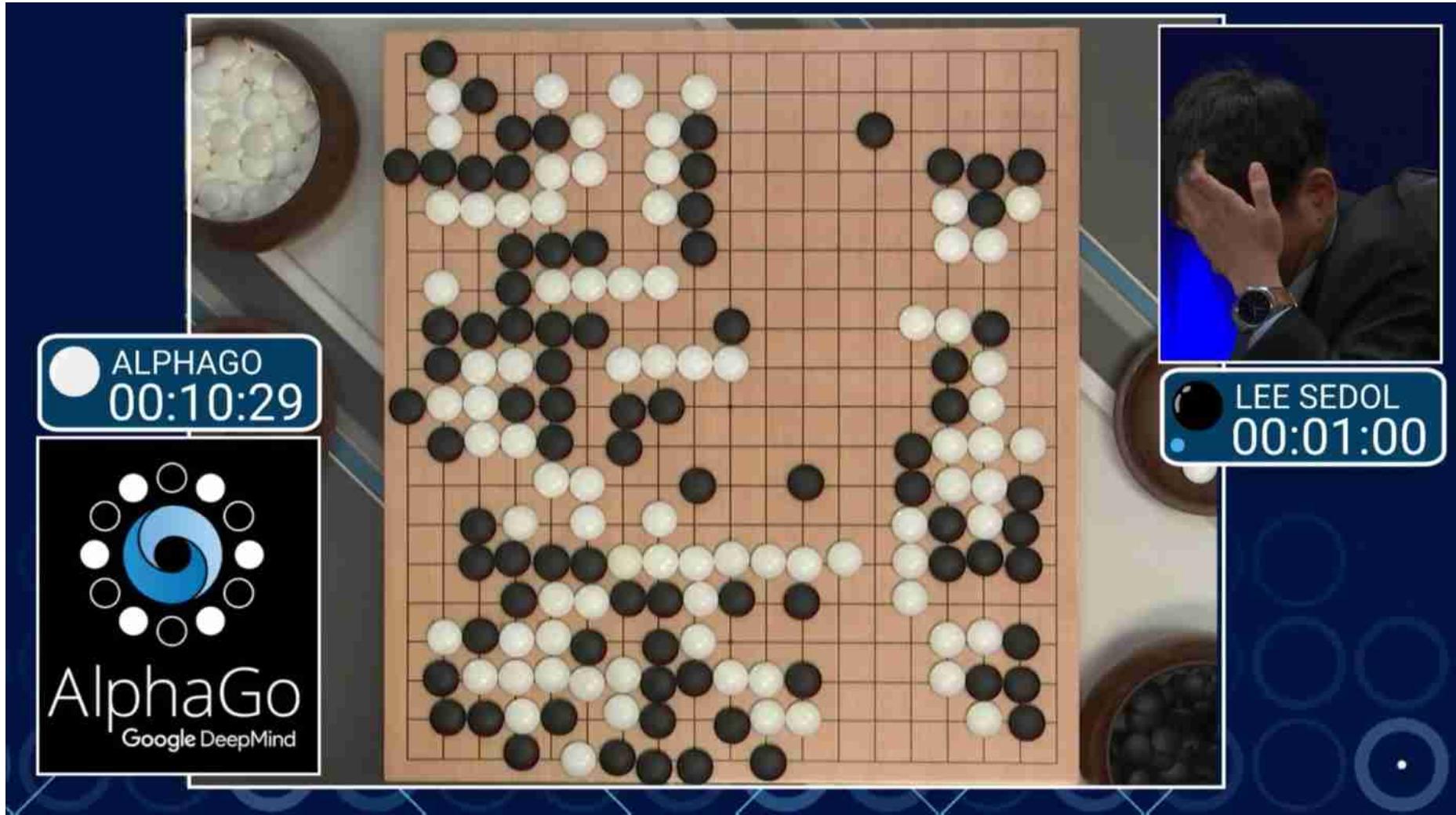


Figure : Video: <https://www.youtube.com/watch?v=YQIMGV5vtd4>

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7. Learning to play games

Playing Games: Alpha Go



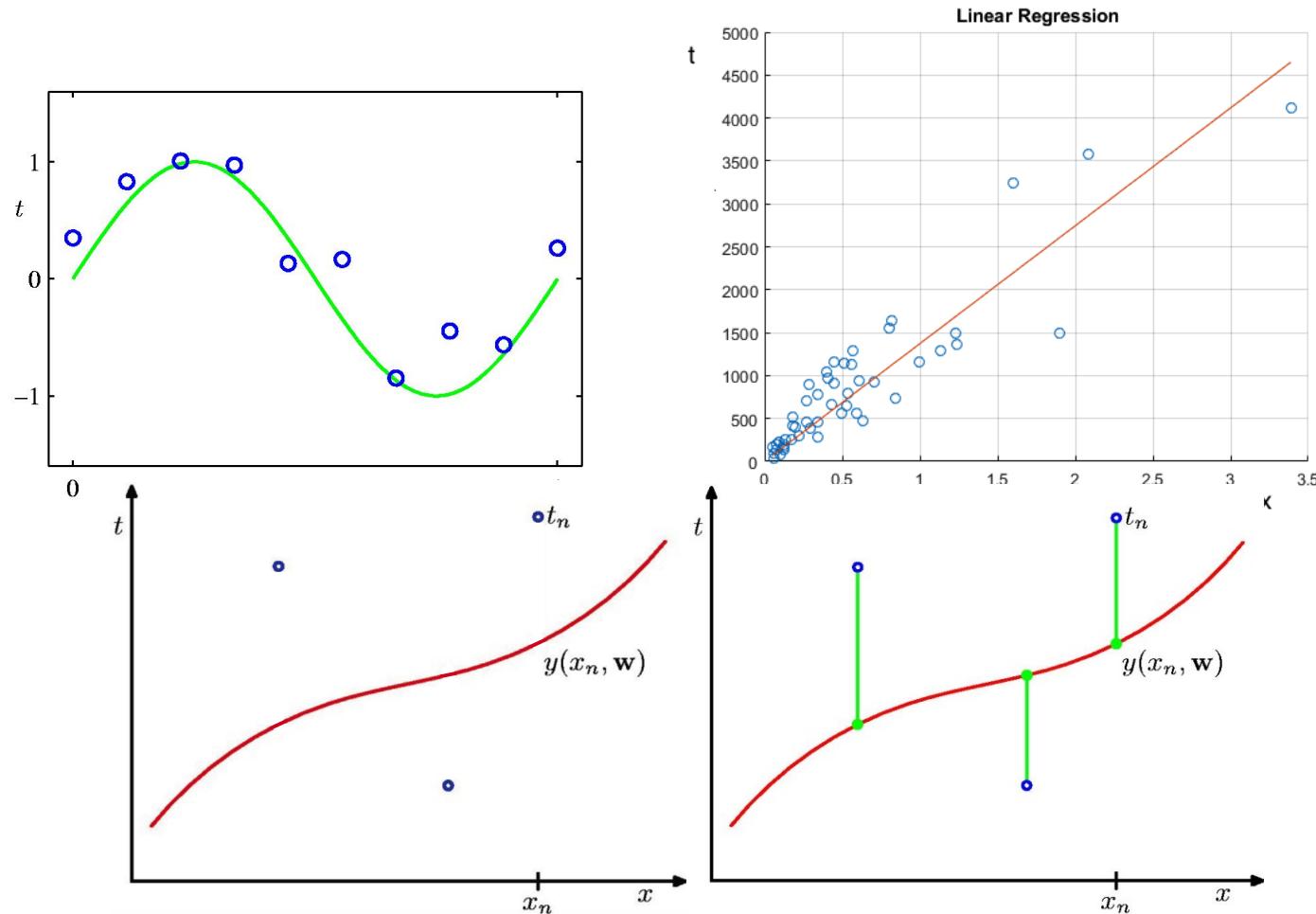
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7. Learning to play games
8. Recognizing anomalies: Unusual sequences of credit card transactions, panic situation at an airport
9. Spam filtering, fraud detection: The enemy adapts so we must adapt too
10. Many more!

Types of learning tasks

- **Supervised**: correct output known for each training example
 - ▶ Learn to predict output when given an input vector
 - ▶ **Classification**: 1-of-N output (speech recognition, object recognition, medical diagnosis)
 - ▶ **Regression**: real-valued output (predicting market prices, customer rating)
- **Unsupervised learning**
 - ▶ Create an internal representation of the input, capturing regularities/structure in data
 - ▶ Examples: form clusters; extract features
 - ▶ How do we know if a representation is good?
- **Reinforcement learning**
 - ▶ Learn action to maximize payoff
 - ▶ Not much information in a payoff signal
 - ▶ Payoff is often delayed

