

COMP4211: Machine Learning

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Machine Learning in Hollywood



(video)

- the HAL 9000 computer in “2001: A Space Odyssey” (1968)
 - can play chess, talk, appreciate art, recognize the emotions in the crew, read lips, etc.

Deep Blue won Kasparov in **1997**



([video](#))

- world chess champion Garry Kasparov vs IBM supercomputer called Deep Blue
- the first match was played in 1996 and won by Kasparov
- the second was played in 1997 and won by Deep Blue

Jeopardy! (an American television quiz show)

IBM's Watson supercomputer destroys all humans in **2011**



([video](#))

Example

clue: “This 'Father of Our Country' didn't really chop down a cherry tree”

response: “Who is/was George Washington?”

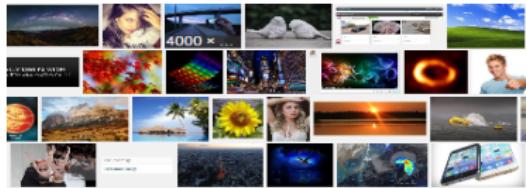
DeepMind's AlphaGo
the first program to defeat a Go world champion



(video)

- March **2016**: it beat Lee Sedol, a 9-dan professional
- discover more: [link](#)

ML is Everywhere



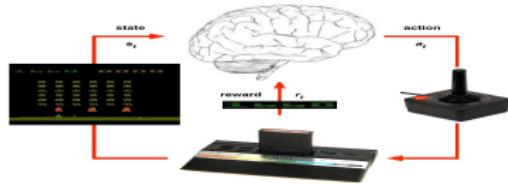
(a) image processing



(c) speech recognition



(b) natural language processing



(d) game playing

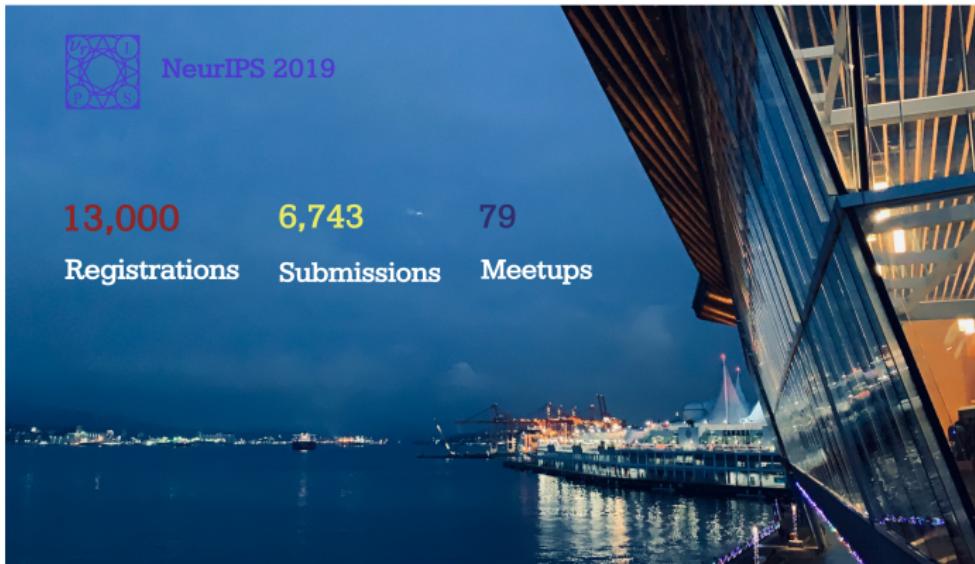


(link)

(e) robotics

Machine Learning is HOT

NeurIPS (Neural Information Processing Systems)



- 2019: registration is based on **lottery**
- 2018: registration **sold out in under 12 minutes**

What is Machine Learning?

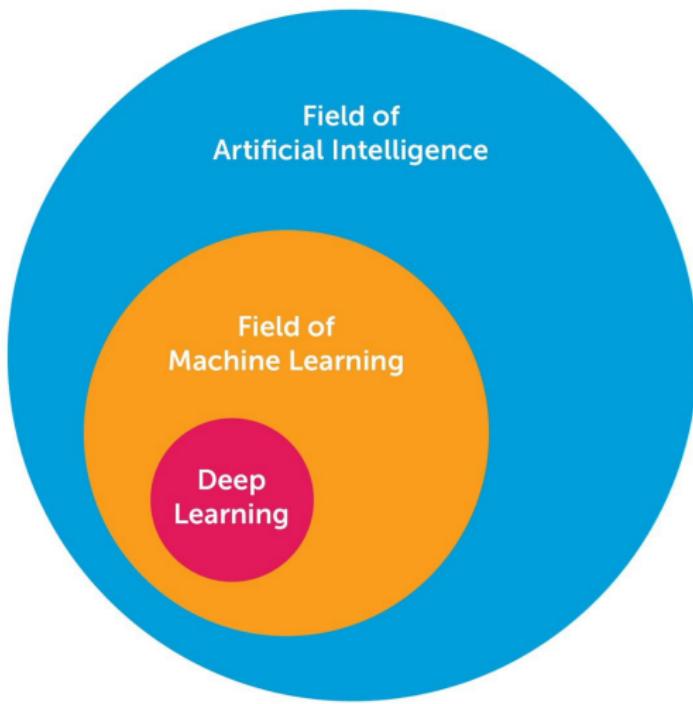
machine/human learning = improving with **experience**



From [Simon 83]

- Learning denotes **changes** in the system that are adaptive in the sense that they enable the system to do the **same** task or tasks drawn from the **same** population **more effectively** the next time

What's Deep Learning?



