EE2211 Introduction to Machine Learning

Lecture 1

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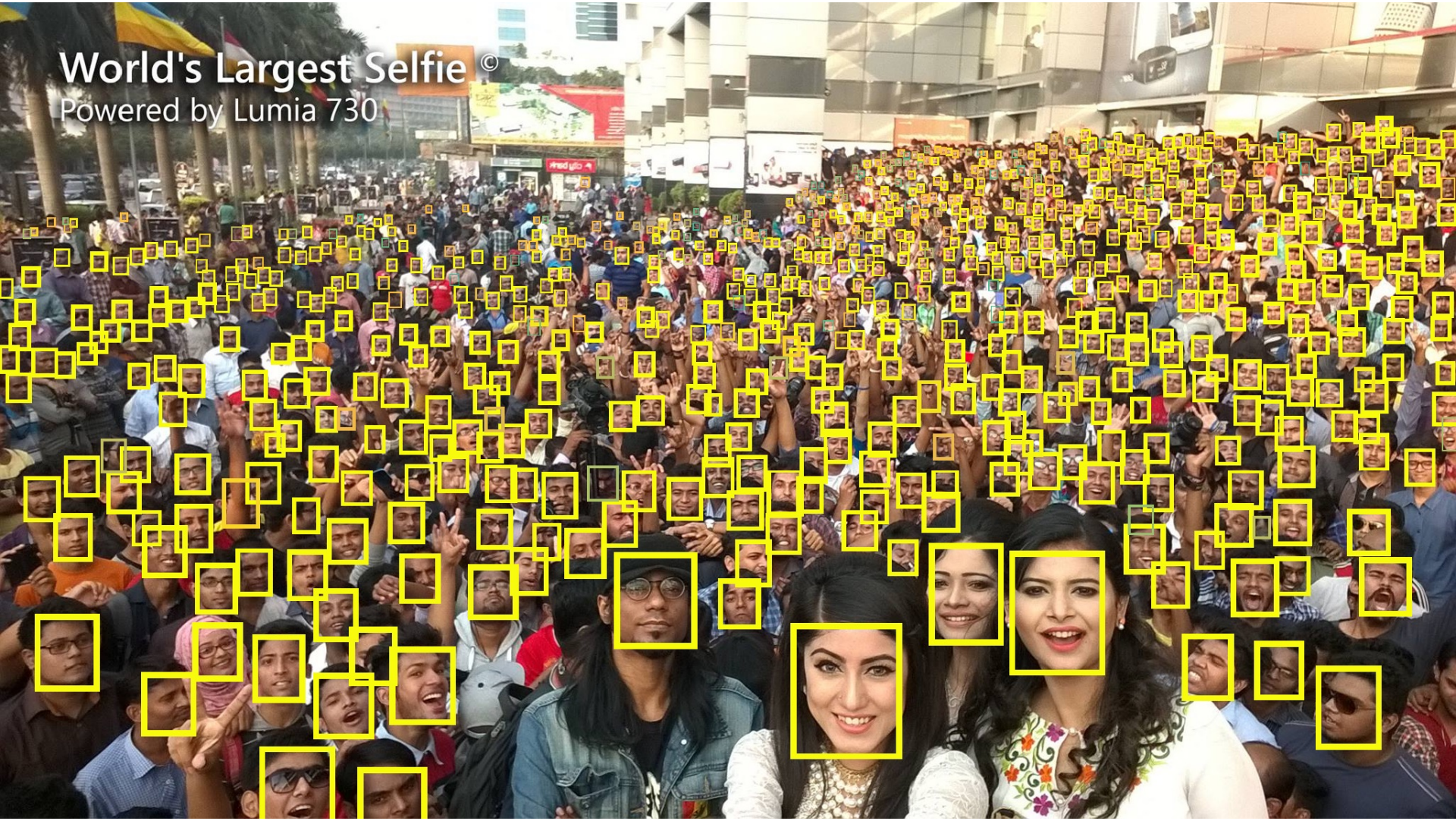
Office Hour: Mon 9:30 – 10:30 AM
(Week 2-4, Week 10-12)

Course Contents

- Introduction and Preliminaries (Xinchao)
  - Introduction
  - Data Engineering
  - Introduction to Probability and Statistics
- Fundamental Machine Learning Algorithms I (Yueming)
  - Systems of linear equations
  - Least squares, Linear regression
  - Ridge regression, Polynomial regression
- Fundamental Machine Learning Algorithms II (Yueming)
  - Over-fitting, bias/variance trade-off
  - Optimization, Gradient descent
  - Decision Trees, Random Forest
- Performance and More Algorithms (Xinchao)
  - Performance Issues
  - K-means Clustering
  - Neural Networks

World’s Largest Selfie

World’s Largest Selfie



Outline

- What is machine learning?
  - Three Definition(s)
- When do we need machine learning?
  - Sometimes we need, sometimes we don't
- Applications of machine learning
- Types of machine learning
  - Supervised, Unsupervised, Reinforcement Learning
- Walking through a toy example on classification
- Inductive vs. Deductive Reasoning

What is machine learning?

Learning is any process by which a system improves performance from experience.

- Herbert Simon

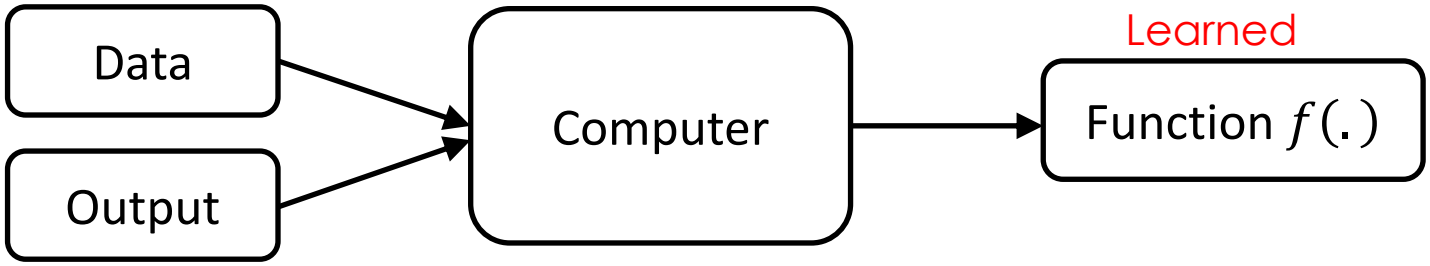
A computer program is said to learn

- from ***experience E***
- with respect to some class of ***tasks T***
- and ***performance measure P***,

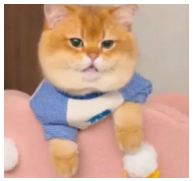
if its performance at tasks in T, as measured by P, improves with experience E.

