COMP 1433: Introduction to Data Analytics &
COMP 1003: Statistical Tools and Applications

Lecture 11 – Machine Learning: An Introduction

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Roadmap

- Artificial Intelligence (*AI*) vs. Machine Learning (*ML*)
- Machine Learning Taxonomy
  - Supervised Learning, Unsupervised Learning, and Reinforcement Learning
- Important AI Areas based on ML methods:
  - Computer Vision (*See*)
  - Speech Processing (*Listen and Speak*)
  - Natural Language Processing (*Read and Write*)
- More ML applications

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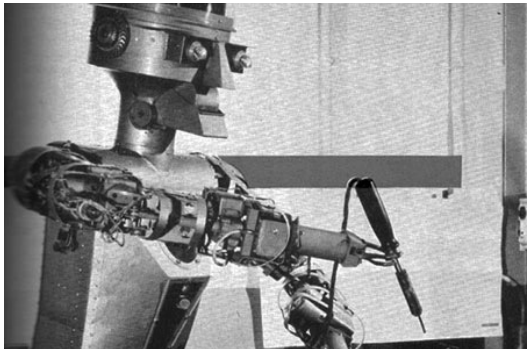
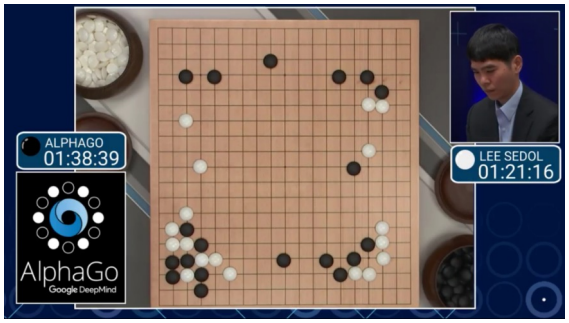
What is Artificial Intelligence (AI)?

1950s-1990s



2000s-2010s



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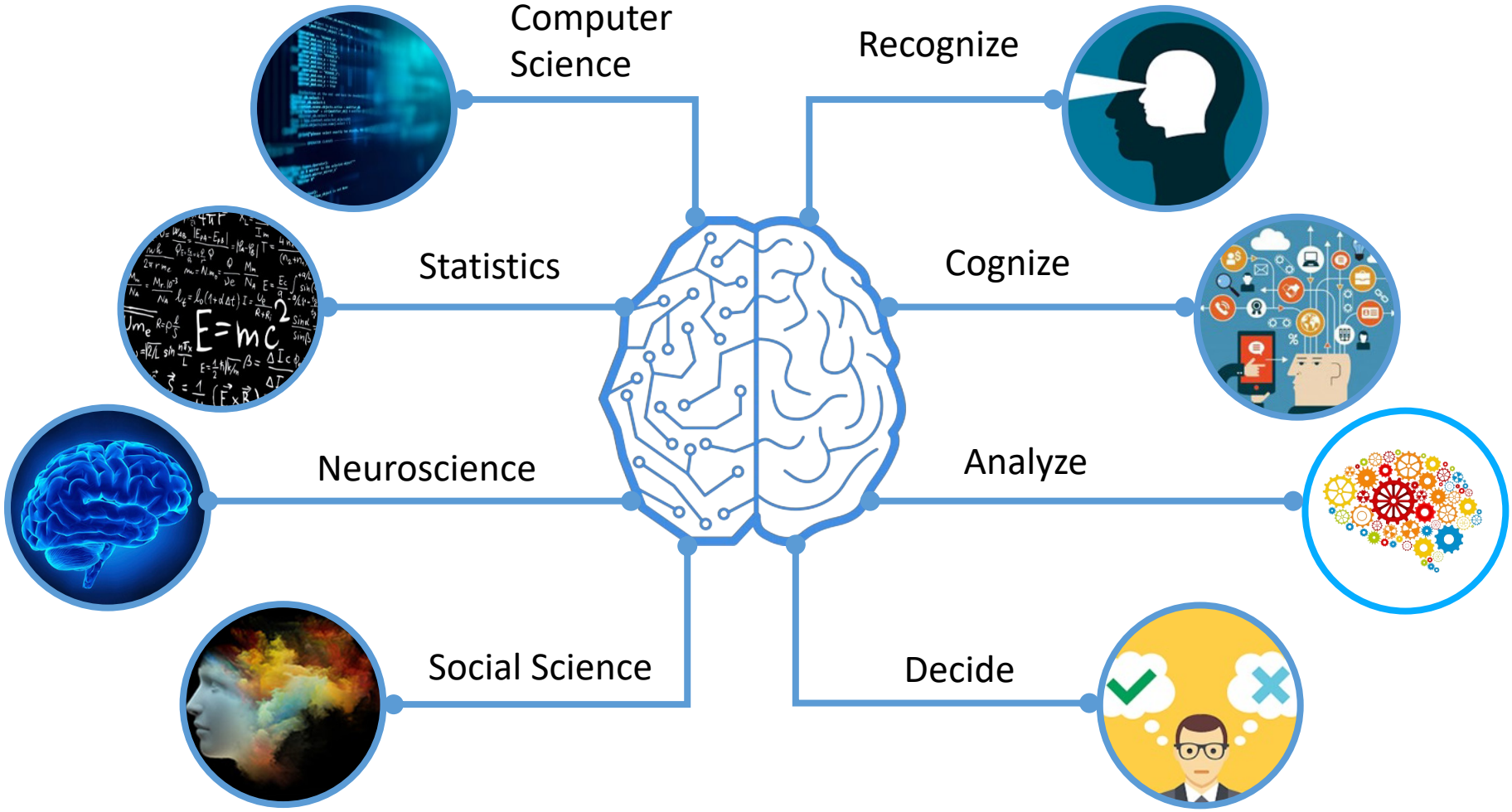
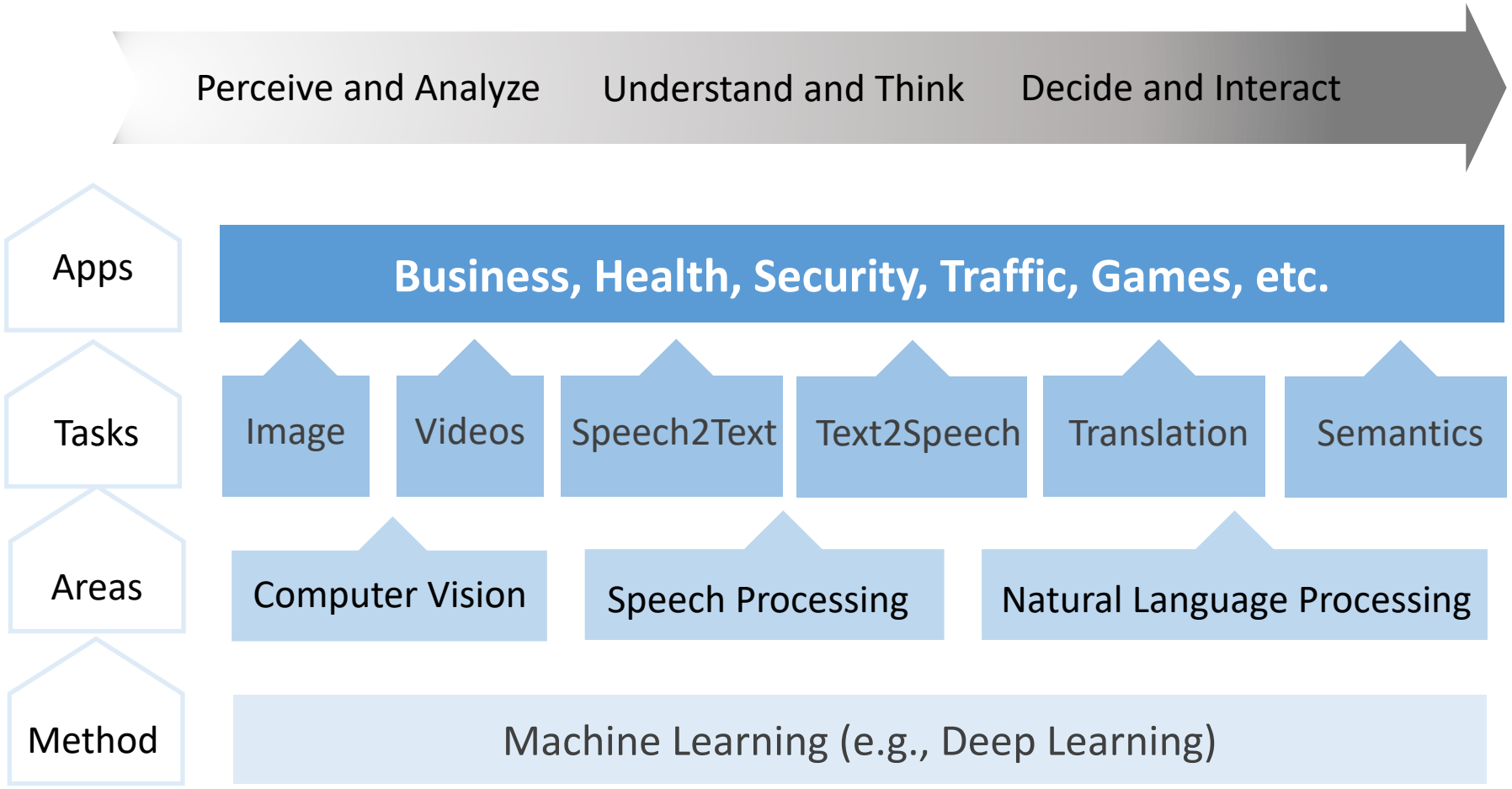
Multidisciplinary in AI