Example ML Applications

Character recognition

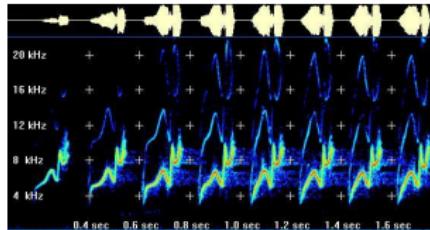
- raw data: image



- class: numerals, English (Chinese, etc.) characters

Speech recognition

- raw data: speech signal

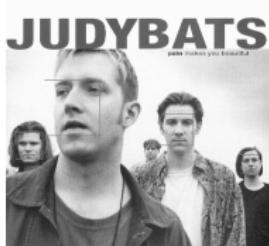


- class: spoken words

Examples...

Face detection

- raw data: image



- class: face/non-face

Fingerprint identification

- raw data: fingerprint image



- class: known/unknown person

Examples...

Document classification

- raw data: (web) document

EIA SAYS DISTILLATE, GAS STOCKS OFF IN WEEK

WASHINGTON, March 11 - Distillate fuel stocks held in primary storage fell by 8.8 mln barrels in the week ended March six to 119.6 mln barrels, the Energy Information Administration (EIA) said.

In its weekly petroleum status report, the Department of Energy agency said gasoline stocks were off 500,000 barrels in the week to 251.0 mln barrels and refinery crude oil stocks fell 1.2 mln barrels to 331.8 mln.

The EIA said residual fuel stocks fell 1.5 mln barrels to 36.4 mln barrels and crude oil stocks in the Strategic Petroleum Reserve (SPR) rose 200,000 barrels to 516.7 mln.

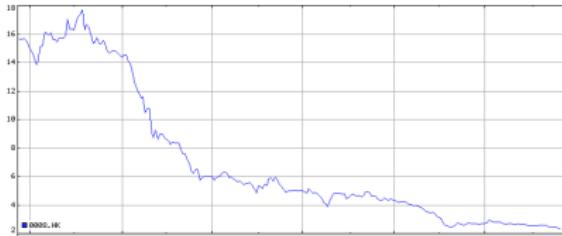
The total of all crude, refined product and SPR stocks fell 10.3 mln barrels to 1,564.8, it said.

- class: semantic categories (e.g. fuel, money, China)

Examples...

Financial engineering

- raw data: financial timeseries (e.g. stock prices)



- class: financially healthy / unhealthy company

How Can This Be Solved?

Is this an apple?



need **training examples**

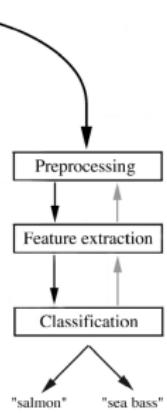
apples



not apples



Example: Automatic Fish Sorting



Different types of fish differ in length, lightness, width, number and shape of fins, position of the mouth, etc

Also there are variations in lighting, position of the fish on the conveyer, etc

- noise
- needs pre-processing

Pre-Processing

Example (remove the background)

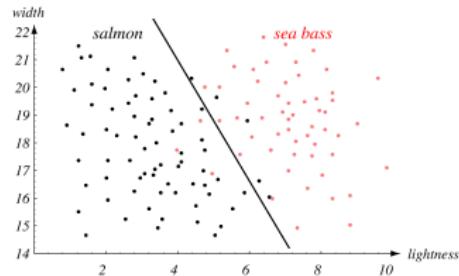


Example (adjust for light level)



Feature Extraction

Consider each fish as a **point** in some **feature space**

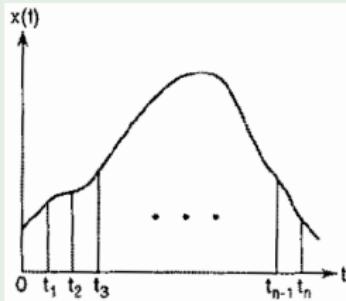


2-dimensional feature space:

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

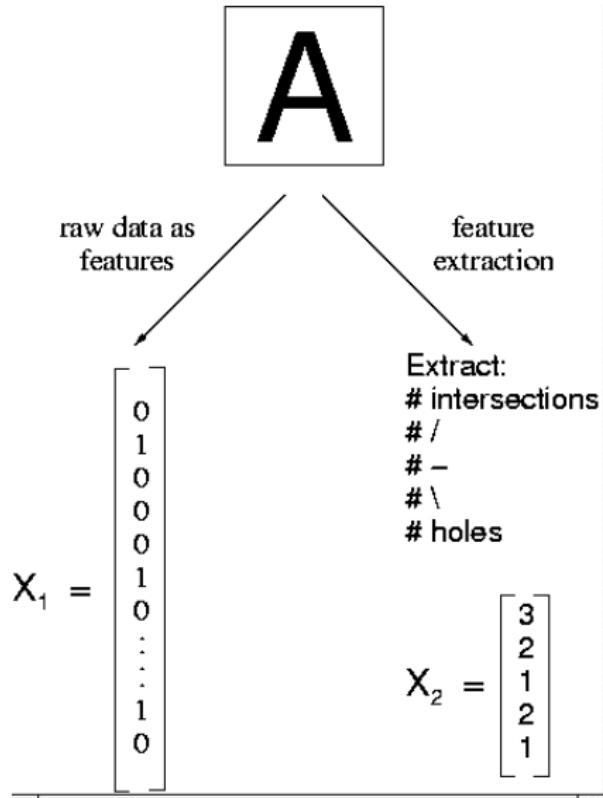
• **feature vector**

Example (waveform)



$$\Rightarrow \mathbf{X} = \begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \\ \vdots \\ \vdots \\ \mathbf{x}_n \end{bmatrix} = \begin{bmatrix} x(t_1) \\ x(t_2) \\ \vdots \\ \vdots \\ x(t_n) \end{bmatrix}$$

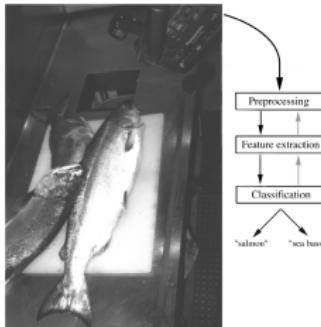
Example Features



Learning (Training)

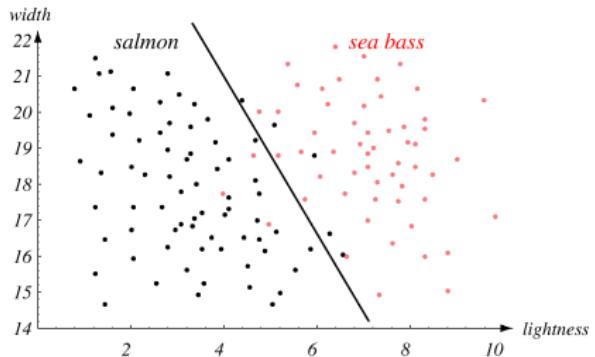
Training sample

- tell me which species a particular fish belong to (data collection)



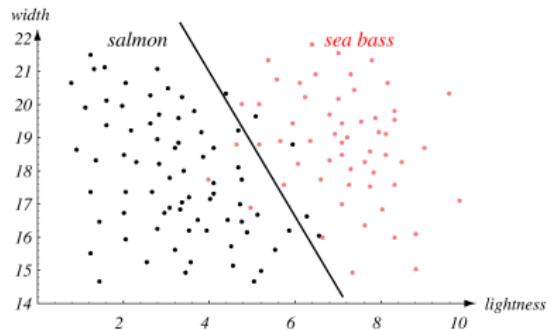
Partition the feature space into 2 regions, one for each type of fish

- decision boundary



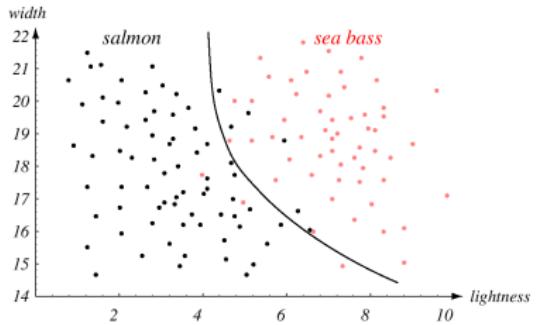
Classifier

Linear classifier



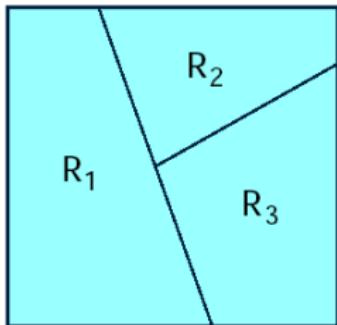
Can also use a more complicated decision boundary

- e.g. quadratic classifier

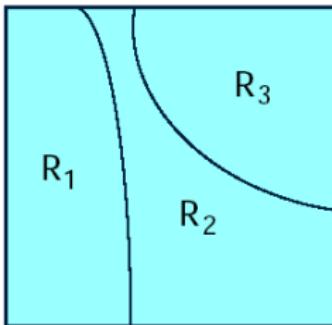


Classifier...