- Tom Mitchell

Machine Learning (Supervised Learning)



Data **Output**

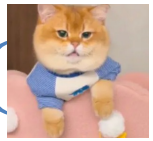


Cat

$\vdots$

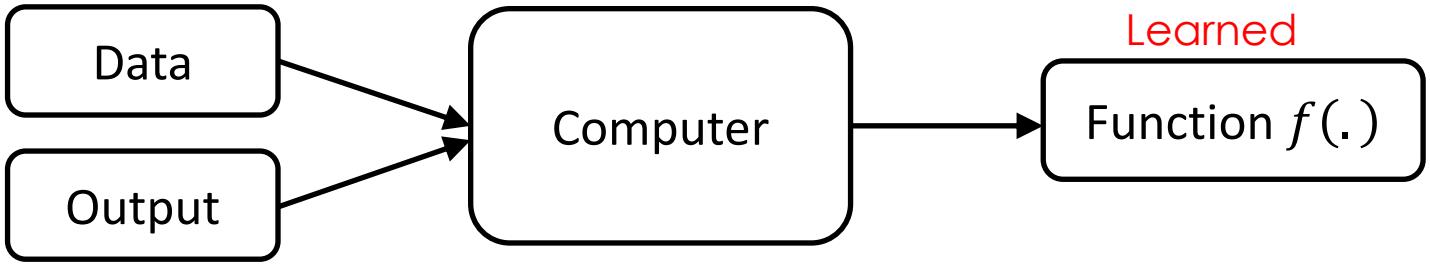
$\longrightarrow f(.)$ such that

Dog

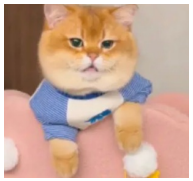
$f($  $)$ = 'cat'

$f($  $)$= 'dog'

Machine Learning (Supervised Learning)



Data **Output**



Cat

Dog

$\longrightarrow f(.)$

When applied

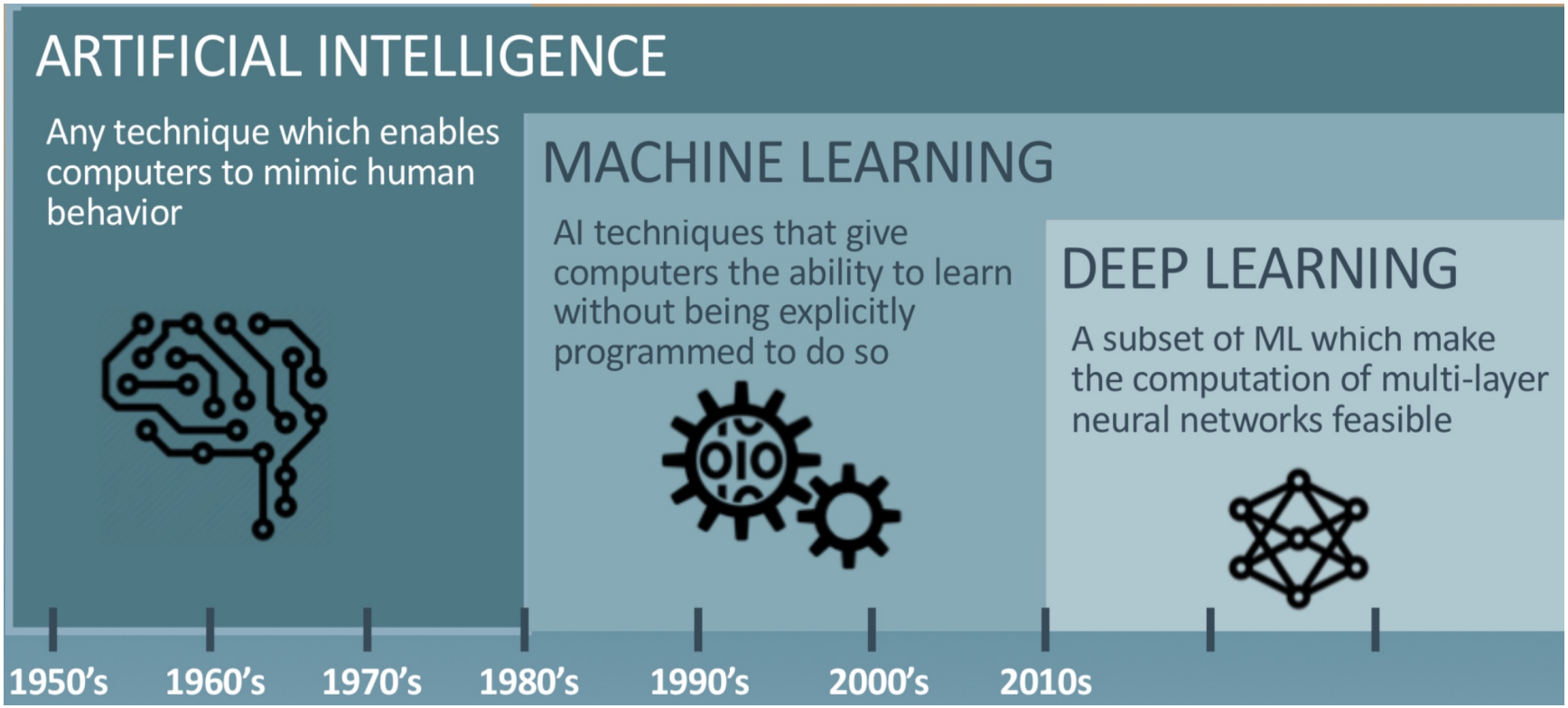
$f($  $) \longrightarrow$ **Cat !**

New image

Machine Learning: field of study that gives computers the ability to learn without being explicitly programmed

- Arthur Samuel

AI, Machine Learning, and Deep Learning



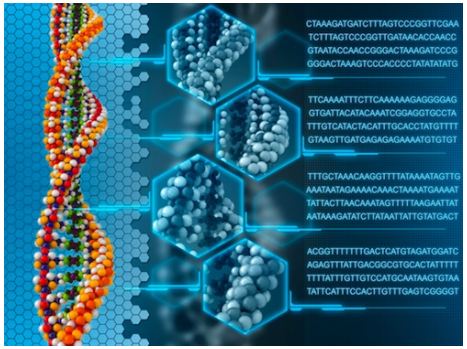
Example of AI but not ML: Deductive Reasoning

NUS is in Singapore, Singapore is in Asia -> NUS is in Asia

When do we need machine learning?