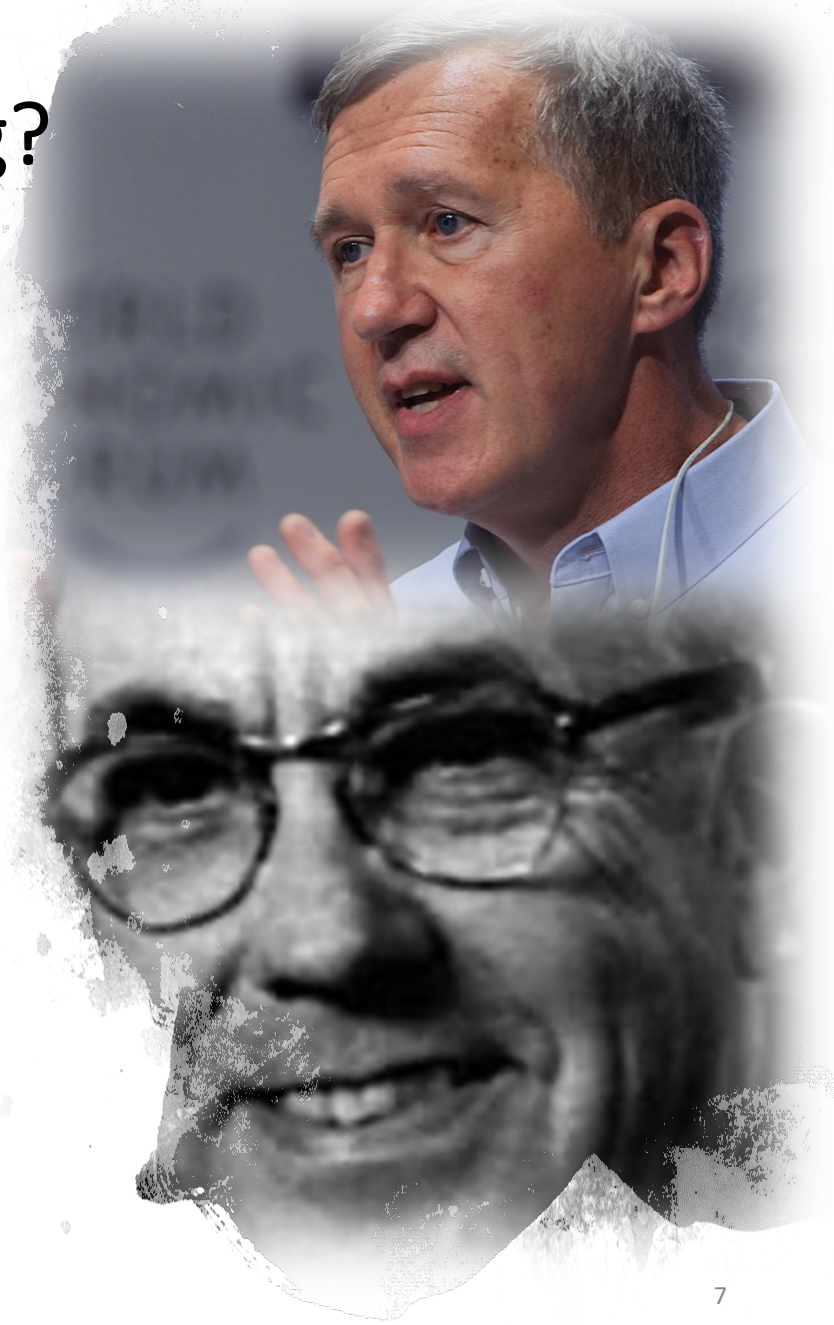


Varying Tasks in AI

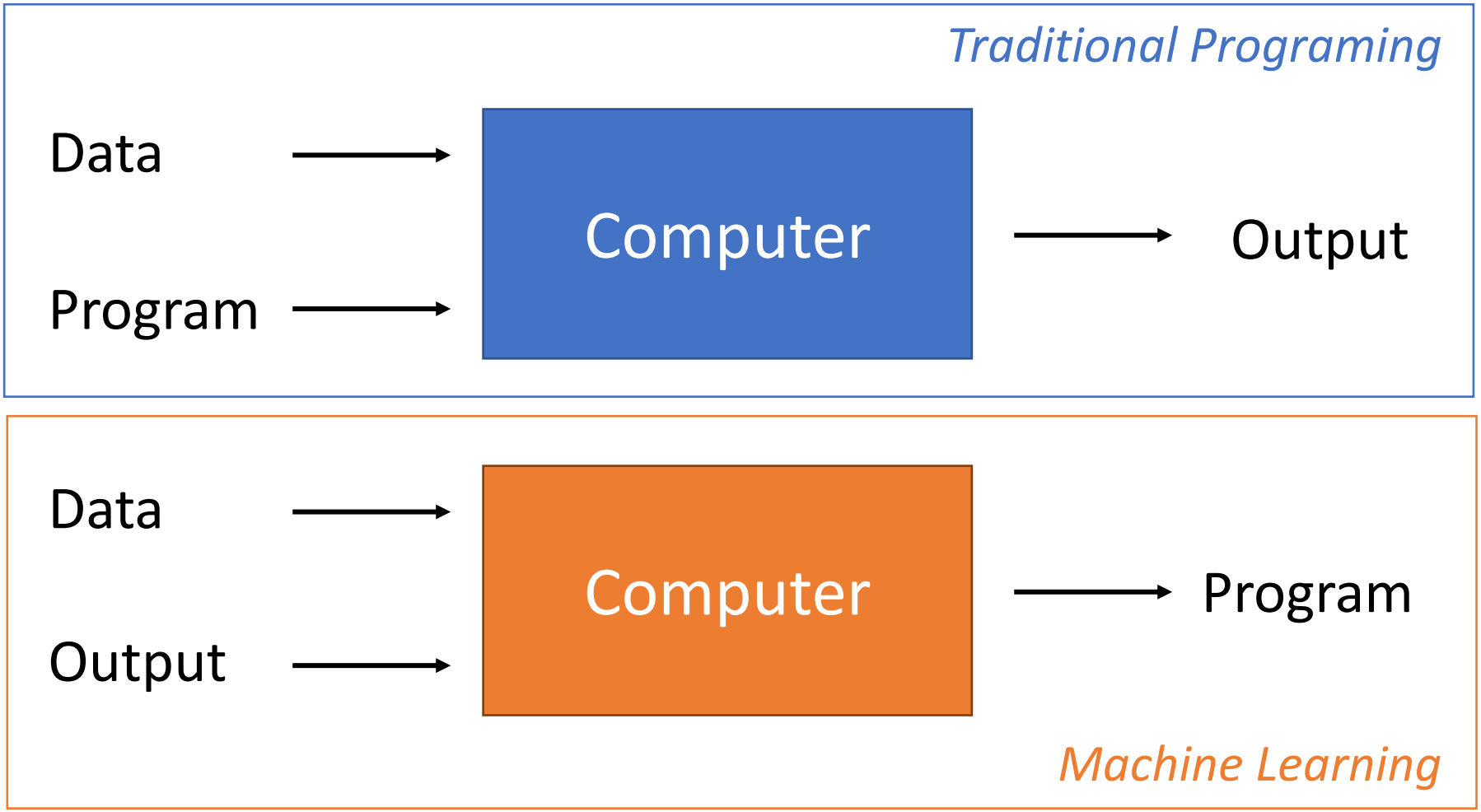


What is Machine Learning?

- Machine Learning is the field of study that gives the computer *the ability to learn without being explicitly programmed*. --- By *Arthur Samuel* (1959):
- Definition by *Tom Mitchell* in 1998:
  - Machine Learning is the study of algorithms that
    - Improve their *performance* P
    - At some *task* T
    - With *experience* E
  - Hence a well-defined learning task is given by three elements $\langle P, T, E \rangle$.

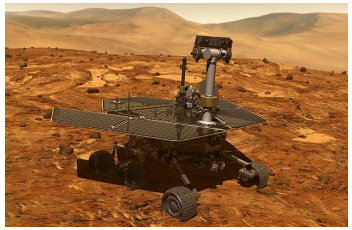


Machine Learning Process



When machine learning is helpful?

- We let machine to learn when:
  - Human expertise does not exist, e.g., navigate on Mars.
  - Human cannot explain their expertise, e.g., speech recognition.
  - Models must be customized, e.g., personalized recommendation.
  - Something needs to be learned from huge volume of data, e.g., social media fake news detection.



- Machine learning may sometimes not help:
  - There is no need to “learn” to calculate the scores.

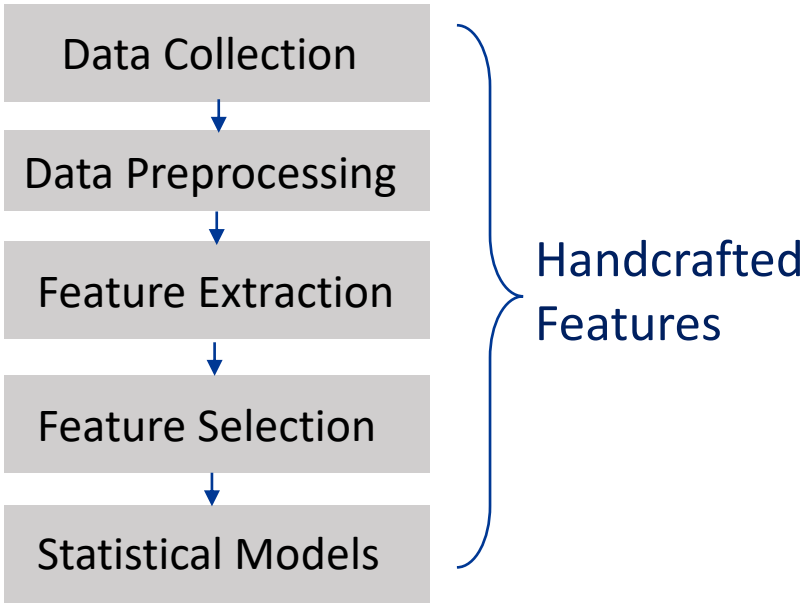
Example task with machine learning

Hard to say what makes a hand-written 2.

Figure created by *Geoffrey Hinton*

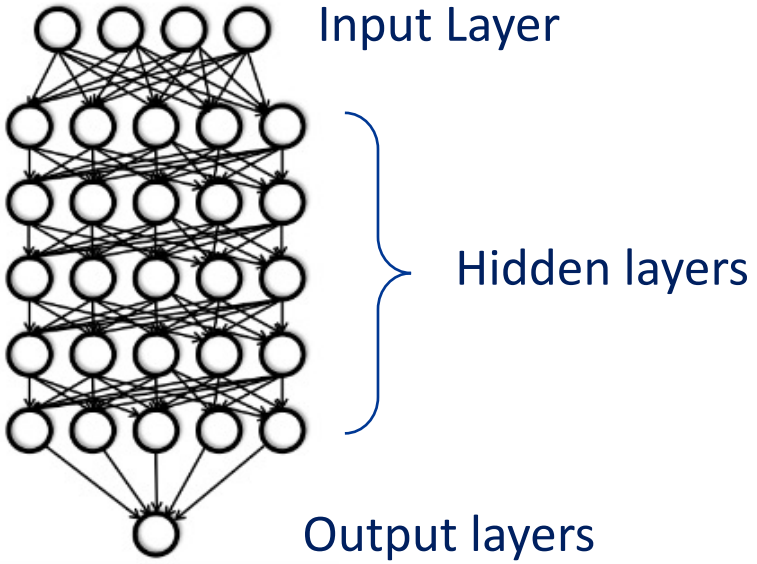
How to learn?

- **Machine Learning**: Allows machine to learn new things from the data.
- **Deep Learning**: More complex model to fit large-scale data.