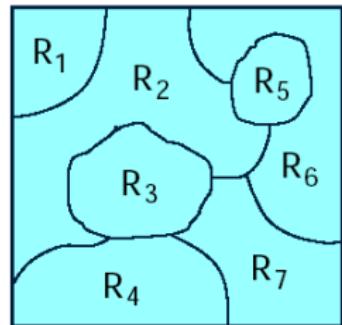
- can be even more complicated



linear
boundaries



quadratic
boundaries

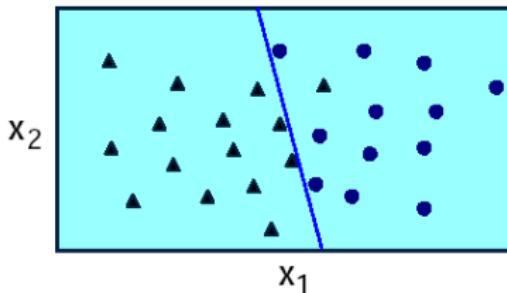


more complicated
boundaries

How to learn the boundary (parameters)?

How to Handle New Images?

Use the trained classifier to **classify** the new image



How to measure the classifier performance?

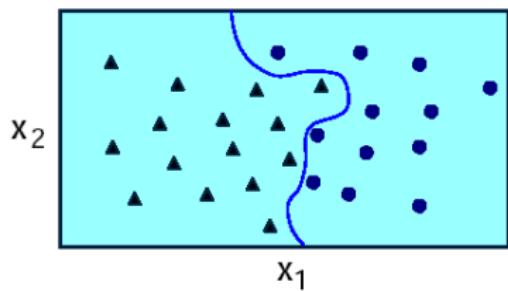
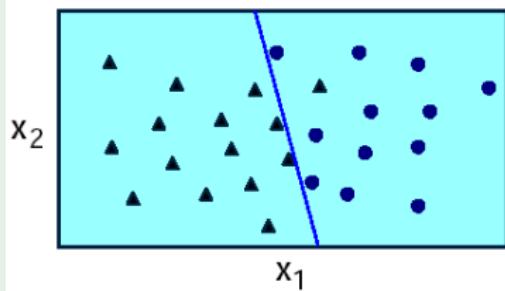
- classification error rate
 - % patterns that are assigned to the wrong category
- other aspects may be important too
 - e.g. computational complexity
 - e.g. user-friendliness

How to Handle New Images?...

Will the classifier work for this unseen fish?

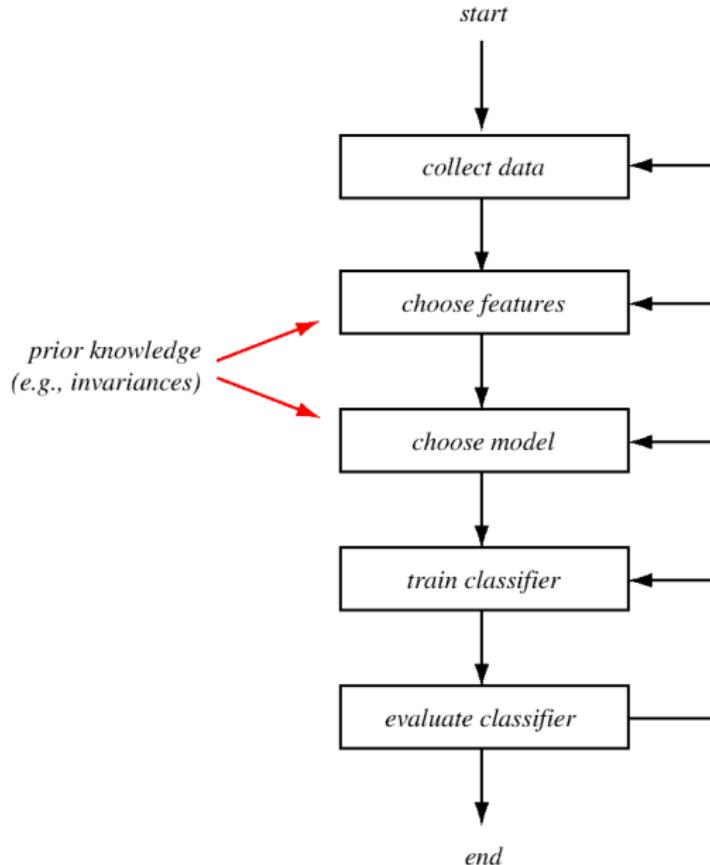
- issue of **generalization**

Example



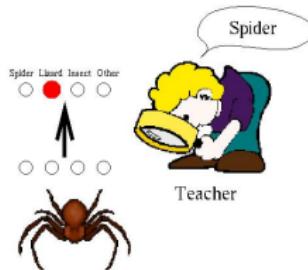
Which model is better?