Lack of human expertise
(Navigating on Mars)

Involves huge amount of data
(Genomics)



Learning is not always useful:

No need to “learn” to calculate payroll!

My Salary = Days_of_work * Daily Salary + Bonus

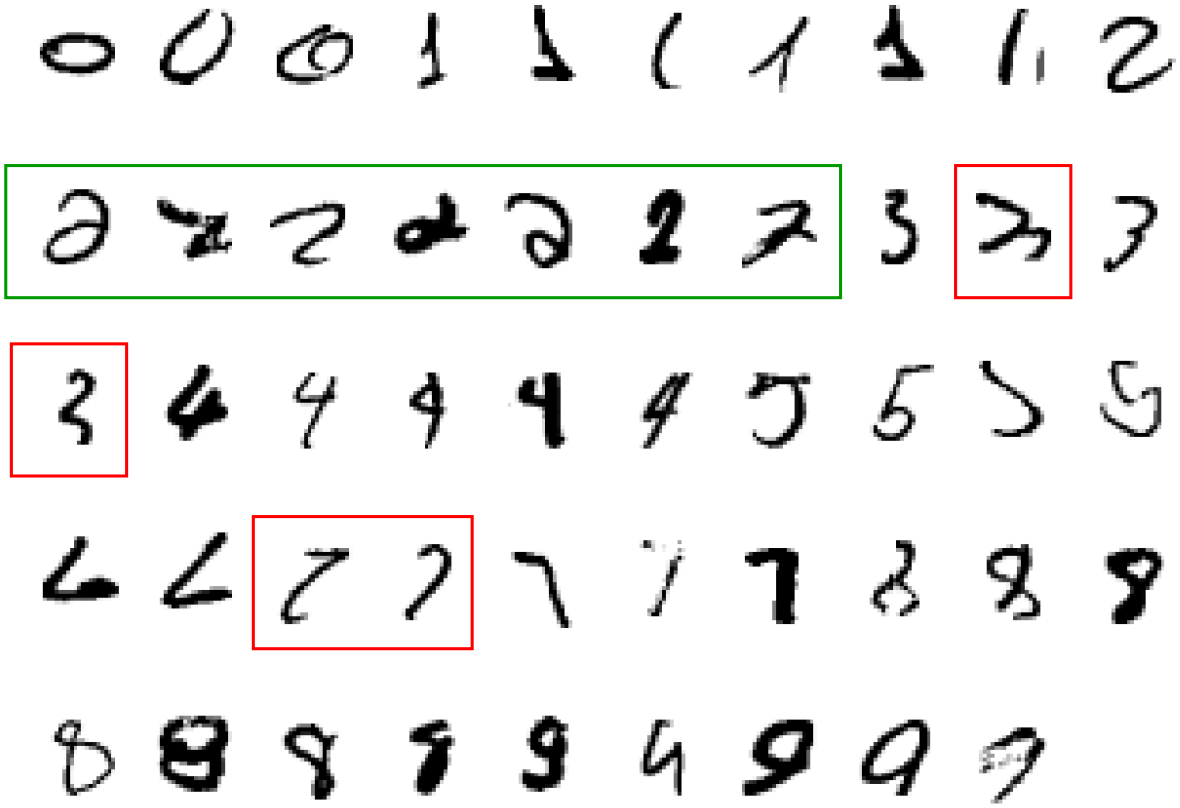
Application of Machine Learning

Task T, Performance P, Experience E

T: Digit Recognition
P: Classification Accuracy
E: Labelled Images

 "four"

 "three"



Labels -> Supervision!

Application of Machine Learning

Task T, Performance P, Experience E

T: Email Categorization
P: Classification Accuracy
E: Email Data, Some Labelled

Application of Machine Learning

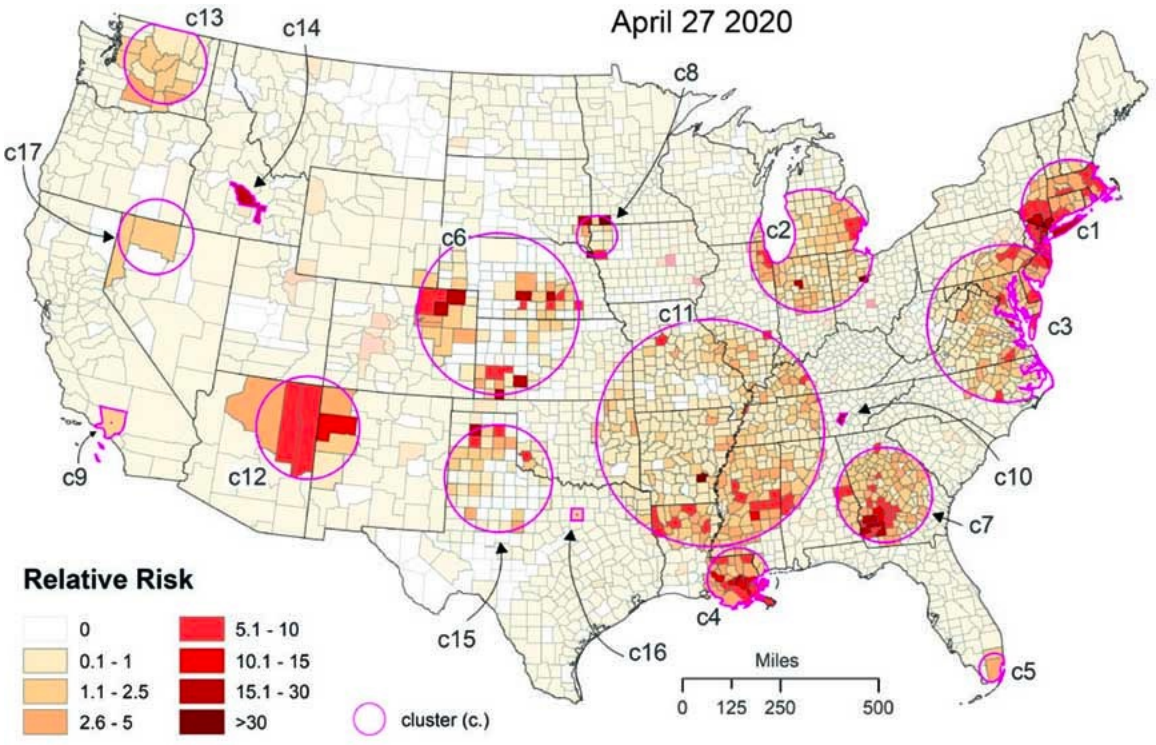
Task T, Performance P, Experience E

T: Playing Go Game
P: Chances of Winning
E: Records of Past Games

Application of Machine Learning

Task T, Performance P, Experience E

T: Identifying Covid-19 Clusters
P: Small Internal Distances
Larger External Distances
E: Records of Patients