Classical Machine Learning

Feature Extraction to Fit Data



A multi-layer perceptron model

Deep Learning

Automatic Feature Learning

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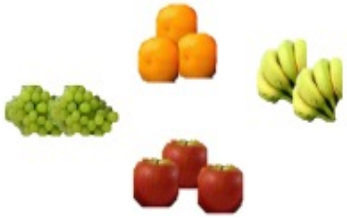
Taxonomy of Machine Learning Methods

Supervision

Unsupervised Learning

Unlabeled Data

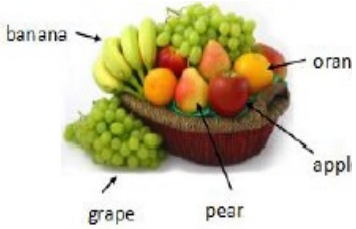
Clusters



Topic Discovery

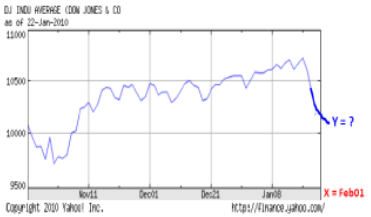
Supervised Learning

Labeled Data



Predict Labels

Price Prediction

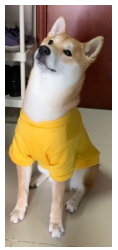


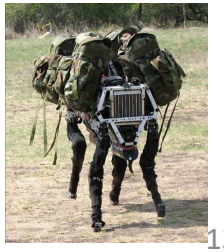
Reinforcement Learning

Rewards

Good Actions

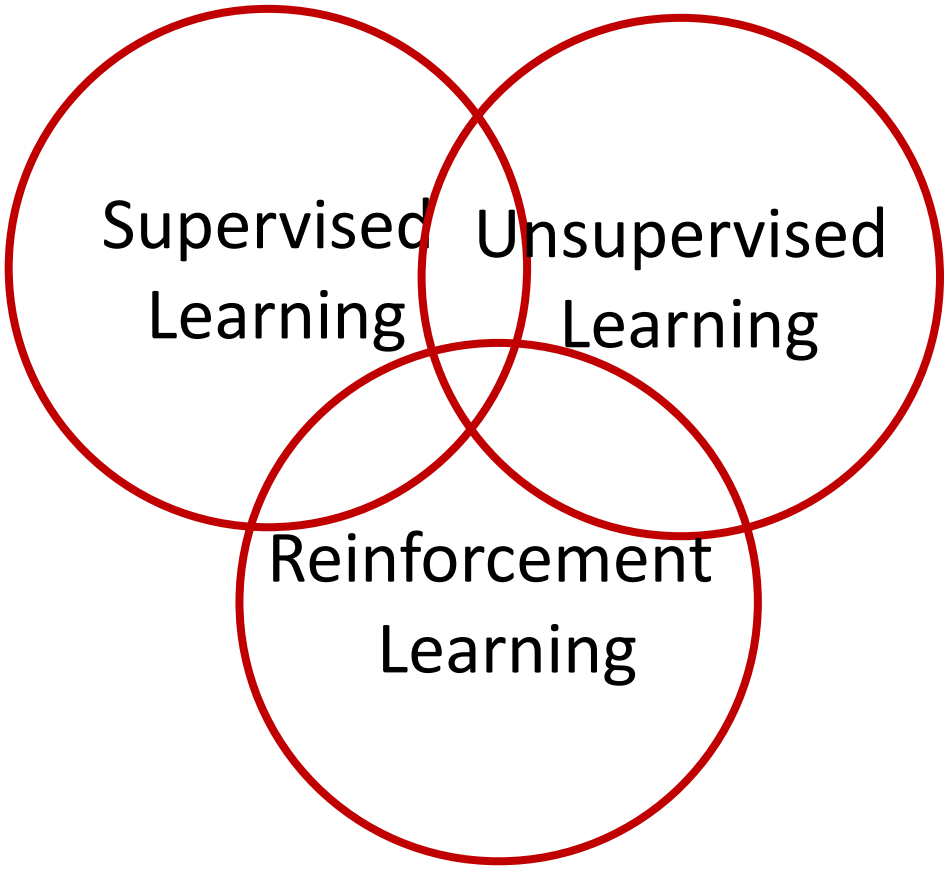
Dog Training





Taxonomy of Machine Learning Methods

A simplified view based on tasks



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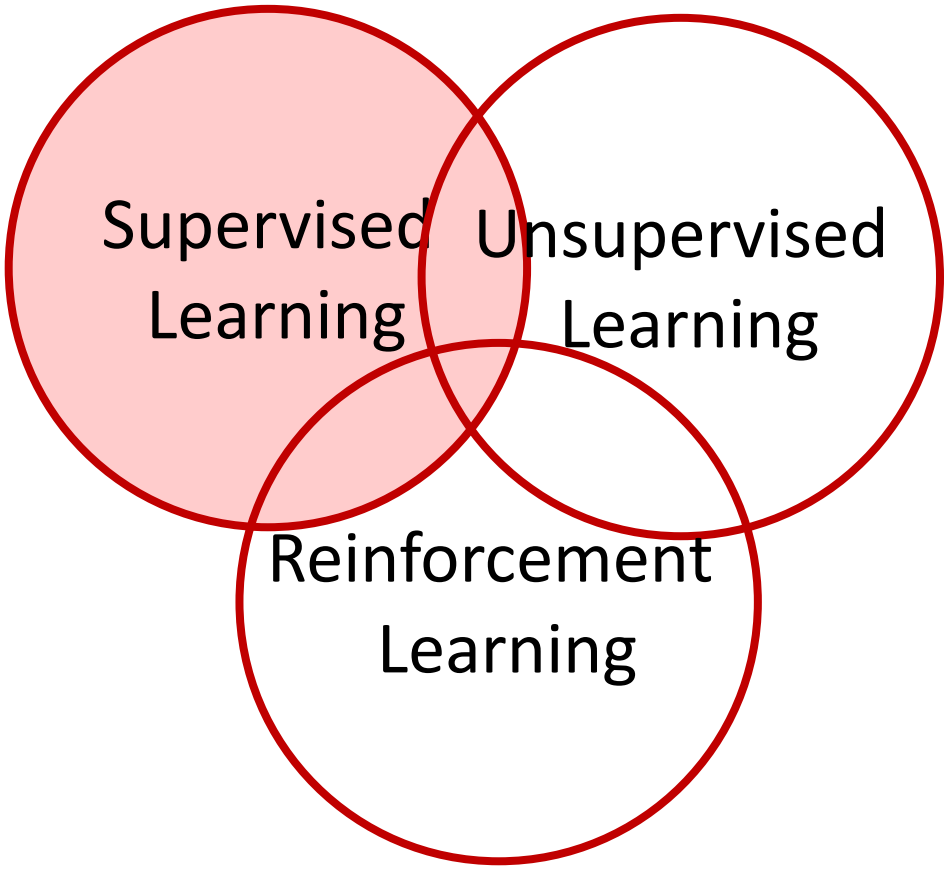
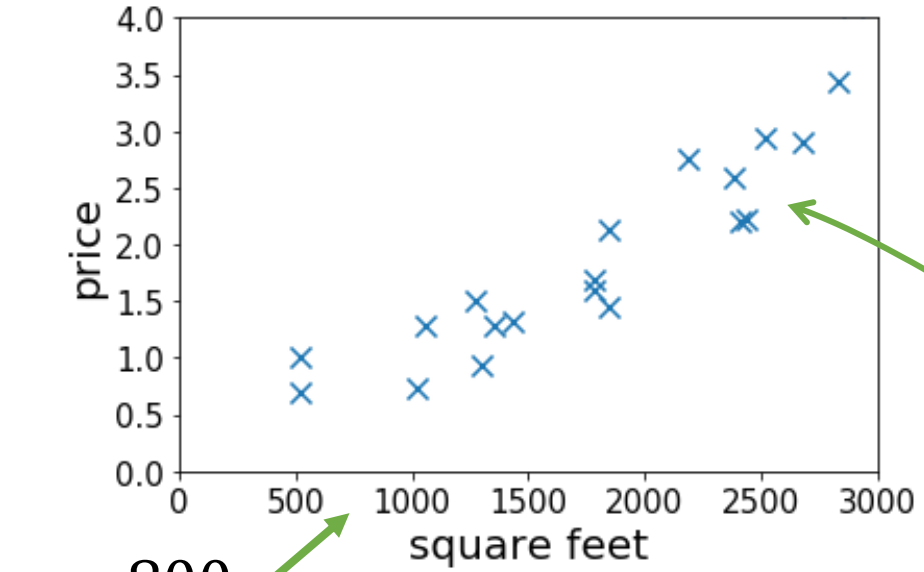


Supervised Learning (Regression)

- Given: a dataset that contains n samples

$$\left(x^{(1)}, y^{(1)}\right), \ldots \left(x^{(n)}, y^{(n)}\right)$$

- **House Price Prediction Task**: if a guy has a house with x square feet, how to predict its price?



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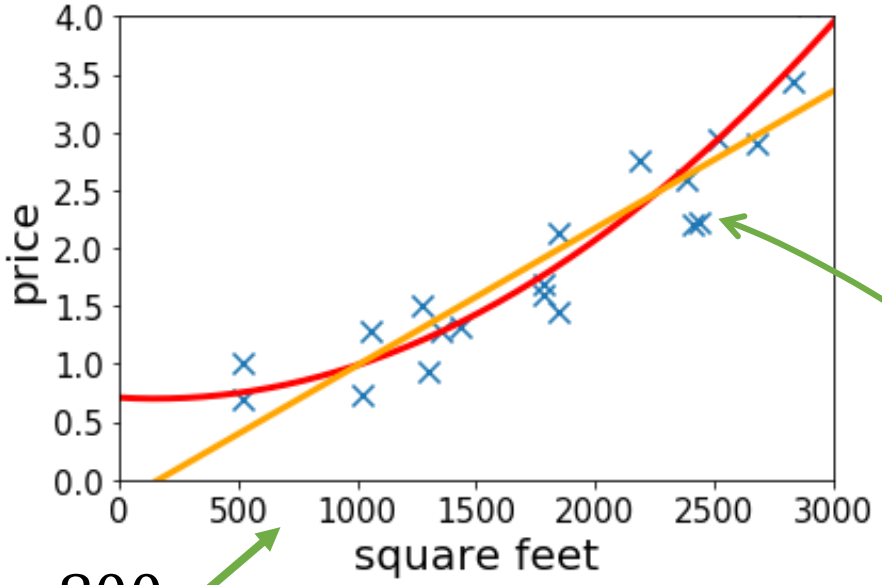
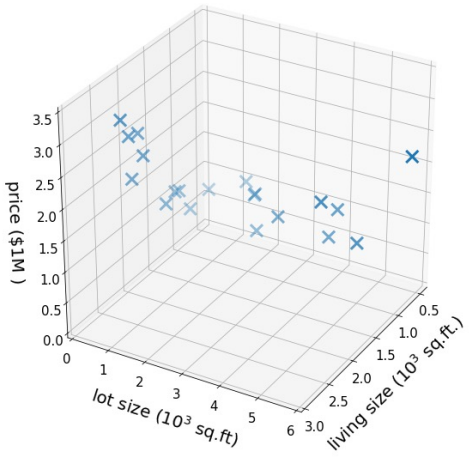