Least-Squares Regression



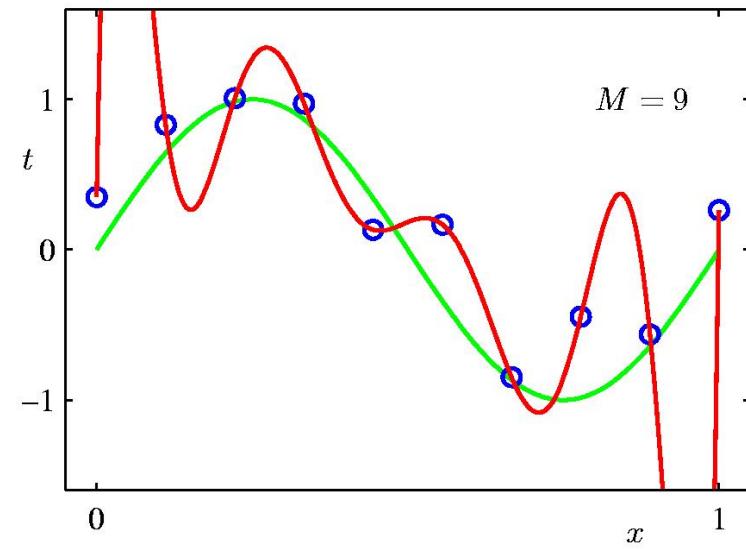
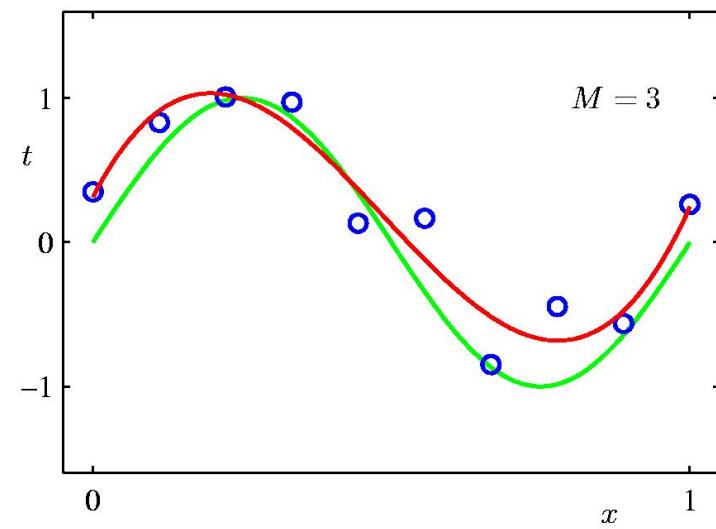
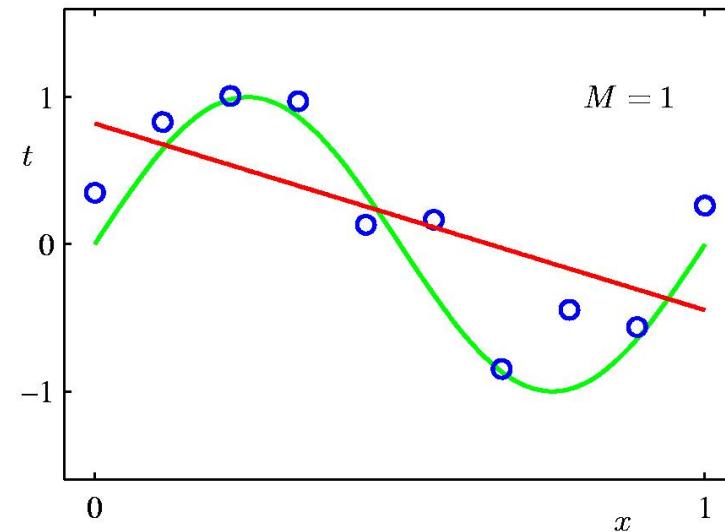
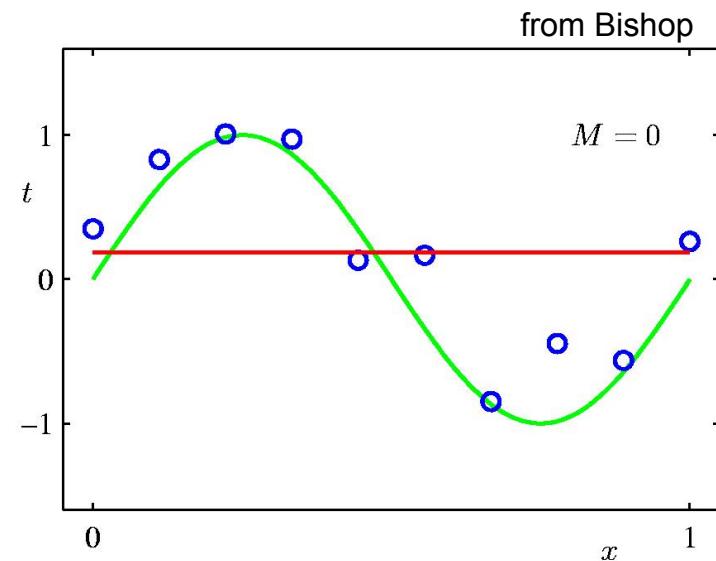
- Define a model

$$y(x) = \text{function}(x, \mathbf{w})$$

Linear:

$$y(x) = w_0 + w_1 x$$

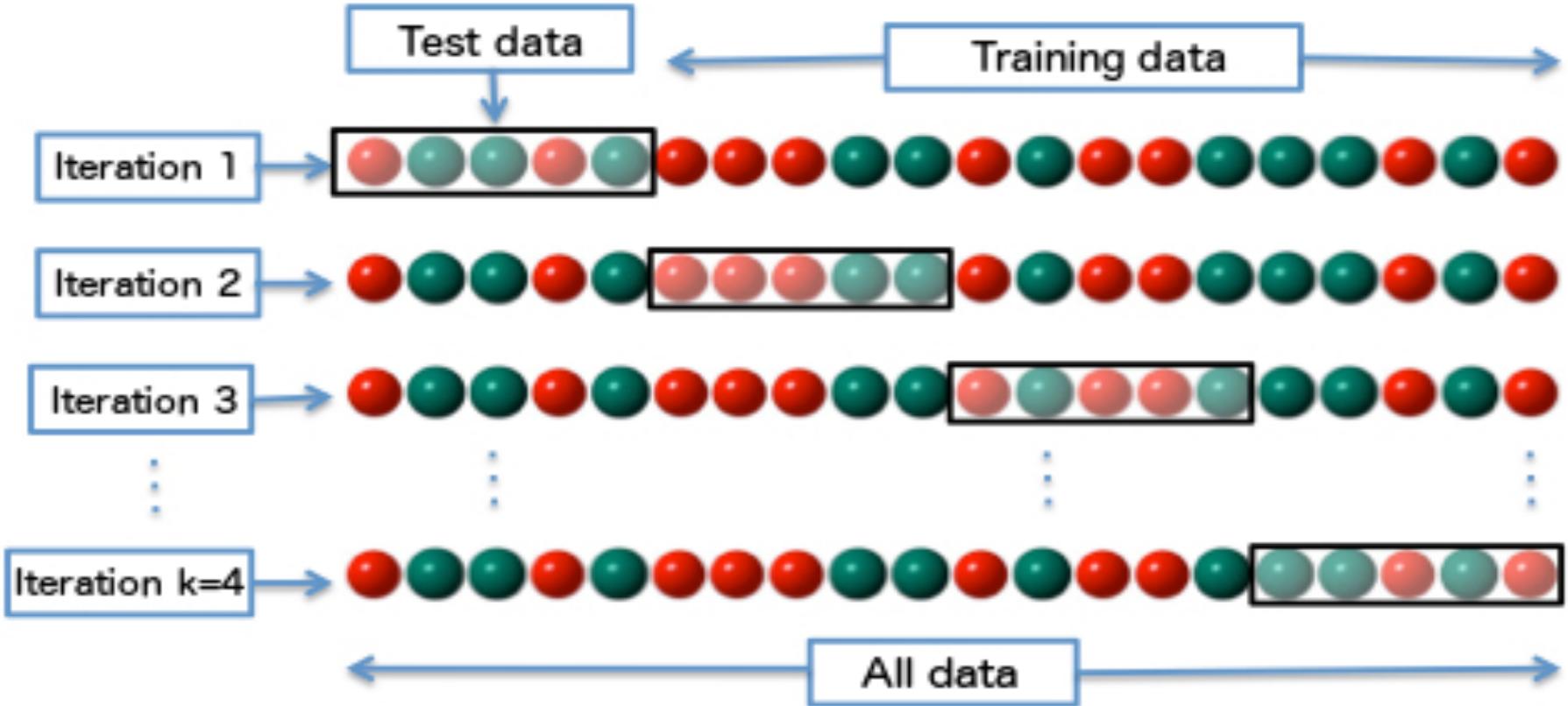
Which Fit is Best?