Web Search Engine

Product Recommendation

Language Translation

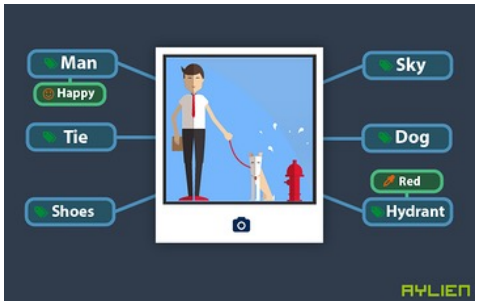
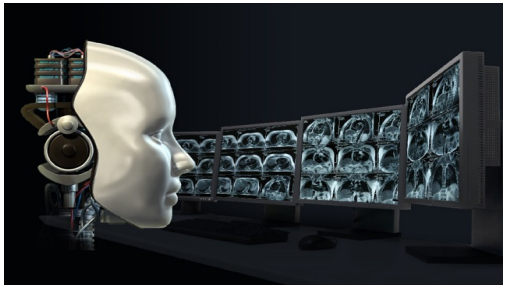


Photo Tagging

Virtual Personal Assistant

Portfolio Management

Traffic Prediction



Medical Diagnosis

Algorithmic Trading

Types of Machine Learning

Supervised Learning

Input:
1) Training Samples,
2) Desired Output (Teacher/Supervision)

Output:
A rule that maps input to output

Unsupervised Learning

Input:
Samples

Output:
Underlying patterns in data

Reinforcement Learning

Input:
Sequence of States, Actions, and Delayed Rewards

Output:
Action Strategy: a rule that maps the environment to action

Types of Machine Learning

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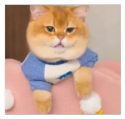
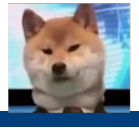
Data **Output**



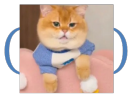
Cat

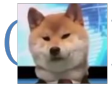
⋮



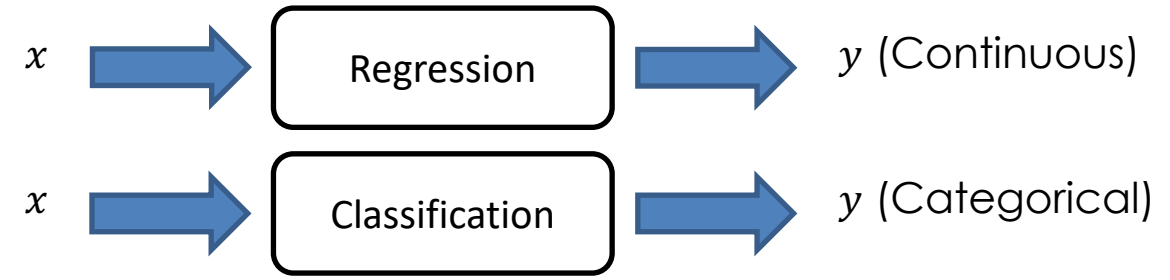
Dog

$\longrightarrow f(.)$ such that

$f($  $)$ = 'cat'

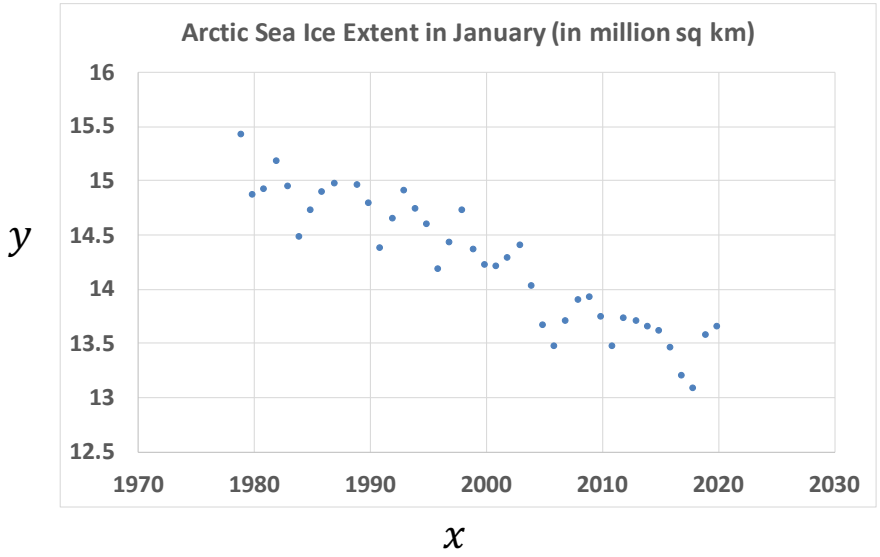
$f($  $)$= 'dog'