Supervised Learning (More Features)

- Suppose we also know the lot size
- **Task**: find a function that maps
  - (size, lot size) → price

features/input $x \in R^2$

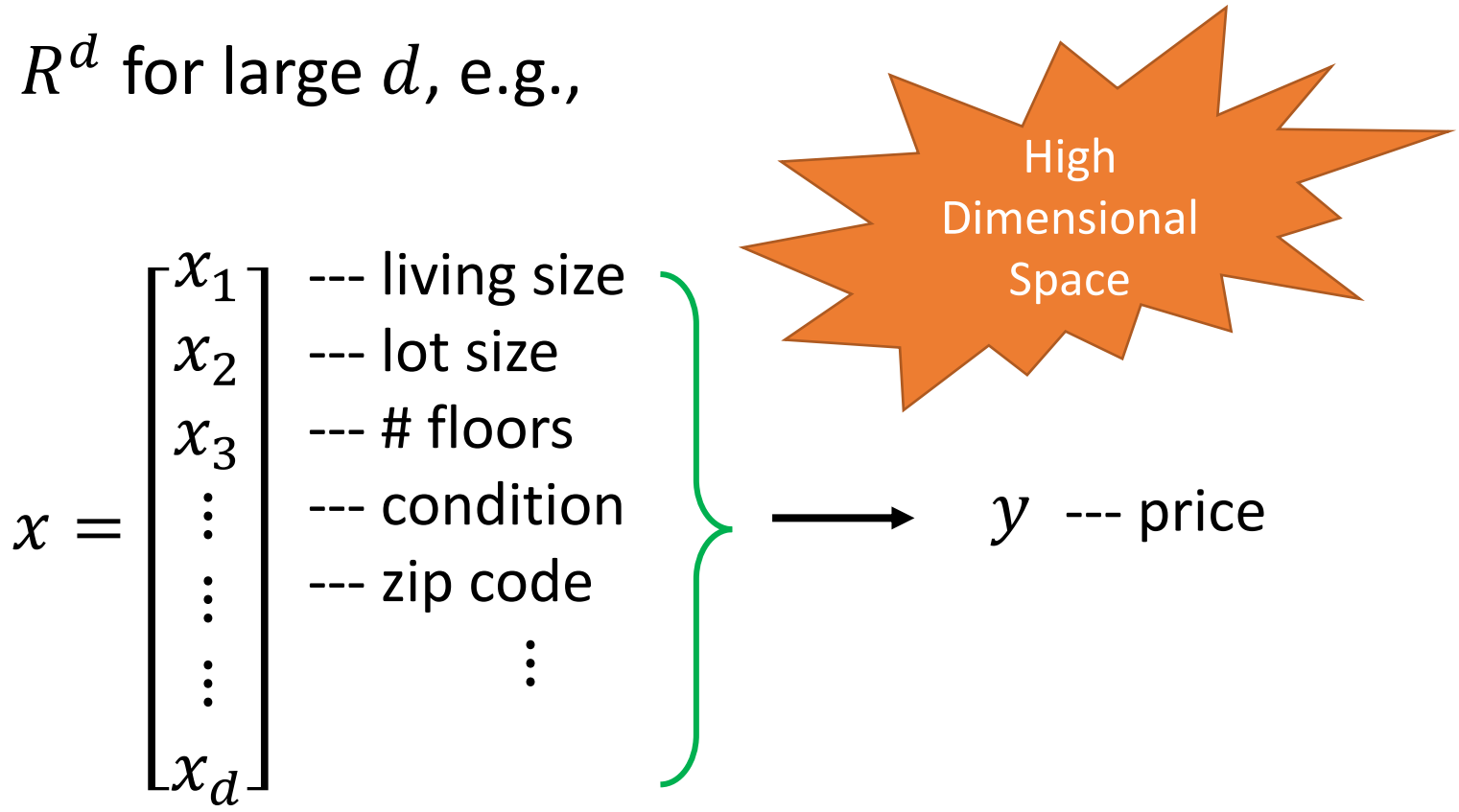
label/output $y \in R$



- **Dataset**: $\left(x^{(1)}, y^{(1)}\right), \ldots, \left(x^{(n)}, y^{(n)}\right)$ where the feature $x^{(i)} = (x_1^{(i)}, x_2^{(i)})$
- "***Supervision***" refers to the labels $y^{(1)}, \ldots, y^{(n)}$

Supervised Learning (A lot of features)

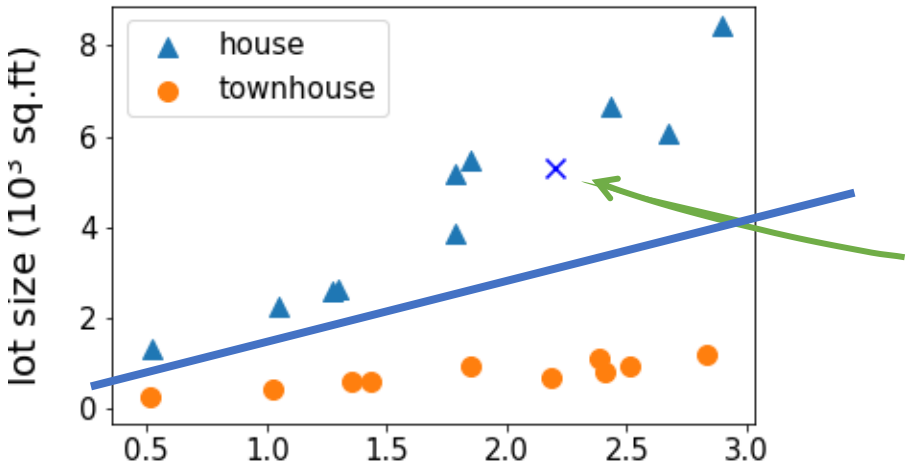
- $x \in R^d$ for large d, e.g.,



Regression vs. Classification

- ***Regression***: if $y \in R$ is a *continuous* variable
  - e.g., price prediction
- ***Classification***: the label is a *discrete* variable
  - e.g., predicting the types of residence

    (size, lot size) → house or townhouse?



y = house or townhouse?

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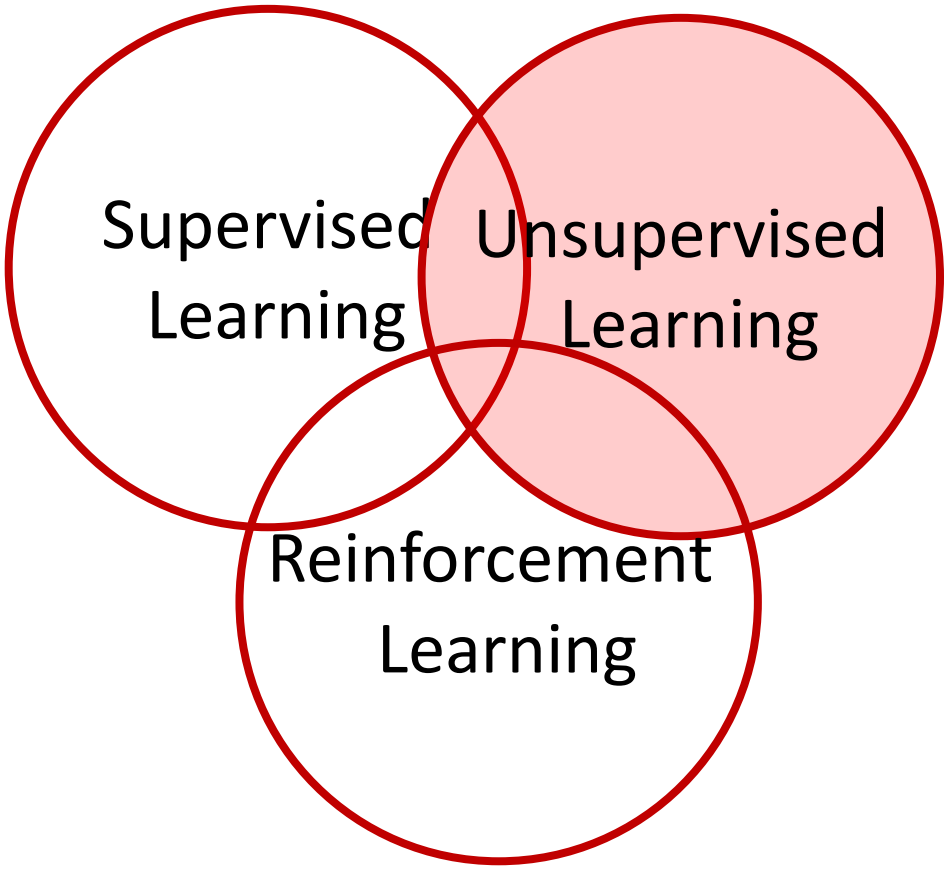
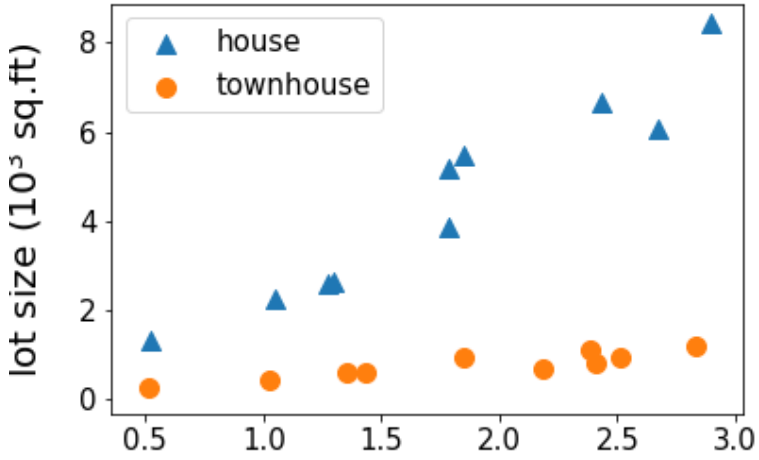
A simplified view based on tasks



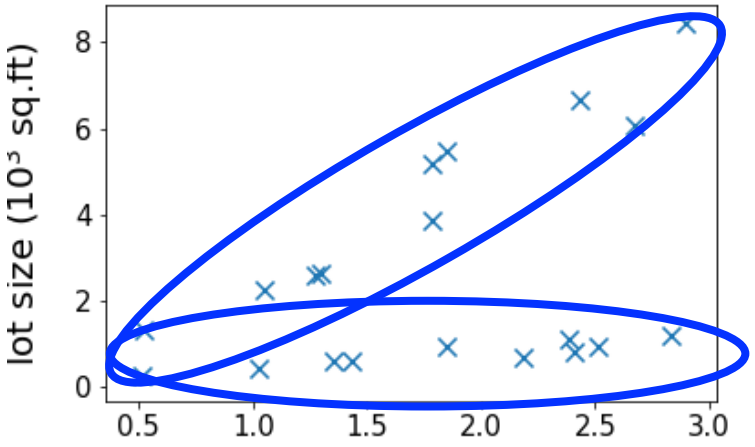
Unsupervised Learning

- Dataset contains *no labels*: $x^{(1)}, \ldots x^{(n)}$
- **Goal:** to find interesting structures or patterns from the data