Classifier Design



Learning Paradigm: Supervised Learning

The learner is provided with a set of **inputs** together with the corresponding desired **outputs**

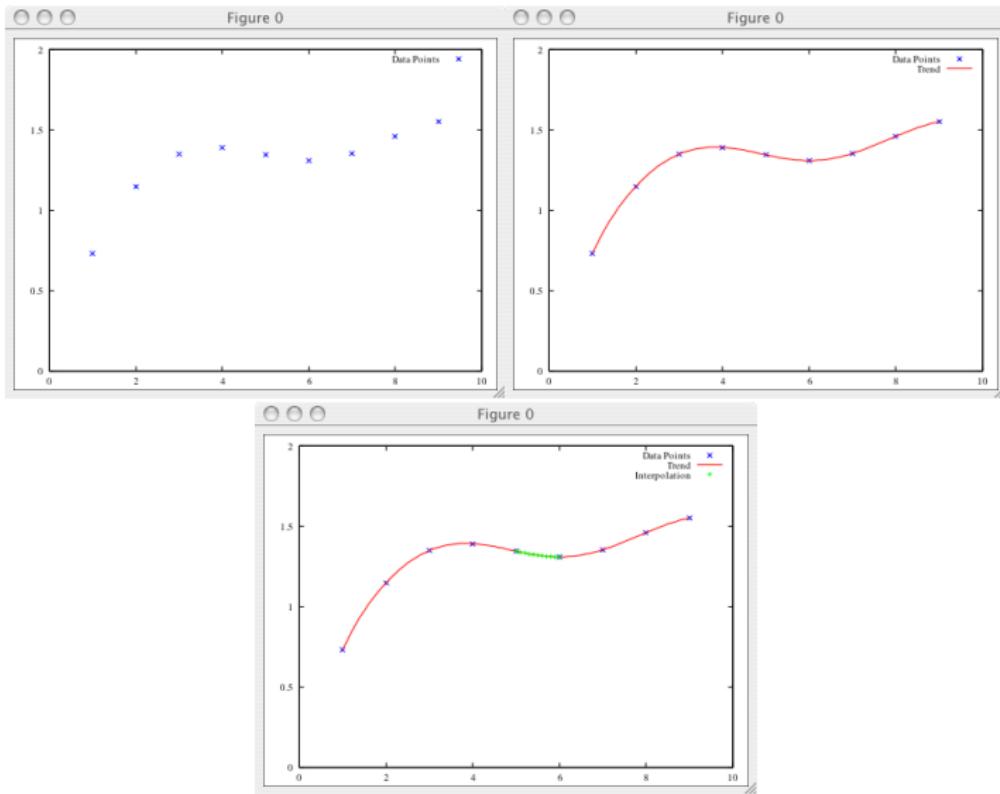


- has a “teacher”

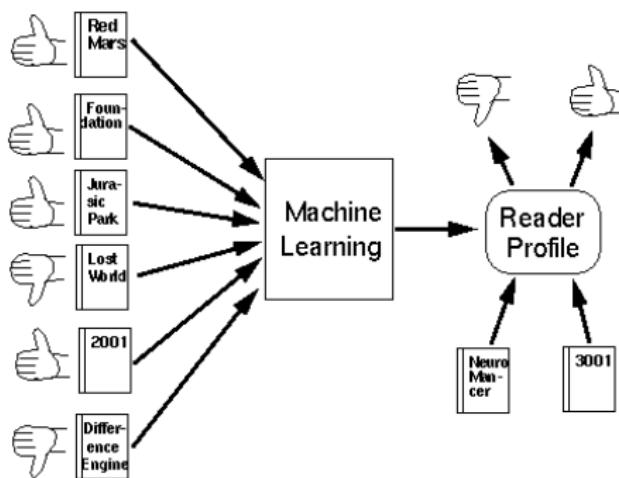
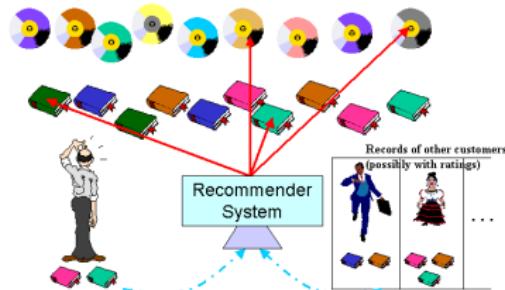
Example

- teaching kids to recognize different animals
- graded examinations with correct answers provided

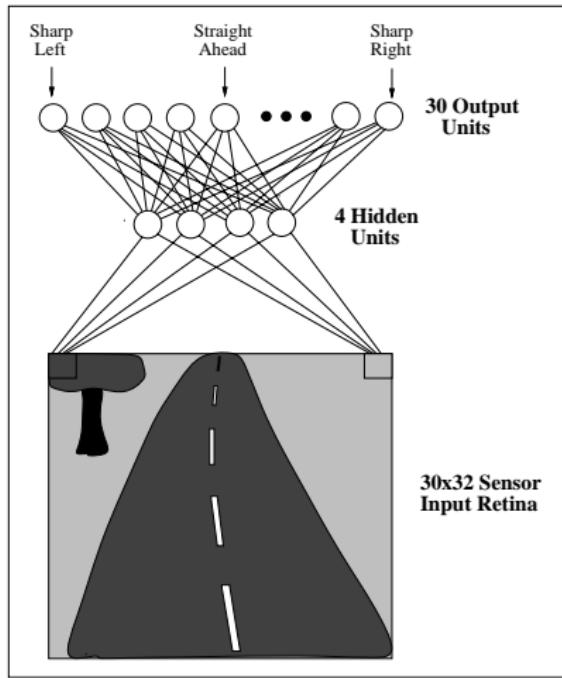
Example: Regression



Example: Recommender System



Example: Control



Examples

- text classification

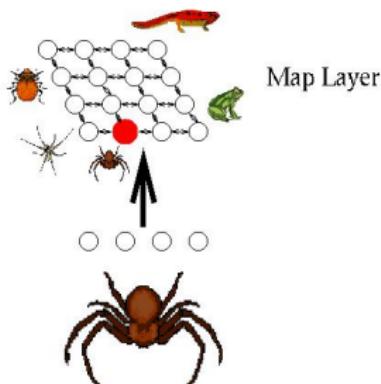
Google™ YAHOO!®

- face detection (video surveillance, digital camera)