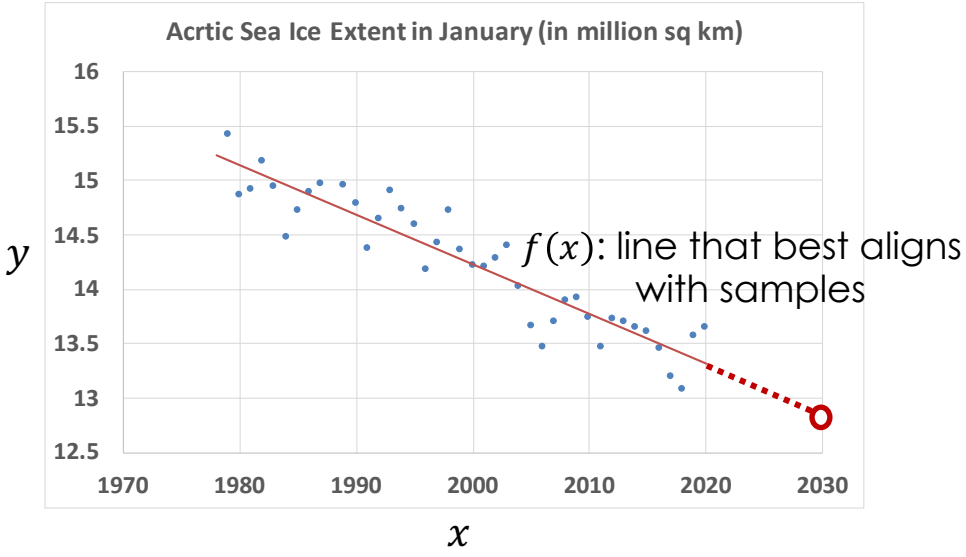
Supervised Learning



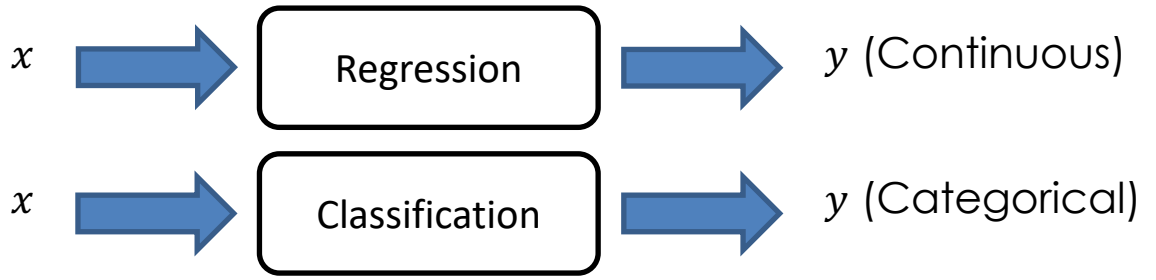
Regression

- Given $(\mathbf{x}_1, y_1), (\mathbf{x}_2, y_2), \ldots, (\mathbf{x}_N, y_N)$
- Learn a function $f(\mathbf{x})$ to predict real-valued y given $\mathbf{x}$





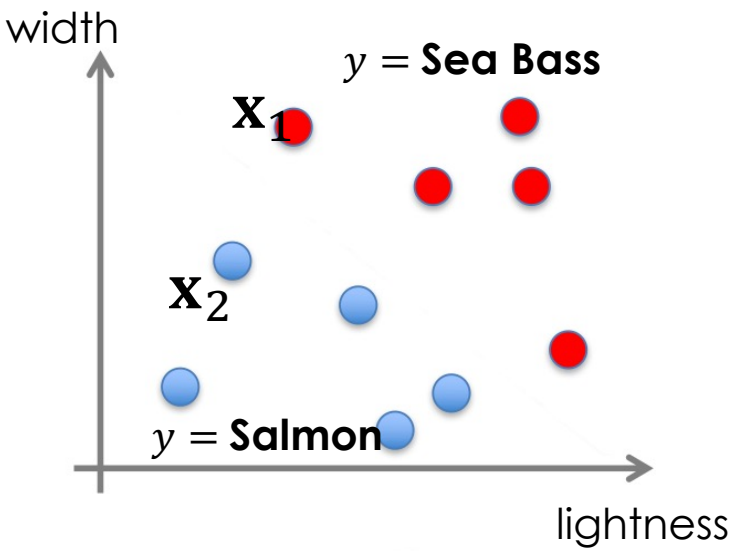
Supervised Learning

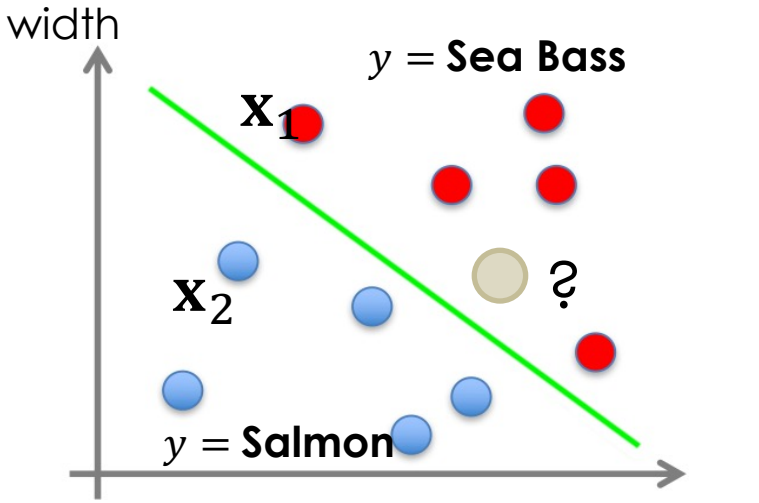


Classification

- Given $(\mathbf{x}_1, y_1), (\mathbf{x}_2, y_2), \ldots, (\mathbf{x}_N, y_N)$
- Learn a function $f(\mathbf{x})$ to predict categorical y given $\mathbf{x}$

Feature Space





$f(x)$: line that separates two classes

Types of Machine Learning

Supervised Learning

Input:
1) Training Samples,
2) Desired Output (Teacher/Supervision)