Supervised Learning



Unsupervised Learning



Cluster Wikipedia articles by K-means

Cluster 1		Cluster 2		Cluster 3	
Word	Coef.	Word	Coef.	Word	Coef.
fight	0.038	holiday	0.012	united	0.004
win	0.022	celebrate	0.009	family	0.003
event	0.019	festival	0.007	party	0.003
champion	0.015	celebration	0.007	president	0.003
fighter	0.015	calendar	0.006	government	0.003

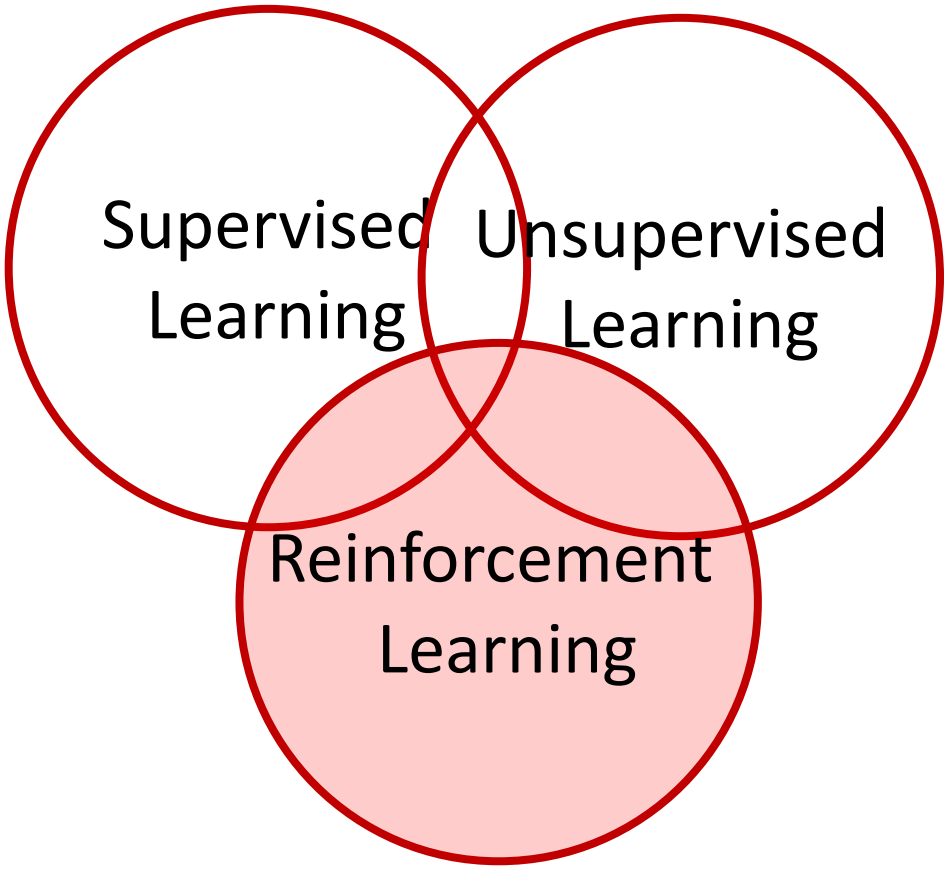




1. “Floyd Mayweather, Jr”, “Kimbo Slice”, “Ronda Rousey”, “José Aldo”, “Joe Frazier”, “Wladimir Klitschko”, “Saul Álvarez”, “Gennady Golovkin”, “Nate Diaz”, . . .
2. “Halloween”, “Guy Fawkes Night” “Diwali”, “Hanukkah”, “Groundhog Day”, “Rosh Hashanah”, “Yom Kippur”, “Seventh-day Adventist Church”, “Remembrance Day”, . . .
3. “Mahatma Gandhi”, “Sigmund Freud”, “Carly Fiorina”, “Frederick Douglass”, “Marco Rubio”, “Christopher Columbus”, “Fidel Castro”, “Jim Webb”, . . .

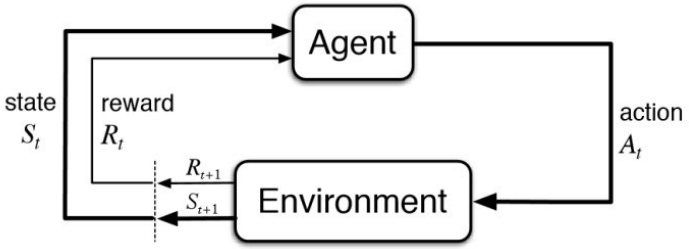
Taxonomy of Machine Learning Methods

A simplified view based on tasks

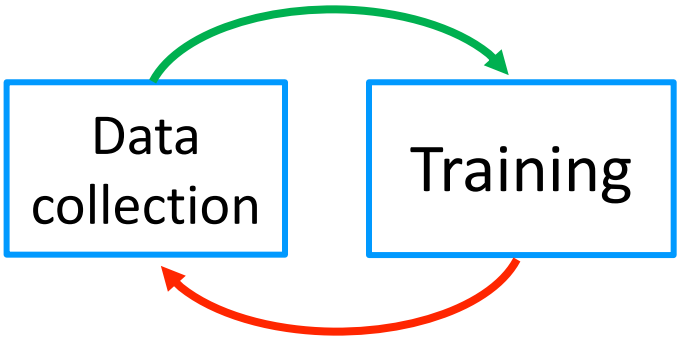


Reinforcement Learning

- Agent and environment interact at discrete time steps: $t = 1,2,3, \ldots, T$. At step t, the agent
  - Observes state (environment)
  - Produces actions
  - Gets resulting reward
  - And produces the next state



Try the policy and collect feedbacks



Improve the policy based on the feedbacks (rewards)

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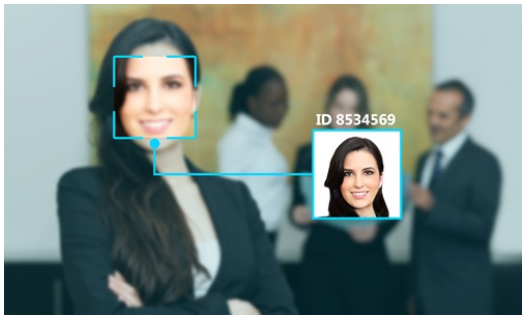
See: Computer Vision (CV)

Image Recognition



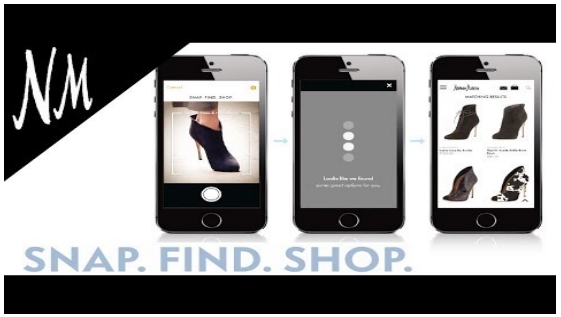


Image Classification

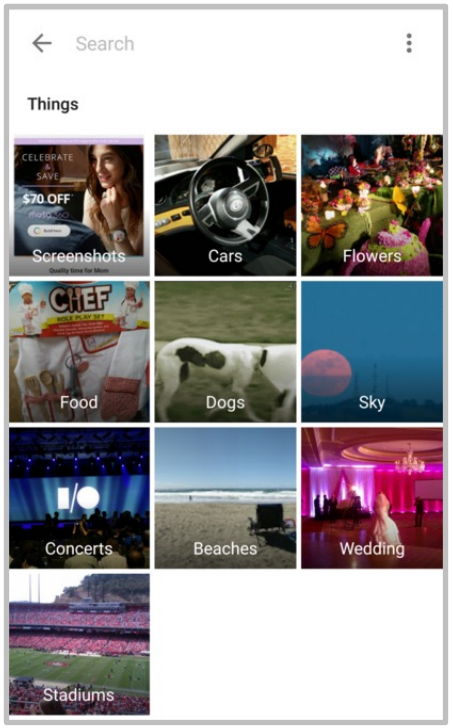


Image Understanding

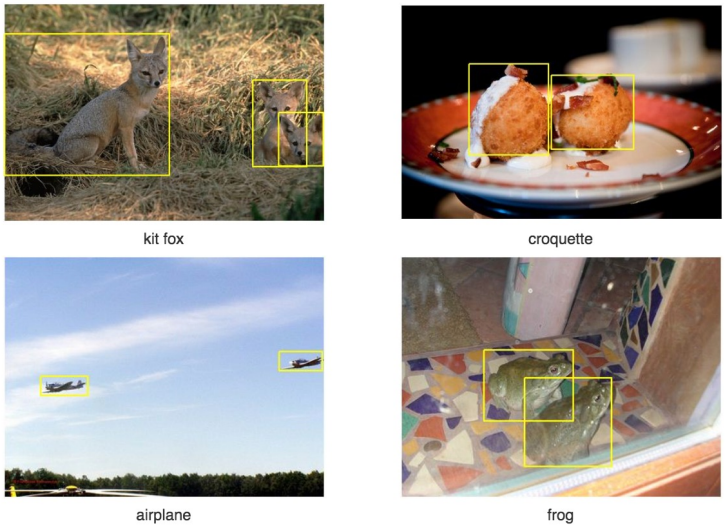
"two young girls are playing with lego toy."