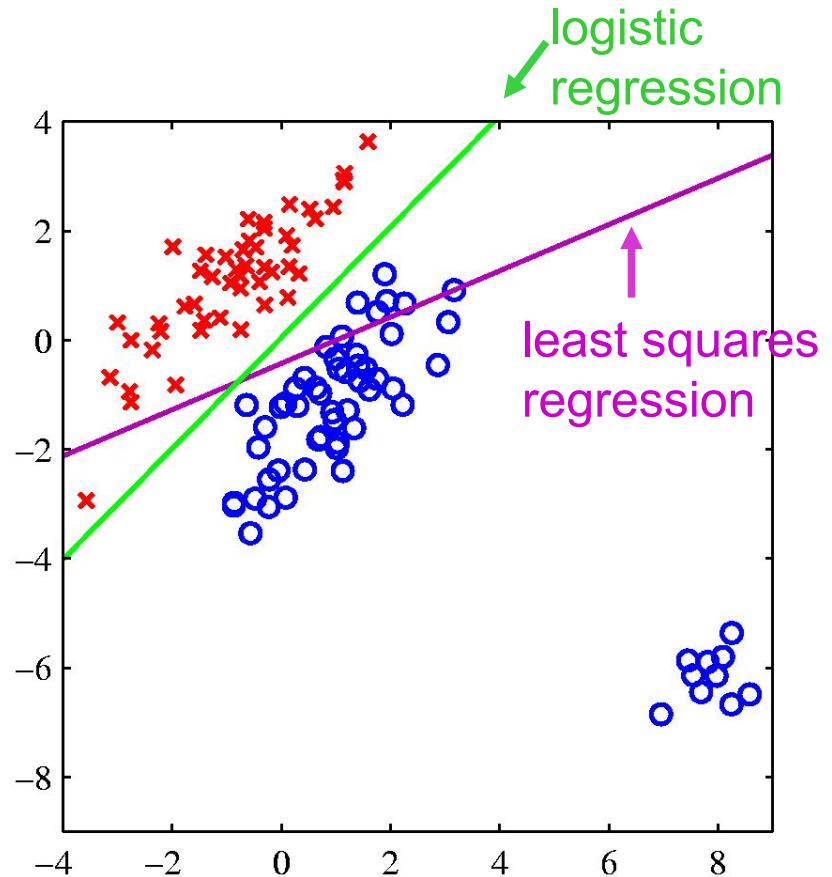
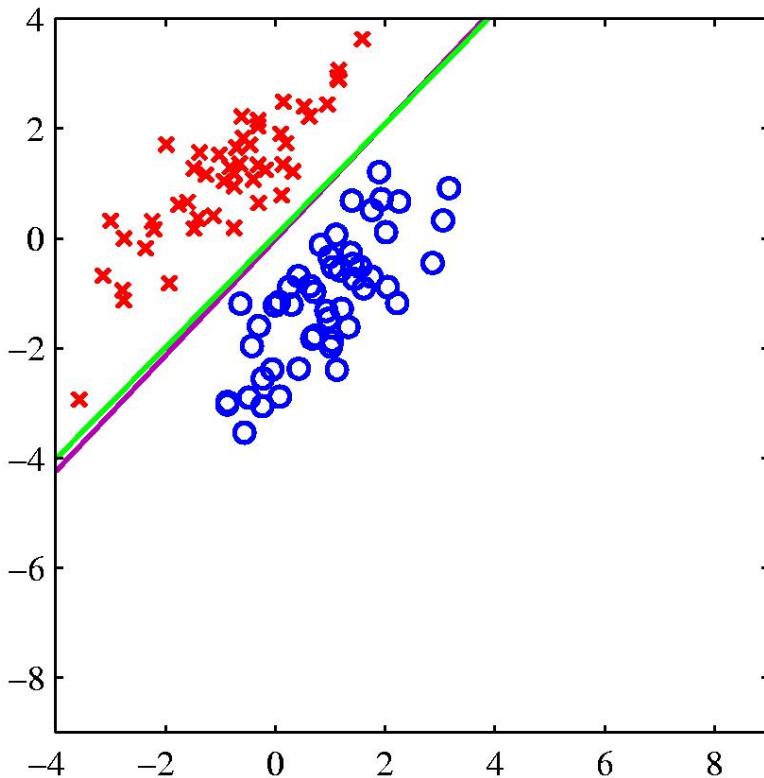
Cross-Validation (with Pictures)

Train your model:

- Leave-one-out cross-validation:
- k-fold cross-validation:



Logistic Regression vs Least Squares Regression



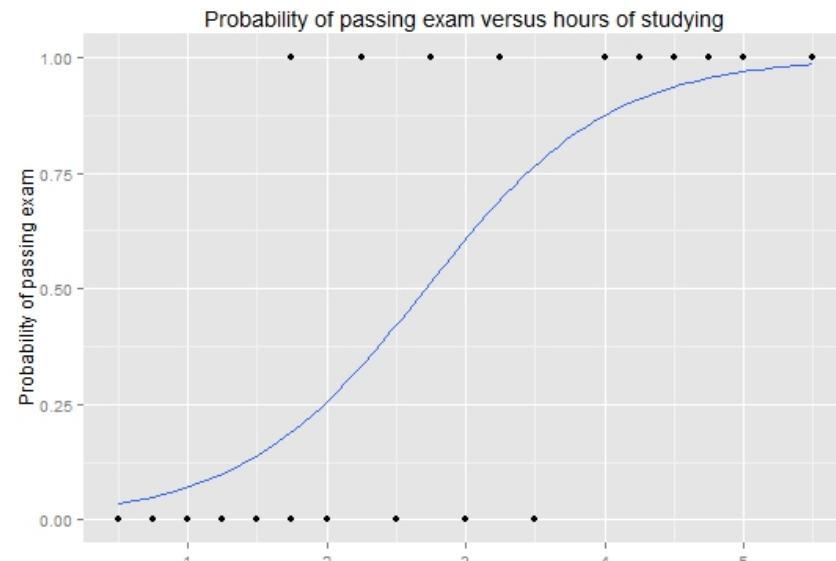
If the right answer is 1 and the model says 1.5, it loses, so it changes the boundary to avoid being “too correct” (tilts away from outliers)

Example

- **Problem:** Given the number of hours a student spent learning, will (s)he pass the exam?
- Training data (top row: $x^{(i)}$, bottom row: $t^{(i)}$)

Hours	0.50	0.75	1.00	1.25	1.50	1.75	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	4.00	4.25	4.50	4.75	5.00	5.50
Pass	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	1	1	1	1	

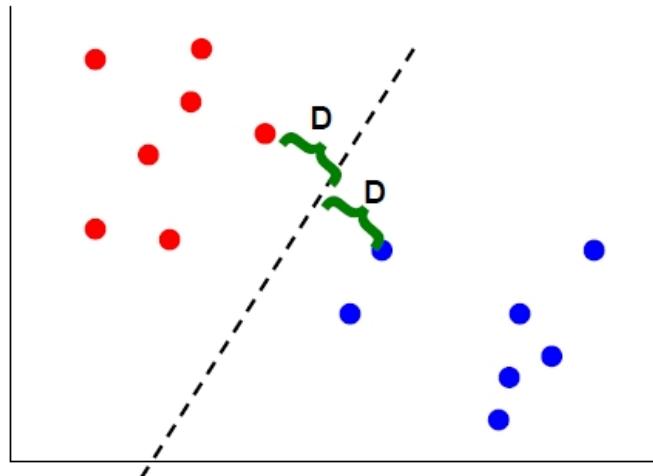
- Learn w for our model, i.e., logistic regression (coming up)
- Make predictions:



Hours of study	Probability of passing exam
1	0.07
2	0.26
3	0.61
4	0.87
5	0.97

Max Margin Classification

- Instead of fitting all the points, focus on the boundary points
- Aim: learn a boundary that leads to the largest **margin** (buffer) from points on both sides



- Why: intuition; theoretical support; and works well in practice
- Subset of vectors that support (determine boundary) are called the **support vectors**

Metrics

How to evaluate how good my classifier is? How is it doing on dog vs no-dog?



— TP (True Positive)

— FP (False Positive)

— FN (False Negative)

PCA: Common Tool

- Handles high-dimensional data
 - ▶ If data has thousands of dimensions, can be difficult for a classifier to deal with
- Often can be described by much lower dimensional representation
- Useful for:
 - ▶ Visualization
 - ▶ Preprocessing
 - ▶ Modeling – prior for new data
 - ▶ Compression

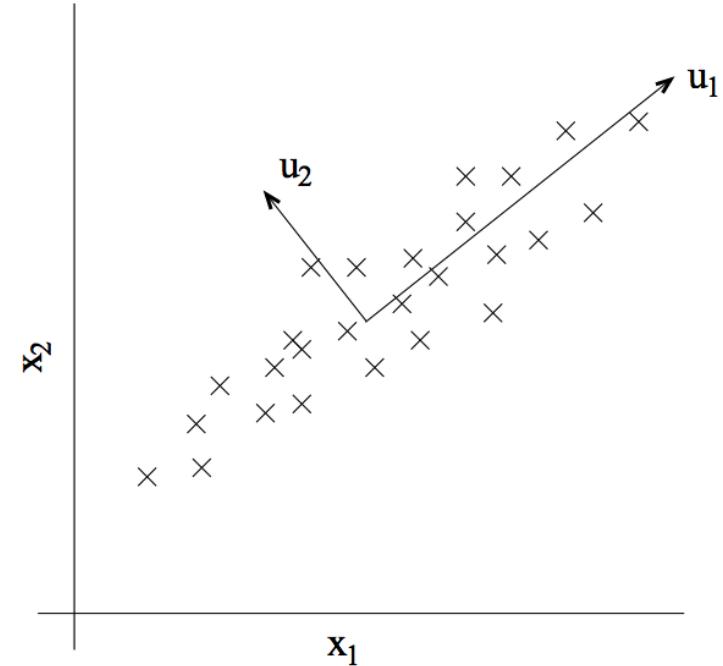
PCA: Intuition

- As in the previous lecture, training data has N vectors, $\{\mathbf{x}_n\}_{n=1}^N$, of dimensionality D , so $\mathbf{x}_i \in \mathbb{R}^D$
- Aim to reduce dimensionality:
 - linearly project to a much lower dimensional space, $M \ll D$:

$$\mathbf{x} \approx U\mathbf{z} + \mathbf{a}$$

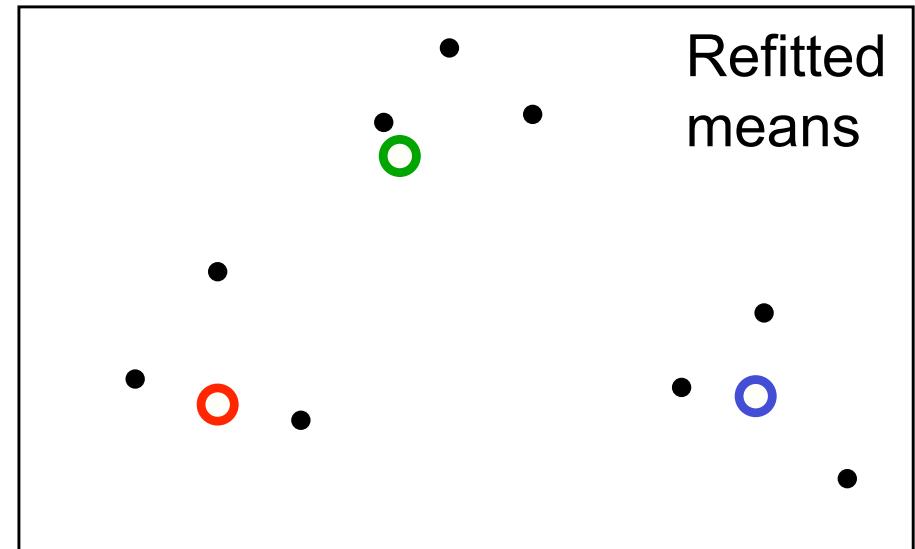
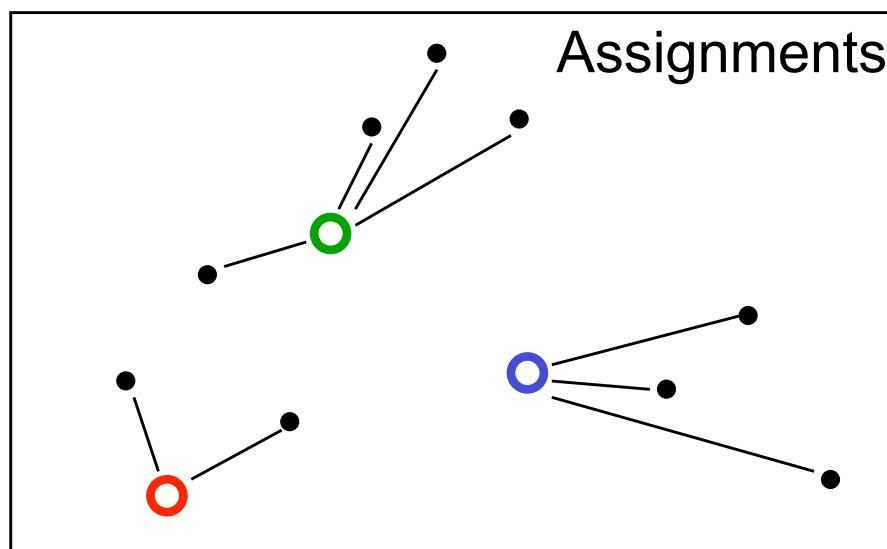
where U is a $D \times M$ matrix and \mathbf{z} a M -dimensional vector

- Search for orthogonal directions in space with the highest variance
 - project data onto this subspace
- Structure of data vectors is encoded in sample covariance



K-means

- **Initialization:** randomly initialize cluster centers
- The algorithm iteratively alternates between two steps:
 - ▶ **Assignment step:** Assign each data point to the closest cluster
 - ▶ **Refitting step:** Move each cluster center to the center of gravity of the data assigned to it