Output:
A rule that maps input to output

Unsupervised Learning

Input:
Samples

Output:
Underlying patterns in data

Reinforcement Learning

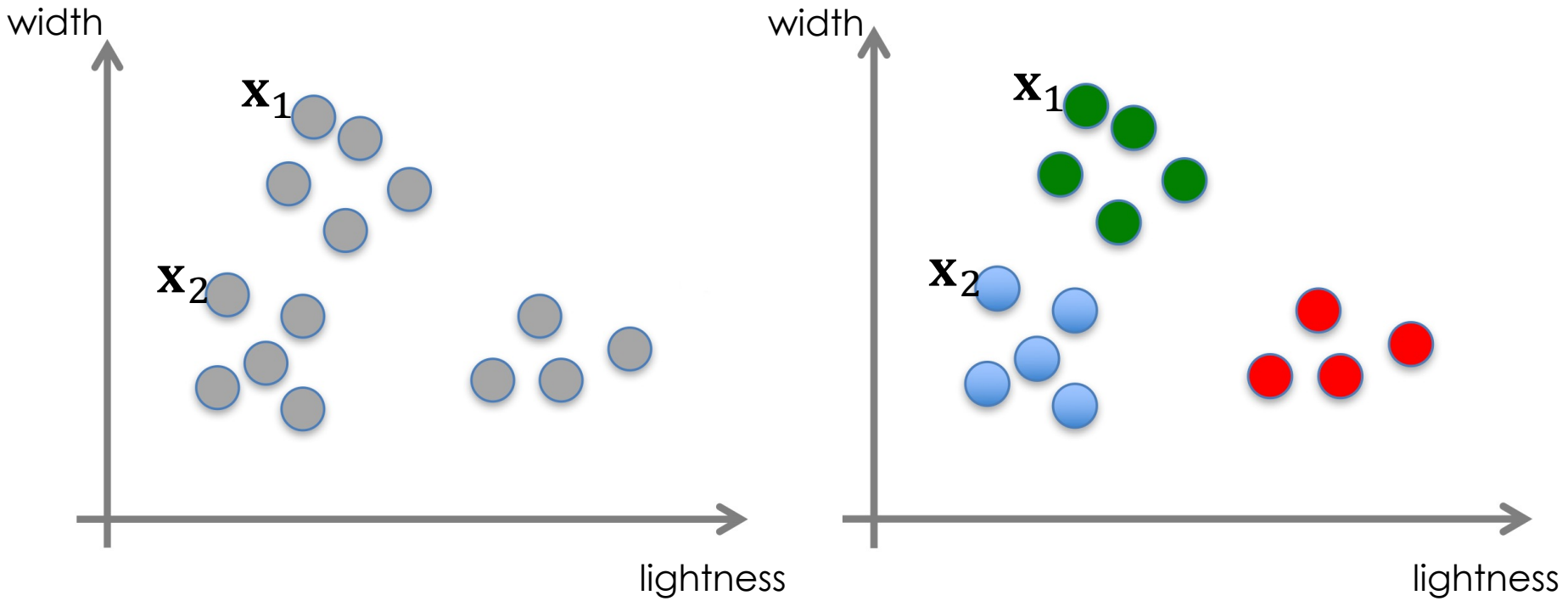
Input:
Sequence of States, Actions, and Delayed Rewards

Output:
Action Strategy: a rule that maps the environment to action

Unsupervised Learning

Clustering

- Given $\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_N$, without labels
- Output Hidden Structure Behind



No Label/Supervision is given!

Types of Machine Learning

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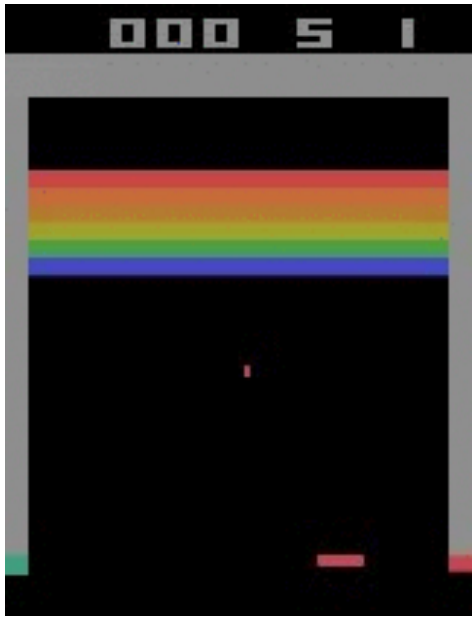
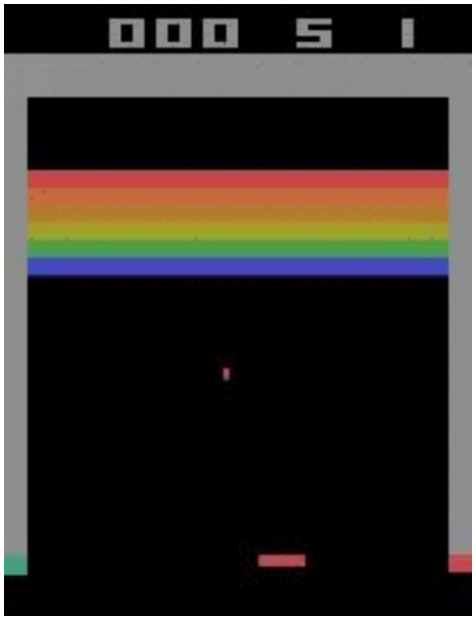
Reinforcement Learning

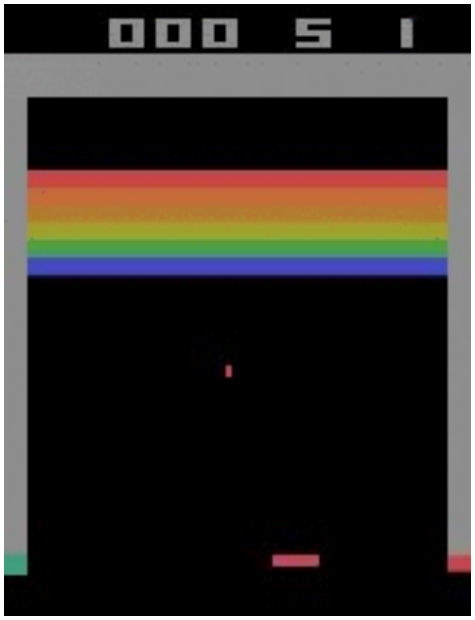
Breakout Game



Initial Performance



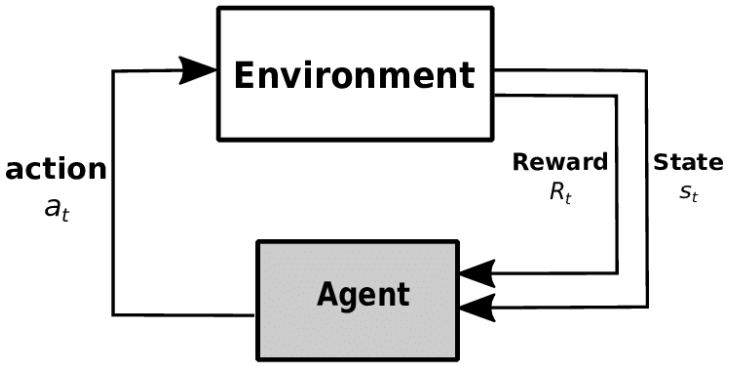
Training 15 minutes

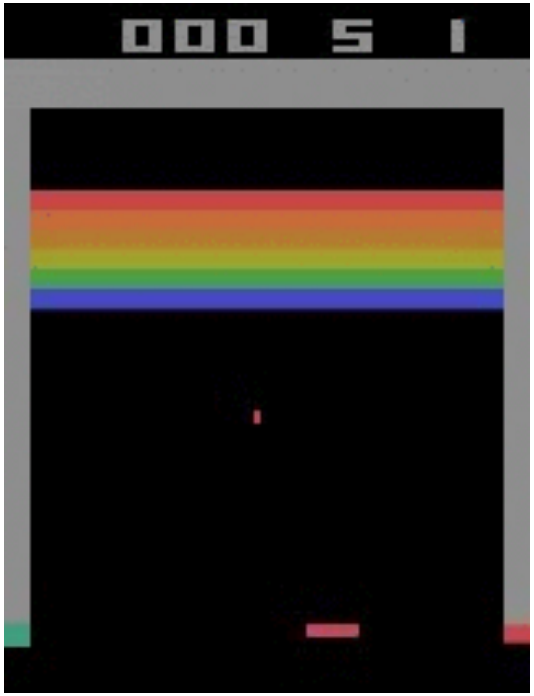


Training 30 minutes

Reinforcement Learning

- Given sequence of states $\boldsymbol{S}$ and actions $\boldsymbol{A}$ with (delayed) rewards $\boldsymbol{R}$
- Output a policy $\pi(a, s)$, to guide us what action a to take in state s