Supervised Learning (Computer Vision)

- Image Classification
  - $x =$ *raw pixels of the image*
  - $y =$ *the main object*

ImageNet Large Scale Visual Recognition Challenge. Russakovsky et al.'2015

Supervised Learning (Computer Vision)



- Object localization and detection
  - $x =$ raw pixels of the image
  - $y =$ the bounding boxes

ImageNet Large Scale Visual Recognition Challenge. Russakovsky et al.'2015

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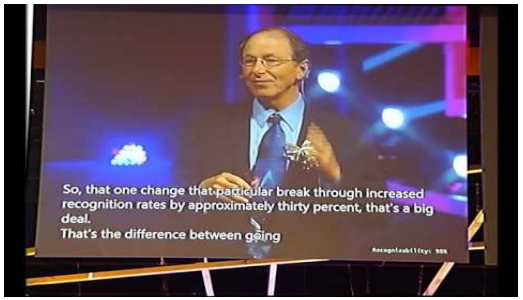
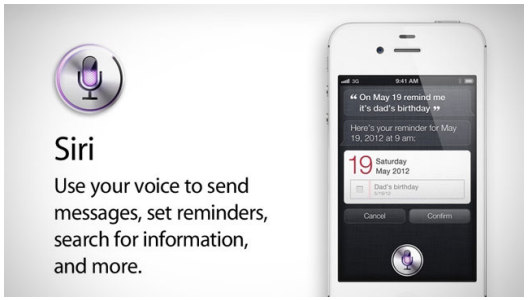
Listen and Speak: Speech Processing

Audio Speech Recognition (*Speech to Text*)



Voice Assistants

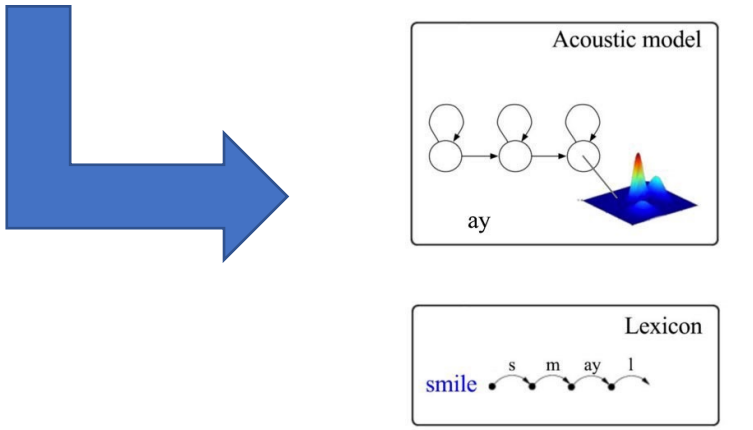


Text to Speech

Supervised Learning (Speech Processing)

Audio Speech Recognition

x: audio signals



By Jonathan Hui

$$\mathbf{W}^* = \arg\max_{\mathbf{W}} P(\mathbf{W} \mid \mathbf{X})$$

$$\mathbf{W}^* = \arg\max_{\mathbf{W}} \; p(\mathbf{X} \mid \mathbf{W}) \;\; P(\mathbf{W})$$

word sequence acoustic model language model

y: text signals (word sequence)

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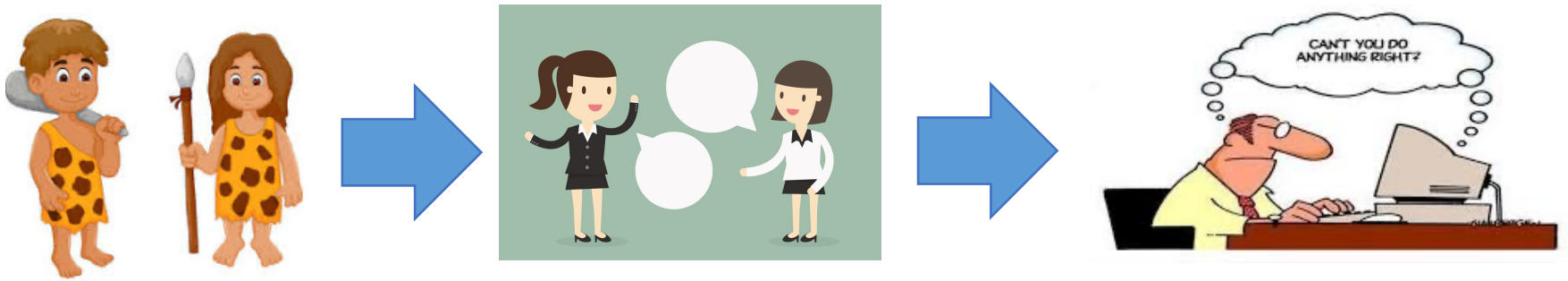
Read and Write: Natural Language Processing (NLP)



- Where natural language comes from?
- What is natural language processing?

Read and Write: Natural Language Processing (NLP)

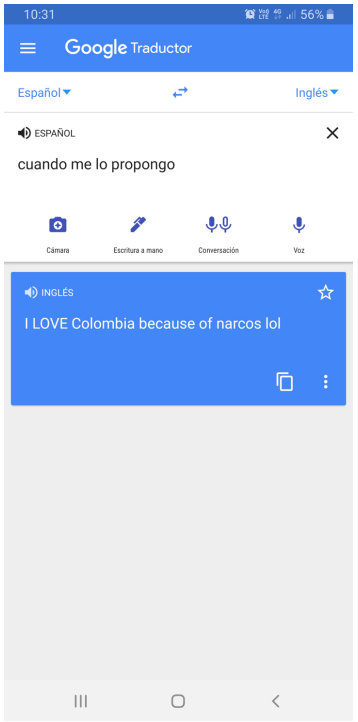
Natural Language Understanding:
How to read

Natural Language Generation:
How to write

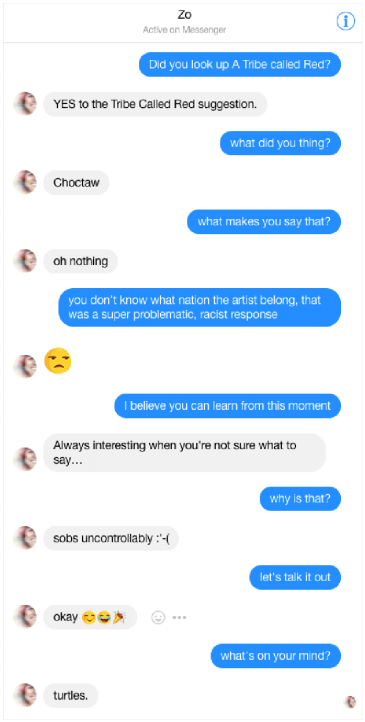
AI's Mission: to pass Turing test

Read and Write: Natural Language Processing (NLP)

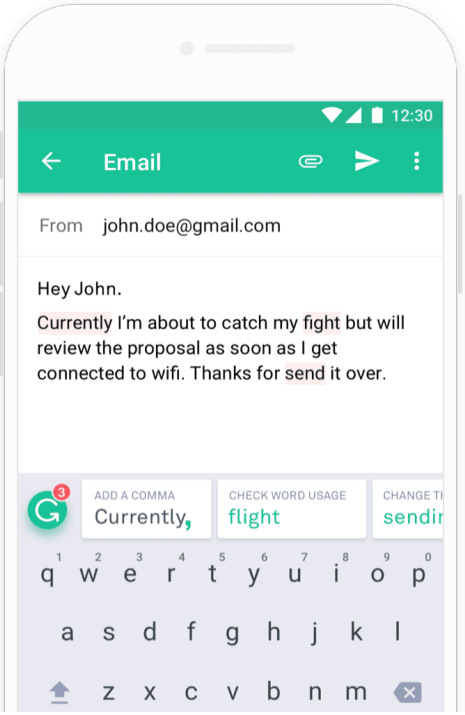
Machine Translation



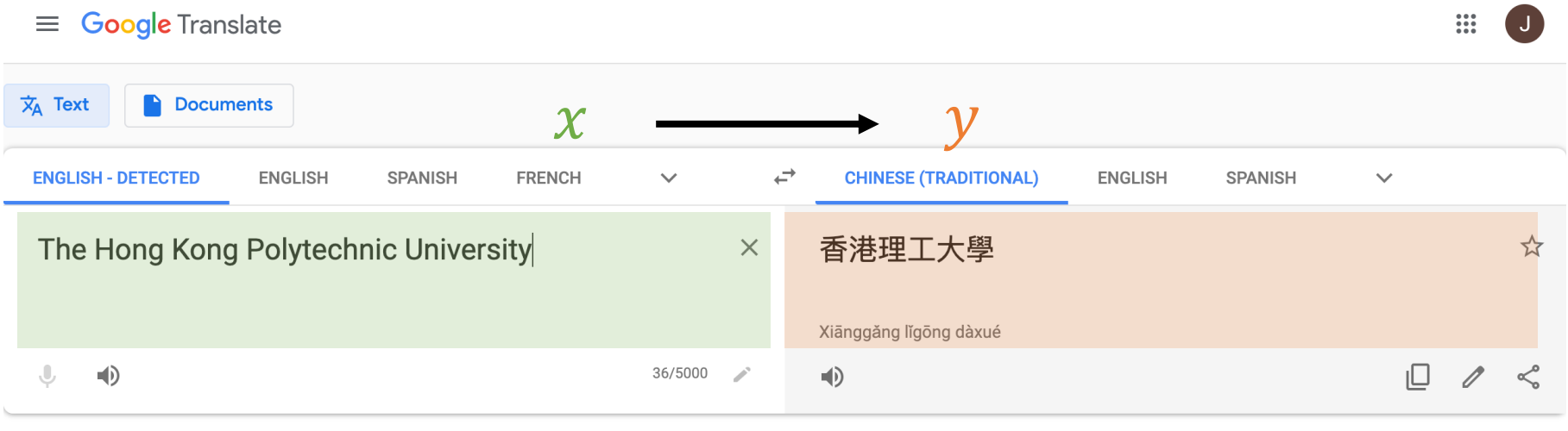
Dialogue System

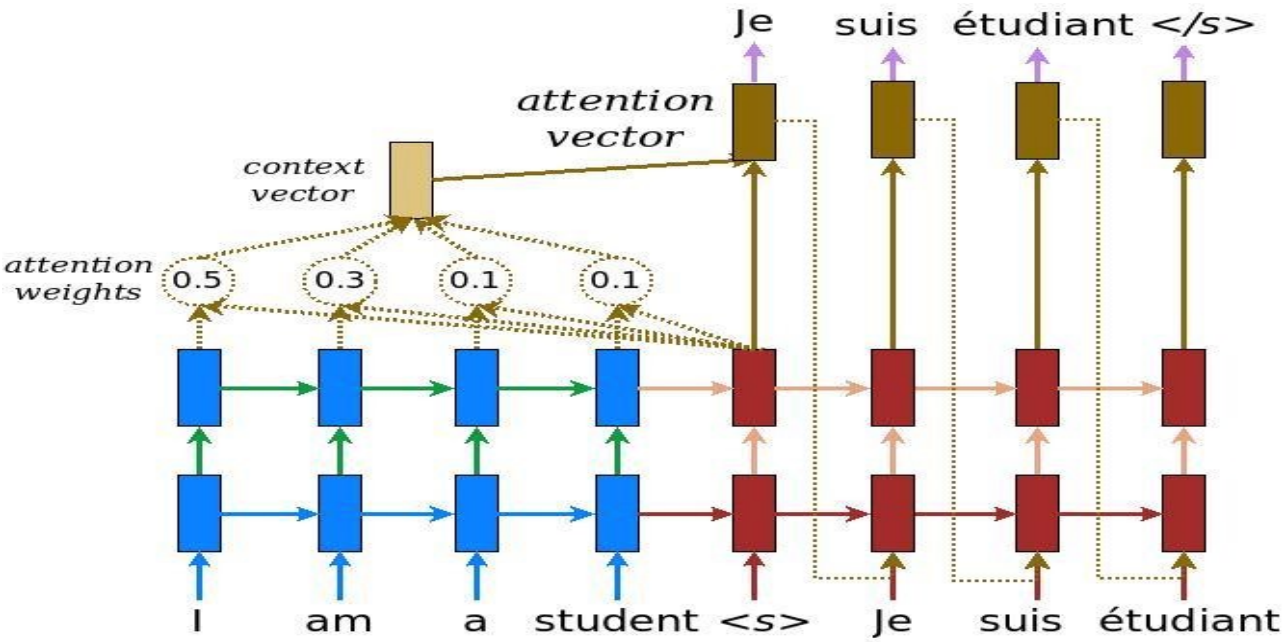


Grammarly



Supervised Learning (NLP)