Learning Paradigm: Unsupervised Learning

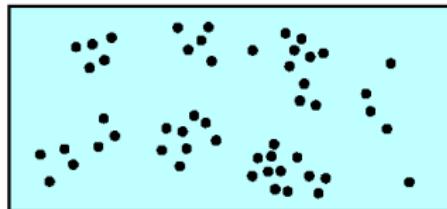
Training examples as **input** patterns, with no associated output



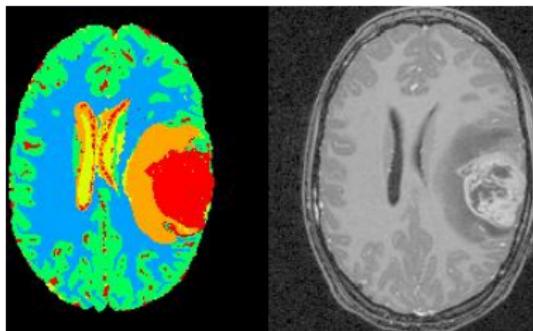
- no teacher
- similarity measure exists to detect groupings / clusterings

Uses of Unsupervised Learning

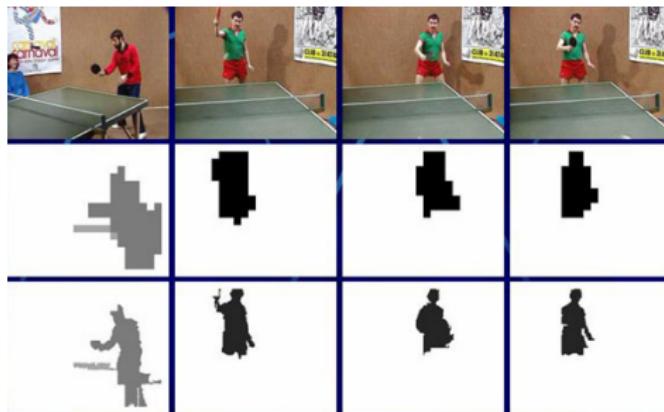
- find **clusters**



- in the early stages of an investigation, it may be helpful to perform **exploratory data analysis** to gain some insight into the nature or structure of the data



Examples

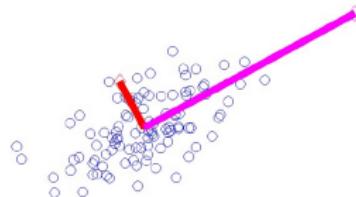


Star Trek IV 0.024 Star Trek II 0.023 Star Trek VI 0.023 Star Trek III 0.021 The Fifth Element 0.018	Dr. Strangelove 0.029 A Clockwork Orange 0.020 Delicatessen 0.018 Cinema Paradiso 0.018 Brazil 0.017717
The Rock 0.553 Eraser 0.232 Independence Day (ID4) 0.089 Mission: Impossible 0.077 Trainspotting 0.021	The Piano 0.288 The Remains of the Day 0.077 In the Name of the Father 0.067 Forrest Gump 0.052 Shadowlands 0.047

Uses of Unsupervised Learning...

- find **features** or preprocess existing features for the subsequent pattern classification problem (supervised learning)

principal component analysis
(PCA)



Example (eigenface)



Example: Content-based Image Retrieval



- visualize image locations and distances

Uses of Unsupervised Learning...

- find the least likely observations from a dataset (**outlier detection**)

Example (network intrusion detection)

Detect whether someone is trying to hack the network or doing anything else unusual on the network