$\boldsymbol{S}$: Ball Location, Paddle Location, Bricks

$\boldsymbol{A}$: left, right

$\boldsymbol{R}$:

positive reward
Knocking a brick, clearing all bricks

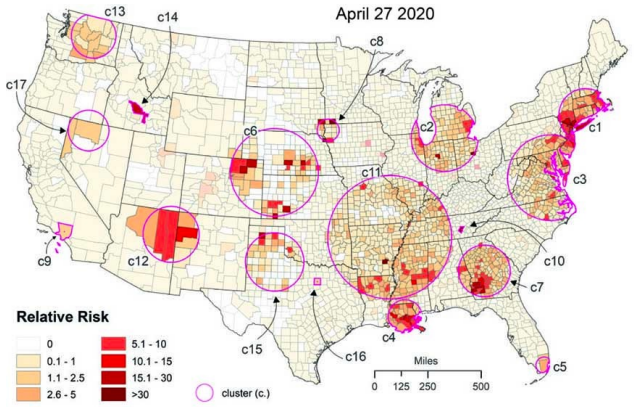
negative reward
Missing the ball

zero reward
Cases in between

Supervised
Unsupervised
Reinforcement

Quiz Time!

Supervised

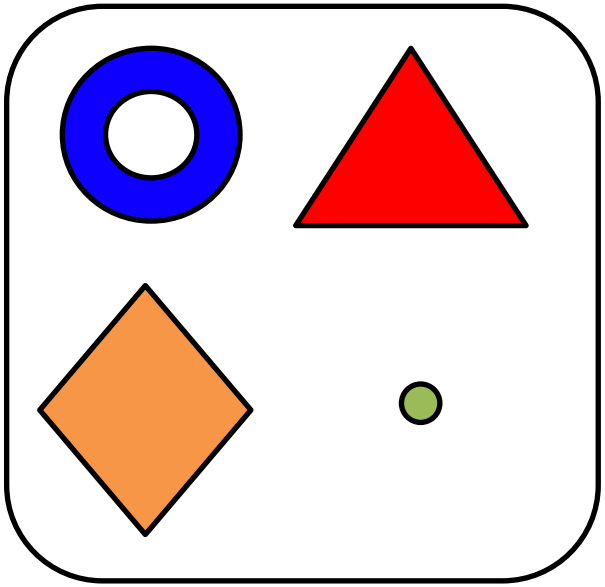


Unsupervised

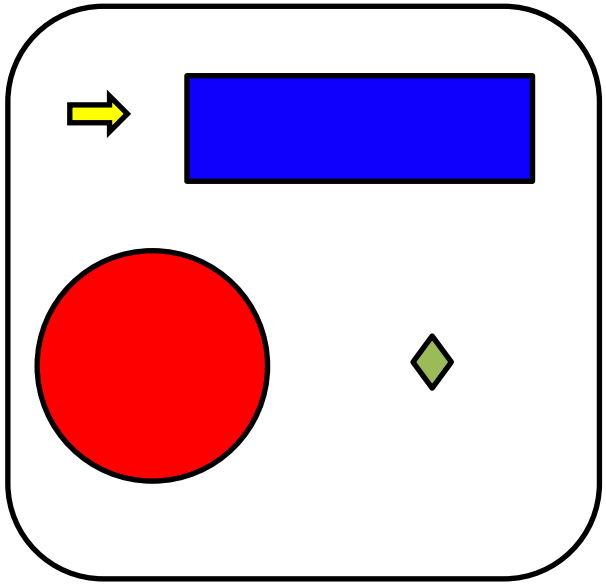
Supervised

Reinforcement

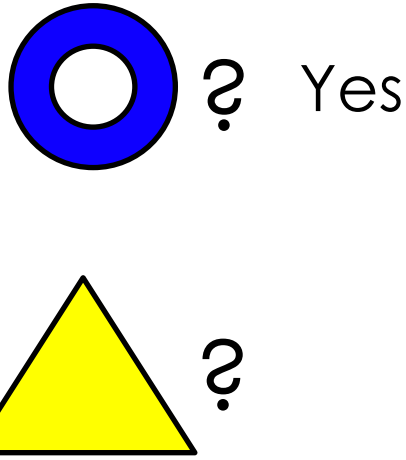
Walking Through A Toy Example: Token Classification