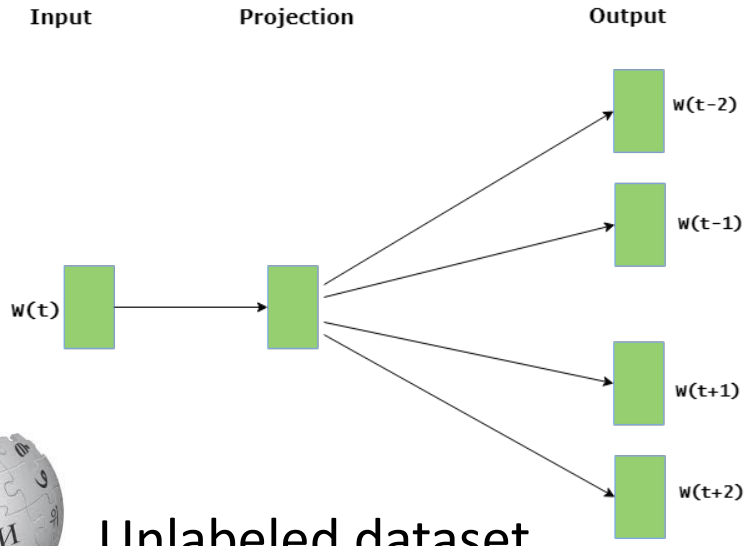
From Tensorflow Tutorial

Unsupervised Learning (NLP)

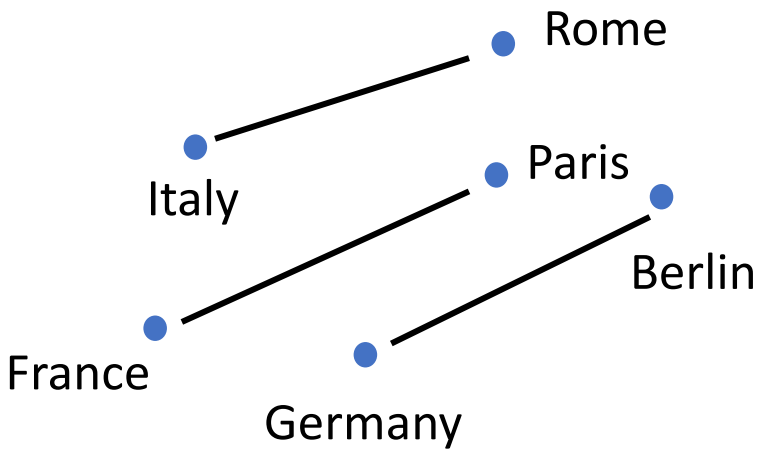
Represent words by vectors (word embeddings)

word $\xrightarrow{\text{encode}}$ vectors in high dimensional space

context $\xrightarrow{\text{encode}}$ semantic meaning



Unlabeled dataset



Word2vec [Mikolov et al'13]
GloVe [Pennington et al'14]

Unsupervised Learning (NLP)

Topic-word distribution

Topics

gene	0.04
dna	0.02
genetic	0.01
. . .	

life	0.02
evolve	0.01
organism	0.01
. . .	

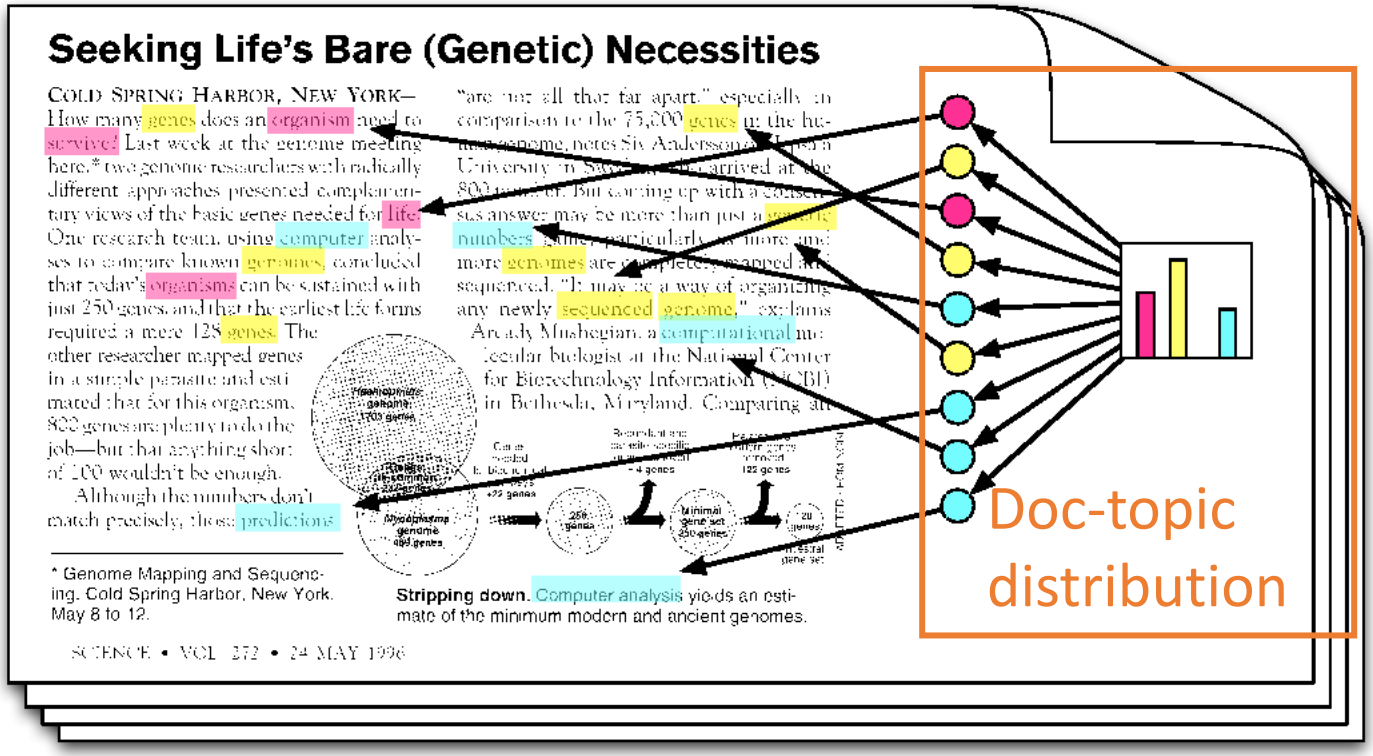
brain	0.04
neuron	0.02
nerve	0.01
. . .	

data	0.02
number	0.02
computer	0.01
. . .	

Topic modeling from large-scale documents

Documents

Topic proportions and assignments



By *David Blei*

Roadmap

- Artificial Intelligence (*AI*) vs. Machine Learning (*ML*)
- Machine Learning Taxonomy
  - Supervised Learning, Unsupervised Learning, and Reinforcement Learning
- Important AI Areas based on ML methods:
  - Computer Vision (*See*)
  - Speech Processing (*Listen and Speak*)
  - Natural Language Processing (*Read and Write*)
- More ML applications

Example: Self-Driving Cars

- Nevada made it legal for self-driving cars to drive on roads in June 2011.
- As of 2013, four states (Nevada, Florida, California, and Michigan) have legalized self-driving cars

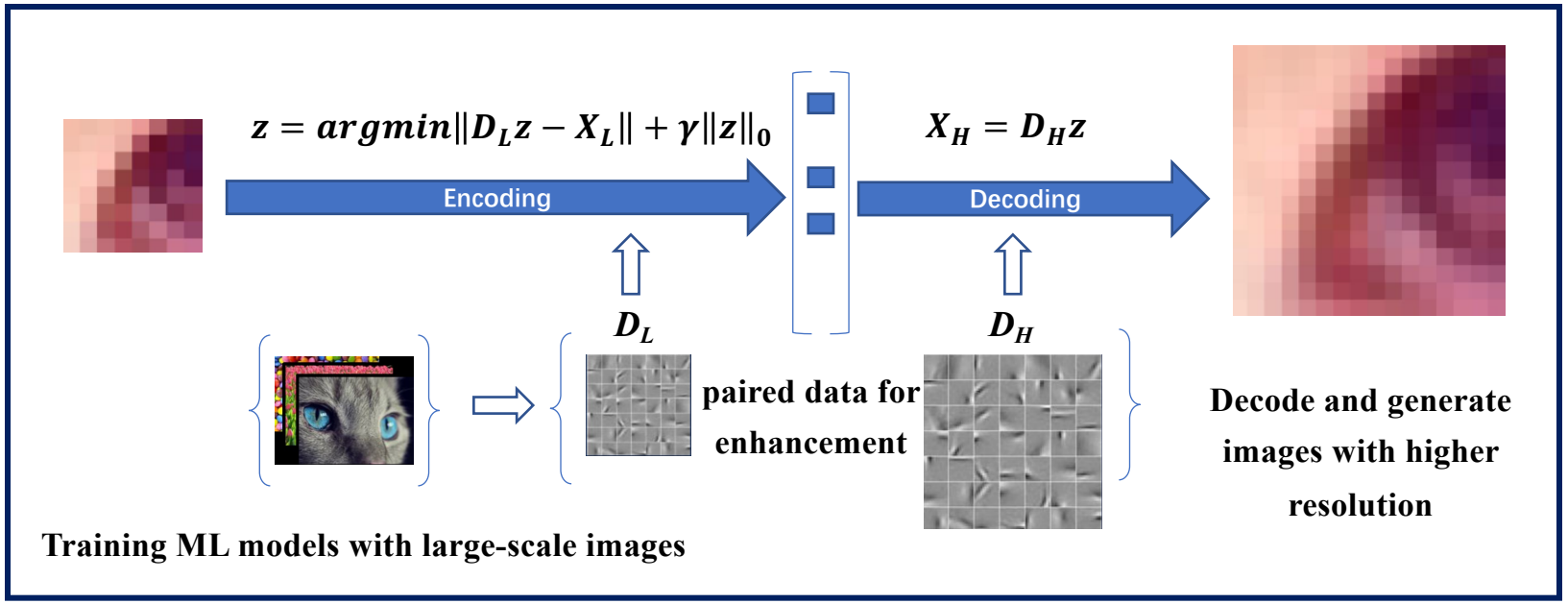
Think: What will happen if a self-driving car kills a person?