File	Logs	Settings	Help	Application	Protocol	Local Address	Remote Address	State	Creation Time	Rx [Bytes]	Type	Tx [Bytes]
<input type="checkbox"/>	SVCHOST.EXE	TCP	all:135	-----	Listening	27/Feb/2007 09:41:27	0	0	0	0	0	
<input type="checkbox"/>	SVCHOST.EXE	TCP	all:3389	-----	Listening	27/Feb/2007 09:41:33	0	0	0	0	0	
<input type="checkbox"/>	SVCHOST.EXE	TCP	all:1025	-----	Listening	27/Feb/2007 09:41:29	0	0	0	0	0	
<input type="checkbox"/>	SYSTEM	TCP	192.168.123.128:139	-----	Listening	27/Feb/2007 09:41:30	0	0	0	0	0	
<input checked="" type="checkbox"/>	PERSFW.EXE	TCP	all:44334	-----	Listening	27/Feb/2007 09:41:43	0	0	0	0	0	
<input checked="" type="checkbox"/>	PERSFW.EXE	TCP	all:44334	localhost:1986	Connected In	27/Feb/2007 16:45:42	2931	<attack>	152516			
<input type="checkbox"/>	SVCHOST.EXE	TCP	all:5000	-----	Listening	27/Feb/2007 09:42:15	0	0	0	0	0	
<input type="checkbox"/>	LSAS.EXE	TCP	all:27155	-----	Listening	27/Feb/2007 09:42:17	0	0	0	0	0	
<input checked="" type="checkbox"/>	PUTTY.EXE	TCP	all:1898	ustful.ust.hk:22	Connected Out	27/Feb/2007 15:54:54	445204	<normal>	141398			
<input checked="" type="checkbox"/>	CCAPP.EXE	TCP	localhost:1035	-----	Listening	27/Feb/2007 09:42:23	0	0	0	0	0	
<input checked="" type="checkbox"/>	SSHCLIENT.EXE	TCP	all:1639	lcpu2.cse.ust.hk:22	Connected Out	27/Feb/2007 11:43:48	135198	<normal>	3764			
<input checked="" type="checkbox"/>	ICQ.EXE	TCP	all:21470	-----	Listening	27/Feb/2007 14:41:02	0	0	0	0	0	
<input checked="" type="checkbox"/>	ICQ.EXE	TCP	all:1759	64.12.24.205:5190	Connected Out	27/Feb/2007 14:41:04	59285	<normal>	12191			
<input checked="" type="checkbox"/>	MSNMSGR.EXE	TCP	all:1722	bv2msg1104003.ph...	Connected Out	27/Feb/2007 14:38:33	176880	<normal>	129012			
<input checked="" type="checkbox"/>	PFWADMIN.EXE	TCP	all:1986	localhost:44334	Connected Out	27/Feb/2007 16:45:42	278215	<normal>	2931			
<input type="checkbox"/>	LSAS.EXE	UDP	all:500	-----	Listening	27/Feb/2007 09:41:40	0	0	0	0	0	
<input type="checkbox"/>	SYSTEM	UDP	192.168.123.128:138	-----	Listening	27/Feb/2007 09:41:30	205	0	40995			
<input type="checkbox"/>	LSAS.EXE	UDP	localhost:1033	-----	Listening	27/Feb/2007 09:42:23	0	0	2			
<input type="checkbox"/>	SYSTEM	UDP	192.168.123.128:137	-----	Listening	27/Feb/2007 09:41:30	1088	0	17982			
<input checked="" type="checkbox"/>	PERSFW.EXE	UDP	all:44334	-----	Listening	27/Feb/2007 09:41:43	0	0	0	0	0	
<input checked="" type="checkbox"/>	IEXPLORE.EXE	UDP	localhost:1600	-----	Listening	27/Feb/2007 11:17:52	1173	0	1173			
<input checked="" type="checkbox"/>	IEXPLORE.EXE	UDP	localhost:1697	-----	Listening	27/Feb/2007 14:09:48	15	0	15			

Outlier Detection

Example (database cleaning)

want to find out whether someone stored bogus information in a database (typos, etc.), mislabelled digits, ugly digits, bad photographs in an electronic album

Example (fraud detection)

credit cards, telephone bills, medical records

Use: Data Generation

Fake Obama created using AI video tool

- precisely model how Mr Obama moves his mouth when he speaks



([video](#))

Examples: Art and Content Creation

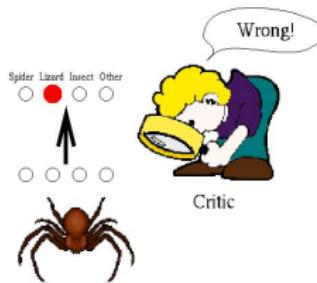
Example (smart paint)



([link](#), [video](#))

Learning Paradigm: Reinforcement Learning

Training examples as **input**-output pairs, with **evaluative output** only



- try to increase the **reinforcement** it receives

Example

- graded examinations with only overall scores but no correct answers

Reinforcement Learning

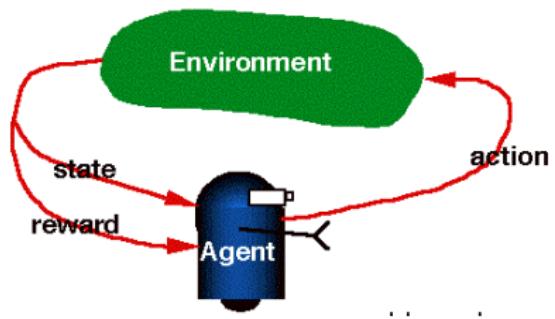
Example



([video](#), [link](#))

State, Action, Reward

Learning from interacting with an environment to achieve a goal



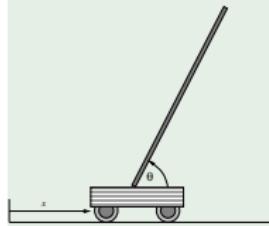
- try to maximize the total **rewards** it receives for its actions