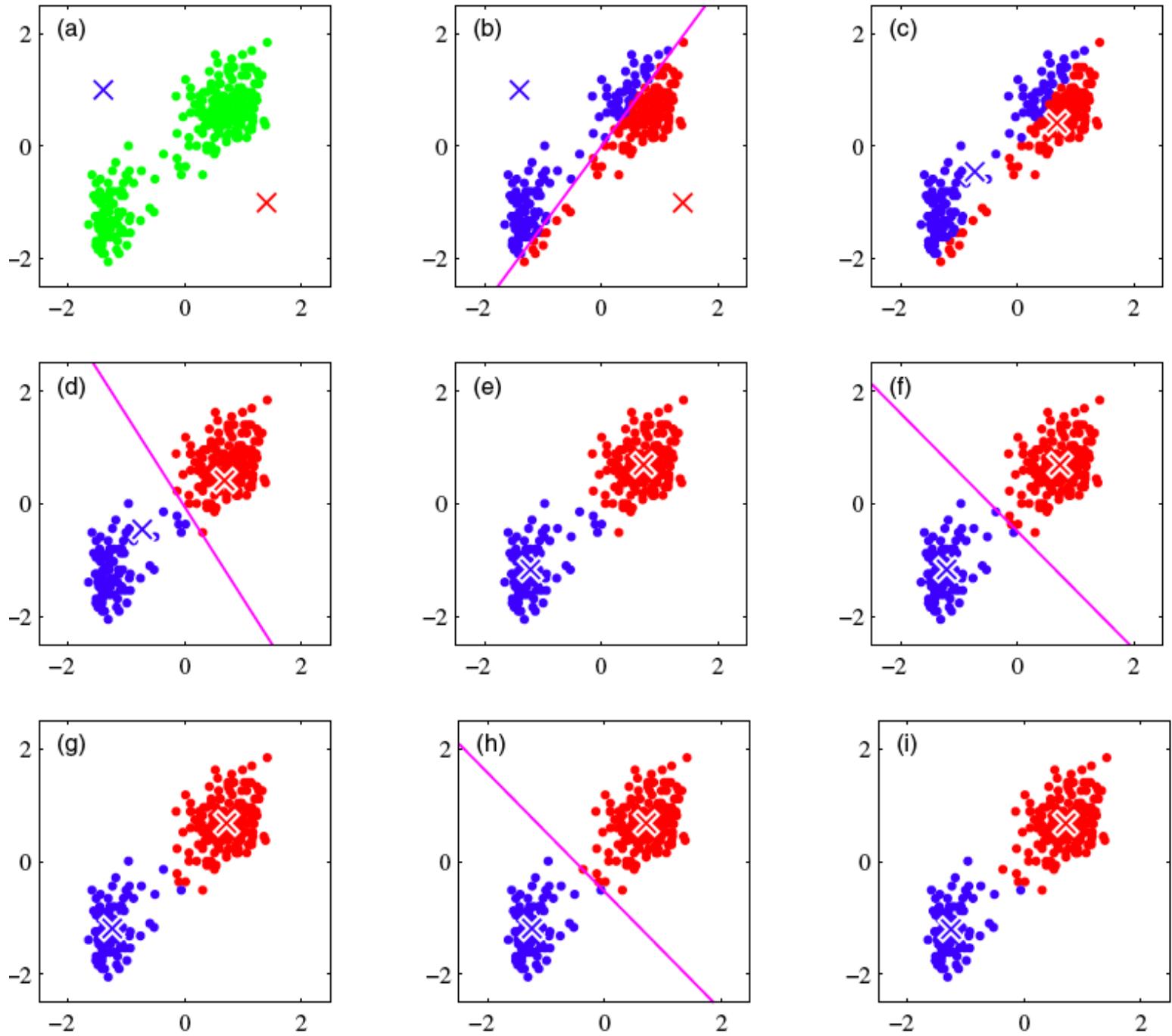
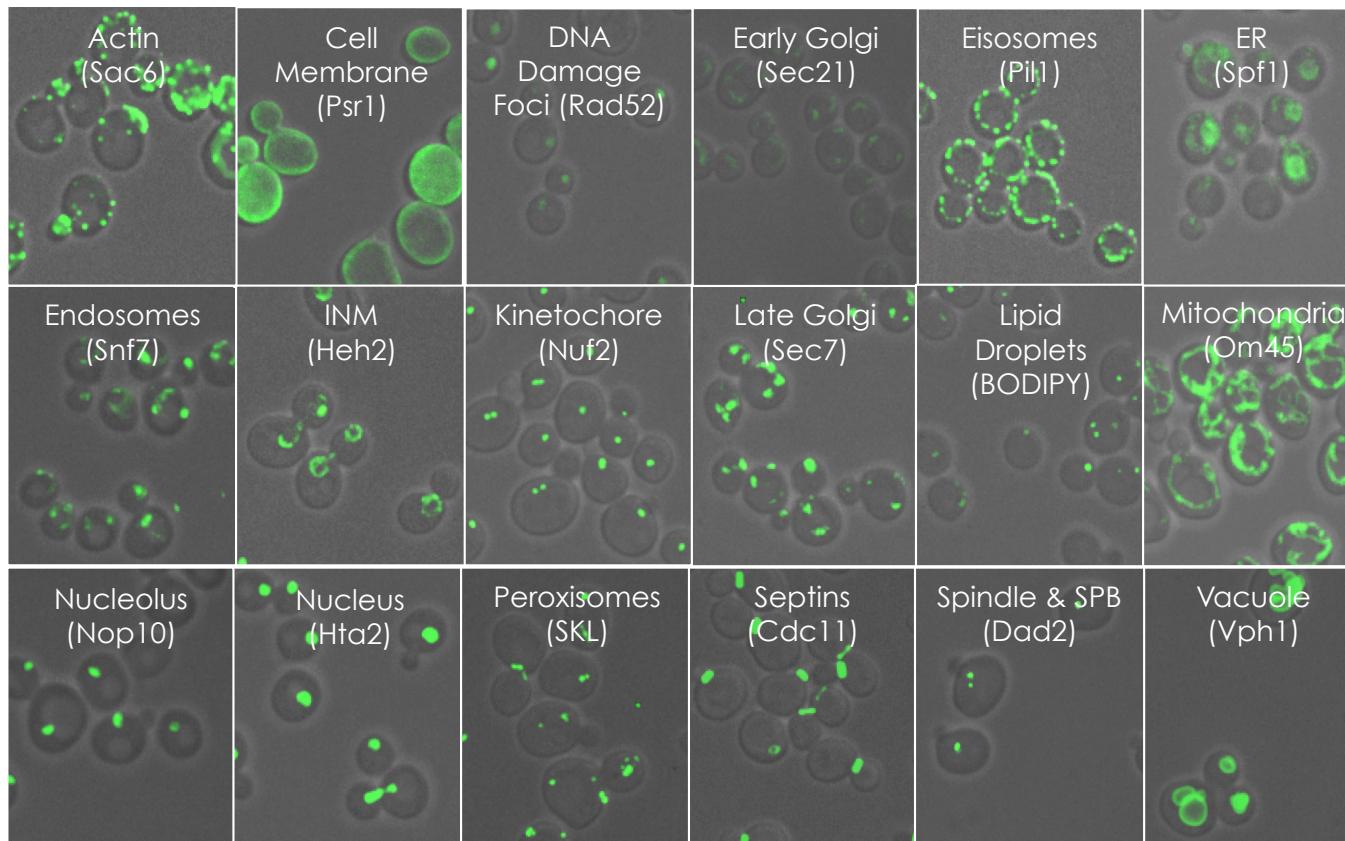


Figure from Bishop

Simple demo: <http://syskall.com/kmeans.js/>

Understanding gene function using ML in yeast

~6000 gene deletions



Organelle morphologies can change with gene deletions