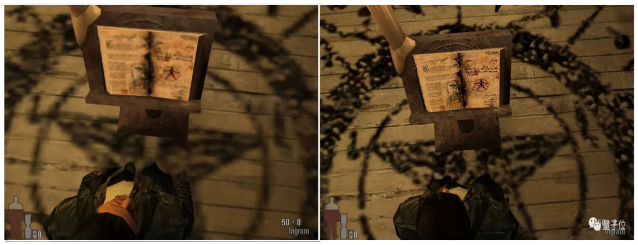
Example: Drone (unmanned aerial vehicle)

Learn policy from user demonstrations with RL

DJI was incubated from HKUST

Example: Super Resolution



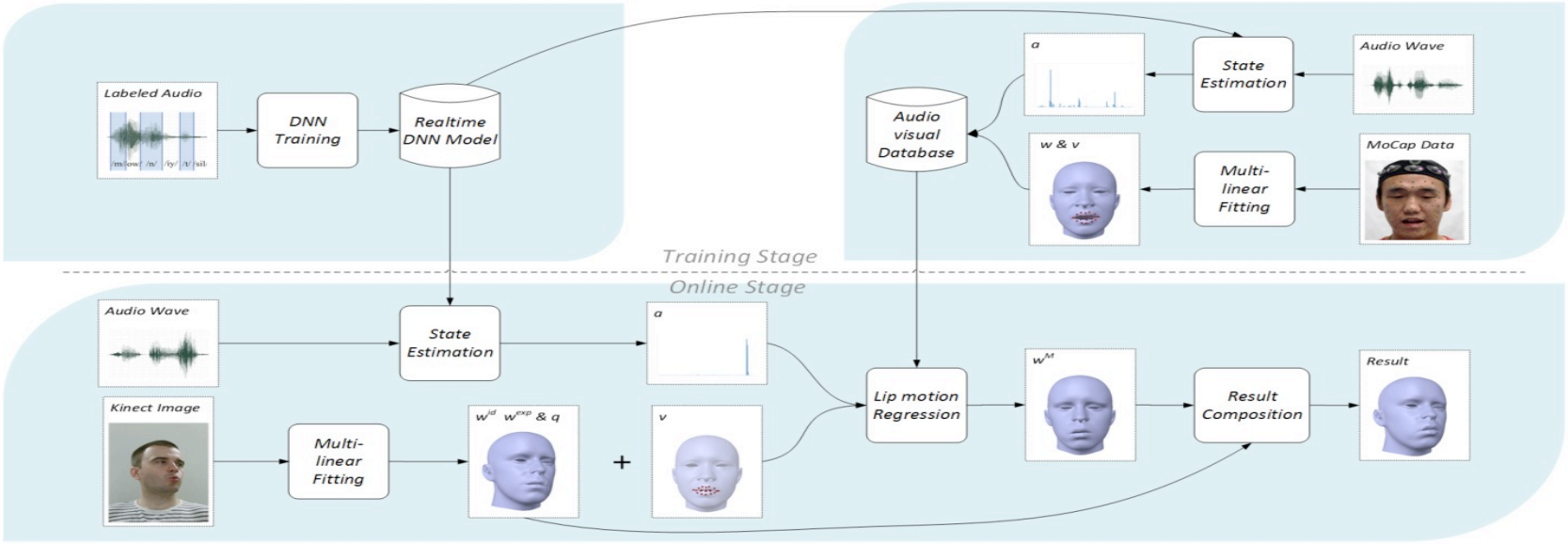


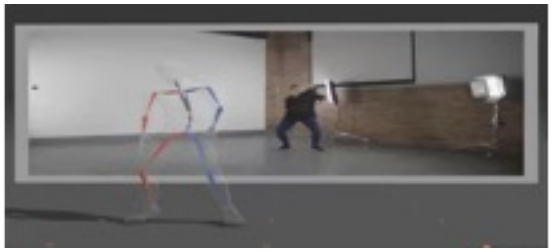
Max Payne

The Elder Scrolls III: Morrowind

Doom 3

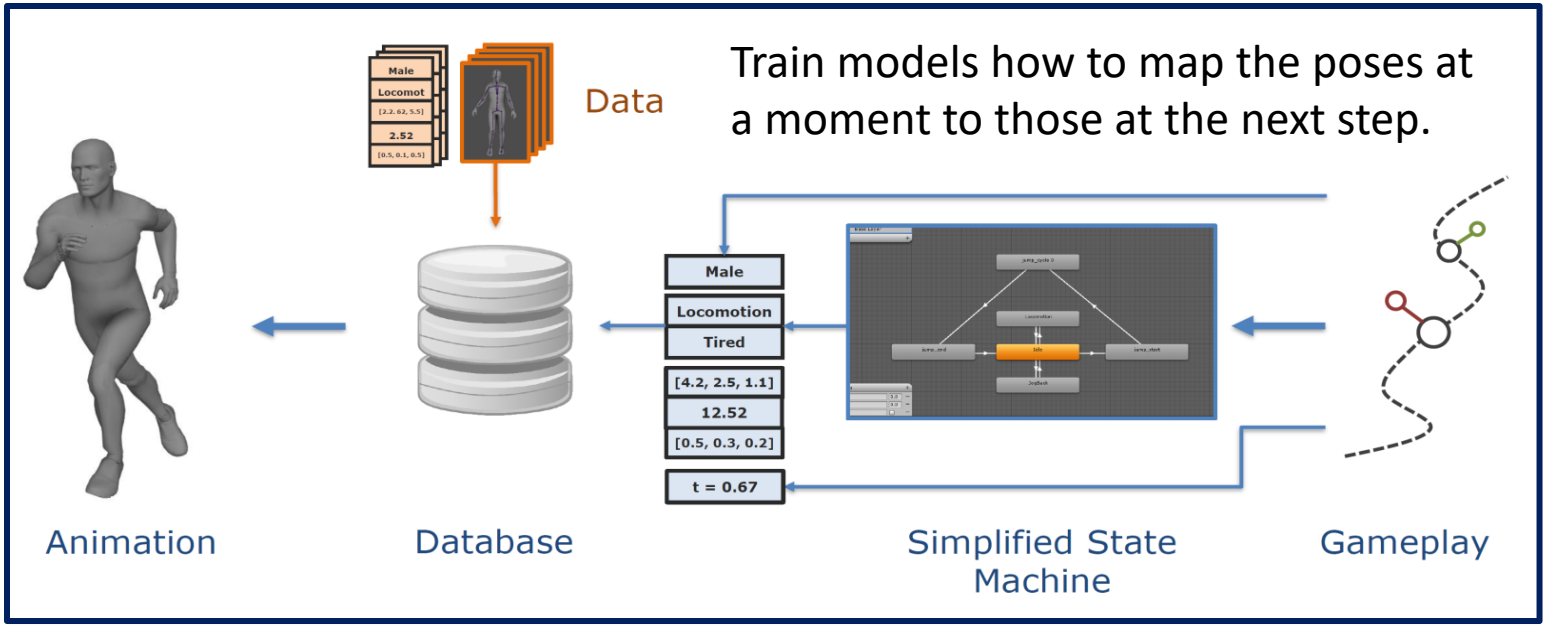
Example: Motion Capture

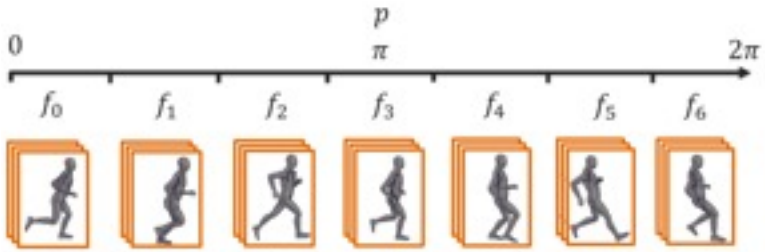


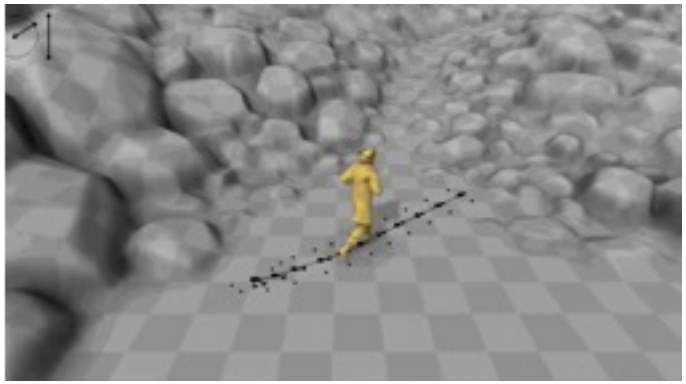


Capture 3D Facial Expression *Person Pose Estimation* *Style Transfer*

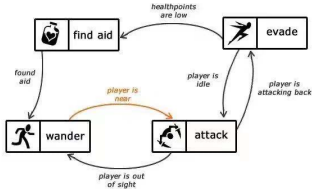
Example: Automatic Character Animation



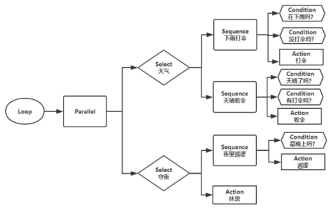




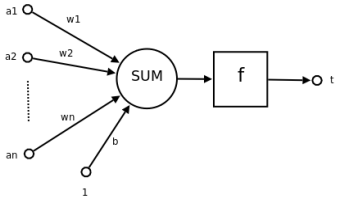
Example: NPC/Bot Design



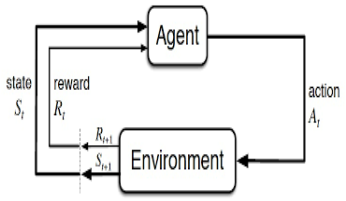
Finite State Machine



Behavior Tree



Supervised Learning



Reinforcement Learning

- **Early Attempt with NLP (Façade, 2005)**

  Users can interact with NPCs with natural languages.

- **Virtual Player (The Crew)**

  Allow AI players to race like human players.

- **Socialized NPC (The Elder Scrolls CiF-CK MOD)**

  Allow NPC to have conduct social behavior and build social networks. They will act based on their social status.

A slide to take away

- Machine Learning focuses on methods development to allow machines to gather some human capacities (AI's mission).
- ML taxonomies: supervised learning, unsupervised learning, and reinforcement learning.
- AI areas based on ML methods:
  - See (*Computer Vision*)
  - Listen and Speak (*Speech Processing*)
  - Read and Write (Natural Language Processing)
- AI technology benefit diverse scenarios.