Yes



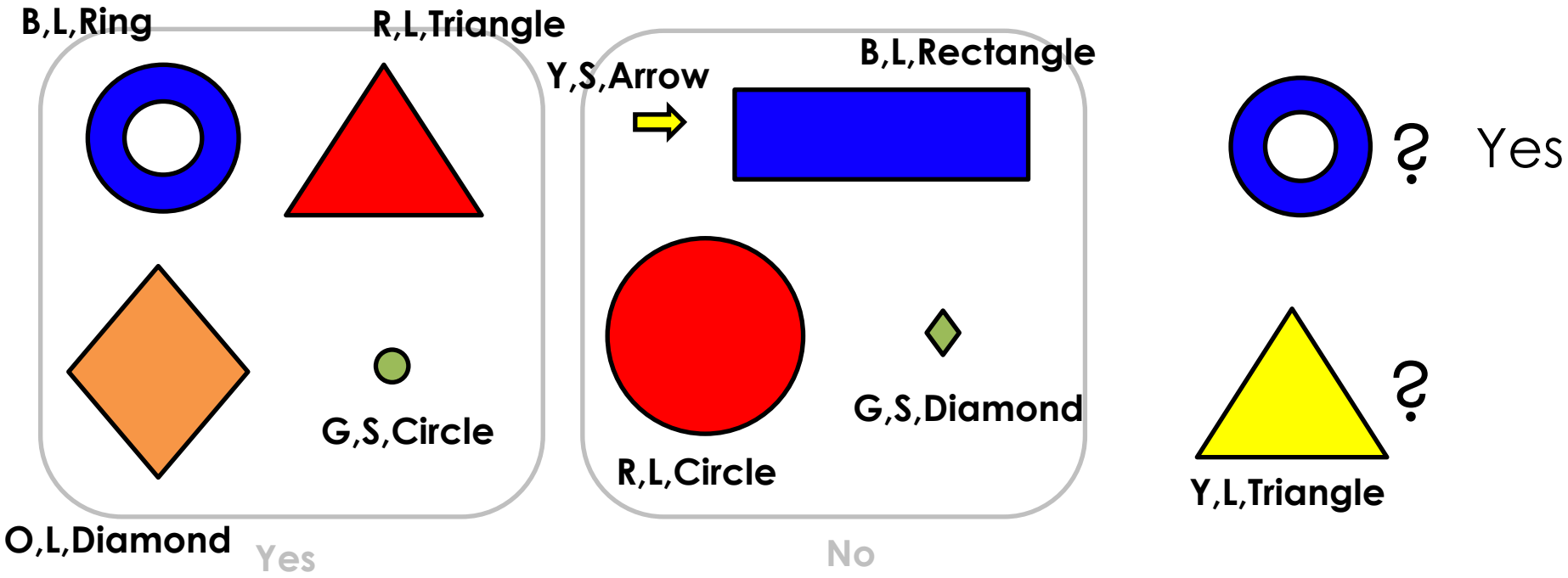
No



Step1: Feature Extraction
Extract Attributes of Samples

Step2: Sample Classification
Decide Label for a Sample

Walking Through A Toy Example: Token Classification



Step 1: Feature Extraction

Color, Size, Shape

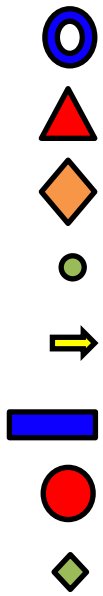
Walking Through A Toy Example: Token Classification

Feature Extraction

	Color	Size	Shape	Label
	Blue	Large	Ring	Yes
	Red	Large	Triangle	Yes
	Orange	Large	Diamond	Yes
	Green	Small	Circle	Yes
	Yellow	Small	Arrow	No
	Blue	Large	Rectangle	No
	Red	Large	Circle	No
	Green	Small	Diamond	No
	Yellow	Large	Triangle	?

Walking Through A Toy Example: Token Classification

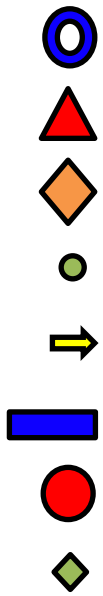
Feature Extraction



Color	Size	Shape	Label
Blue	Large	Ring	Yes
Red	Large	Triangle	Yes
Orange	Large	Diamond	Yes
Green	Small	Circle	Yes
Yellow	Small	Arrow	No
Blue	Large	Rectangle	No
Red	Large	Circle	No
Green	Small	Diamond	No

Walking Through A Toy Example: Token Classification

Feature Extraction



Color	Size	Shape	Label
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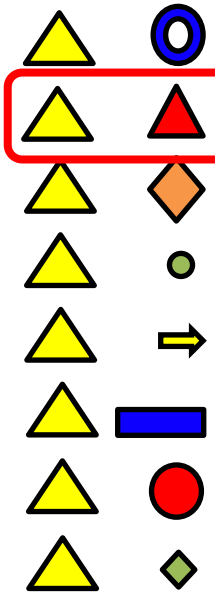
Green	Small	Circle	Yes
Yellow	Small	Arrow	No
Blue	Large	Rectangle	No
Red	Large	Circle	No
Green	Small	Diamond	No

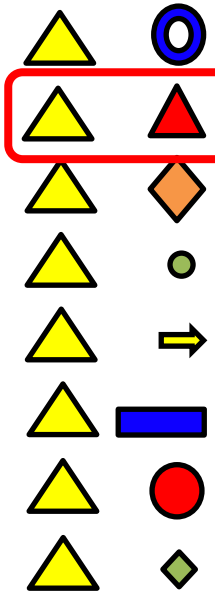
Similarity



Color	Size	Shape	Total
0	1	0	1
0	1	1	2
0	1	0	1
0	0	0	0
1	0	0	1
0	1	0	1
0	1	0	1
0	0	0	0

Walking Through A Toy Example: Token Classification

Similarity



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0	1	1	2
0	1	0	1
0	0	0	0
1	0	0	1
0	1	0	1
0	1	0	1
0	0	0	0

Nearest Neighbor Classifier:

1) Find the "nearest neighbor" of a sample in the feature space

2) Assign the label of the nearest neighbor to the sample

Inductive vs. Deductive Reasoning

- Main Task of Machine Learning: to make inference

Two Types of Inference

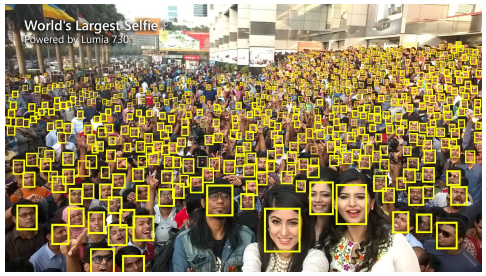
Inductive

- To reach **probable** conclusions
- Not all needed information is available, causing uncertainty

Deductive

- To reach logical conclusions **deterministically**
- All information that can lead to the correct conclusion is available

Probability and Statistics



Rule-based reasoning

NUS is in Singapore, Singapore is in Asia -> NUS is in Asia

Inductive Reasoning

Note: humans use inductive reasoning all the time and not in a formal way like using probability/statistics.

Ref: Gardener, Martin (March 1979). "MATHEMATICAL GAMES: On the fabric of inductive logic, and some probability paradoxes" (PDF). *Scientific American*. **234**

Summary by Quick Quiz

Three Components in ML Definition

Task T, Performance P, Experience E

Two Types of Supervised Learning

Classification, Regression

Three Types of in ML

Supervised Learning
Unsupervised Learning
Reinforcement Learning

One Type of Unsupervised Learning

Clustering

Inductive and Deductive

Inductive: Probable
Deductive: Rule-based

Example of a Classifier Model

Nearest Neighbor Classifier