Example

- RL: learn actions that maximize the total return on the portfolio

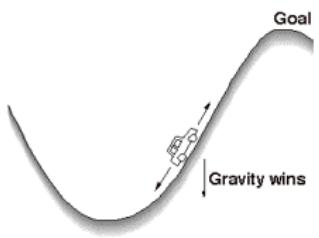


Example (Pole balancing)



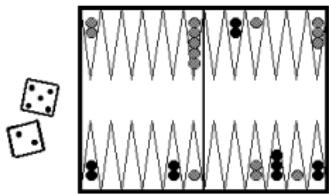
- **goal**: balance the pole as long as possible
- **states**: dynamic states of cart-pole system
- **actions**: push left, push right
- **rewards**: always 0 unless pole falls or cart hits end of track, in which case -1

Example (Mountain car)



- goal: minimize time to the “goal”
- states: car’s position and velocity
- actions: forward, reverse, none
- rewards: always -1 until car reaches the goal

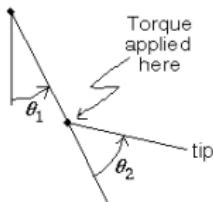
Example (Backgammon)



- goal: win
- states: configurations of the playing board
- actions: moves
- rewards: win: +1, lose: -1, else: 0

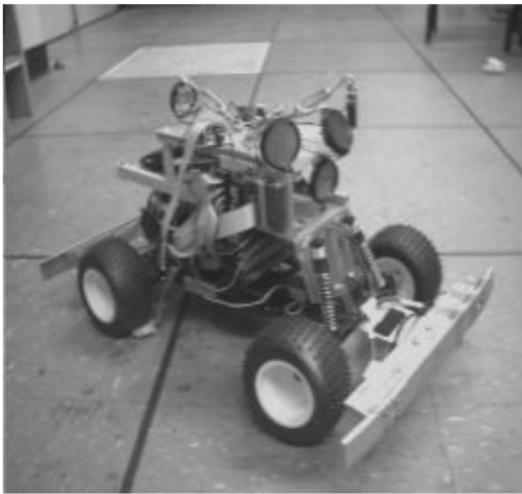
Example (Acrobat)

Goal: Raise tip above line



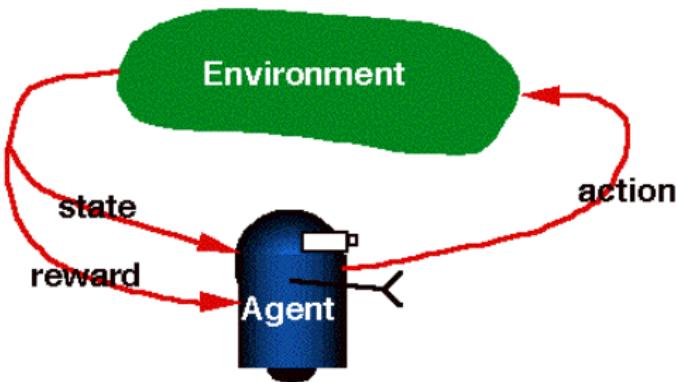
- goal: minimize time to “goal”
- state variables: 2 joint angles, 2 angular velocities
- rewards: -1 per time sweep

Example: Robotics



- **input:** sensory information and reinforcement signal
- **output:** avoid **negative** reward and try to have **positive** reward
(obstacle avoidance, wall following, etc.)

Deep Reinforcement Learning

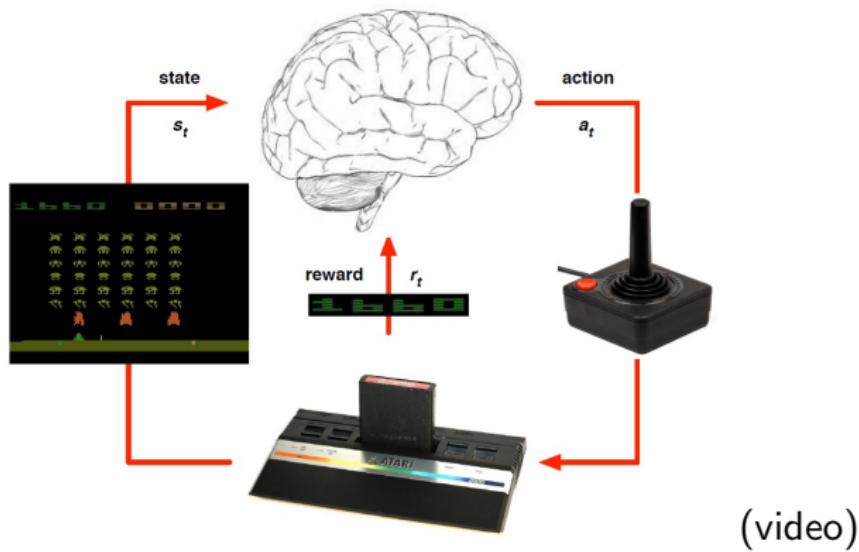


use **deep network** as agent

- → deep learning + reinforcement learning = deep reinforcement learning

Example: Game Playing

Atari



AlphaGo

Example: Game Playing...

OpenAI + Dota 2



(link, video)