Machine Learning

CS 539

Worcester Polytechnic Institute
Department of Computer Science
Instructor: Prof. Kyumin Lee

A Little About Me

- Born in South Korea
- Software Engineer at NHN from 2006-2008, South Korea
- Ph.D. at Texas A&M in 2013
- Research Internship at eBay Research Labs in 2011 and IBM Research in 2012
- Associate Professor at WPI
- Summer Research Fellow at Air Force Research Lab in 2022
- Director of Infolab: Information Retrieval, Machine Learning/AI, Natural Language Processing, Social Computing and AI for social good

Teaching Assistant (TA)

Di You

Graduate Assistant (GA)

Naitik Zaveri

Now… Your turn: group discussion

- Introduce yourself (background/hobby and any prior experience related to ML)
- Why are you taking this course?
- What’s your background/specialty?
- Anything else to share to understand each other?

Course Objectives

- Introduce
  - theory, design, and implementation of machine learning algorithms and applications.
- Study
  - supervised, unsupervised, and reinforcement learning such as regression, classification, clustering, reinforcement learning, ensemble methods and deep learning.
- Read
  - research papers and apply research results in machine learning.

Course Structure

Course Information

- Instructor
  - Kyumin Lee
  - kmlee@wpi.edu
  - Office hours: F: 1:00pm-2:00pm
  - Office: Unity Hall 363
- TA
  - Di You
  - dyou@wpi.edu
  - Office hours: T, W, Th: 11:00am-12:00pm (noon)
  - Office: Unity Hall 341
- GA
  - Naitik Zaveri
  - dyou@wpi.edu
  - No office hours but students can contact him via email or set up a meeting if necessary
- Class hours:
  - 4:00 ~ 5:20 pm T and F

Course Information

- Course web page
  - Check the course Canvas page and Schedule page
  - https://canvas.wpi.edu/

- Communication
  - Will post important announcements via Canvas mailing list
  - Send us a question via email

Course Materials

- Primary Textbook:
  - Machine Learning: The Art and Science of Algorithms That Make Sense of Data by Peter Flach

- Additional Readings will be drawn from the following books:
  - Learning From Data by Y. S. Abu-Mostafa, M. Magdon-Ismail, and H.T. Lin., AML Book
  - Machine Learning by Tom Mitchell, McGraw Hill
  - Machine Learning Lecture Notes by Andrew Ng
  - Reinforcement Learning: An Introduction by Sutton and Barto, MIT Press
  - Deep Learning with Python by François Chollet, Manning Publications
  - Selected Research Papers

Optional

- For a more advanced treatment of machine learning topics, you may read one of the following books:
  - Pattern Recognition and Machine Learning by Bishop, Springer.
  - Machine Learning: A Probabilistic Perspective by Kevin P. Murphy, MIT Press.
  - Deep Learning by Yoshua Bengio, Ian Goodfellow, and Aaron Courville.

Course Communication

- Check schedule page to understand upcoming deadlines and topics

- I will post important announcements to the Canvas page and sometimes send messages via Canvas message service
  - Make sure to check the Canvas messages or get them via email.
  - https://community.canvaslms.com/t5/Question-Forum/How-do-I-get-my-emails-in-canvas-to-be-sent-to-my-normal-email/td-p/123356

- You may email me anytime ... but I only guarantee a response within two days

- The best way to discuss general questions or share something cool stuff is to email it via Canvas mailing list.

Class Structure

- Lectures
  - By instructor -- I’ll teach machine learning techniques
  - By us - Discussion and interaction in the class

- Your part
  - Homework
    - 5 assignments
  - Exams
  - Project
    - Proposal, execution, workshop presentation

- Participation
  - Ask good questions

Grading

- 30% Assignments
- 20% Midterm
- 20% Final
- 30% Project

Assignments

- 5 assignments
  - Be familiar with Python
- Submit your solution to Canvas
- Late day policy: look at the syllabus

Midterm and Final

Exams

- The exams are closed book.

- There will be exam reviews in the previous class before the exam dates.

Project

The Project

- 4 or 5-person team

- Project idea:
  - Propose anything you wish (related to machine learning)
  - You are encouraged to talk to me

- **30% of your final grade!!**

Project Grading Criteria

- [10%] Project Proposal: March 15 by 11:59pm
- [10%] Project Website: April 30 by 11:59pm
- [10%] Project Workshop: April 30 and May 1 in-class

So far…

- Read the syllabus carefully
- Be familiar with Python for Assignments
- Form a team and notify the names of your team members by Jan 25

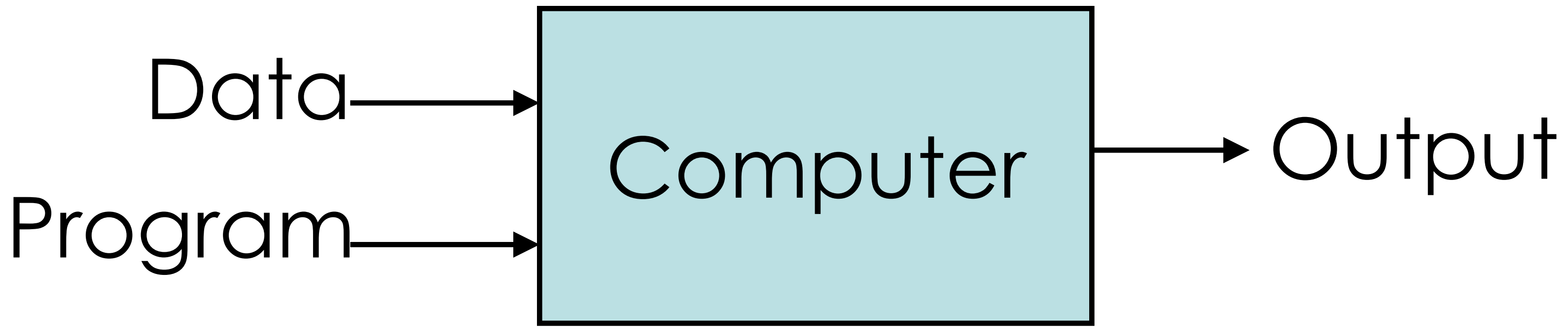
Introduction to Machine Learning

What is Machine Learning?

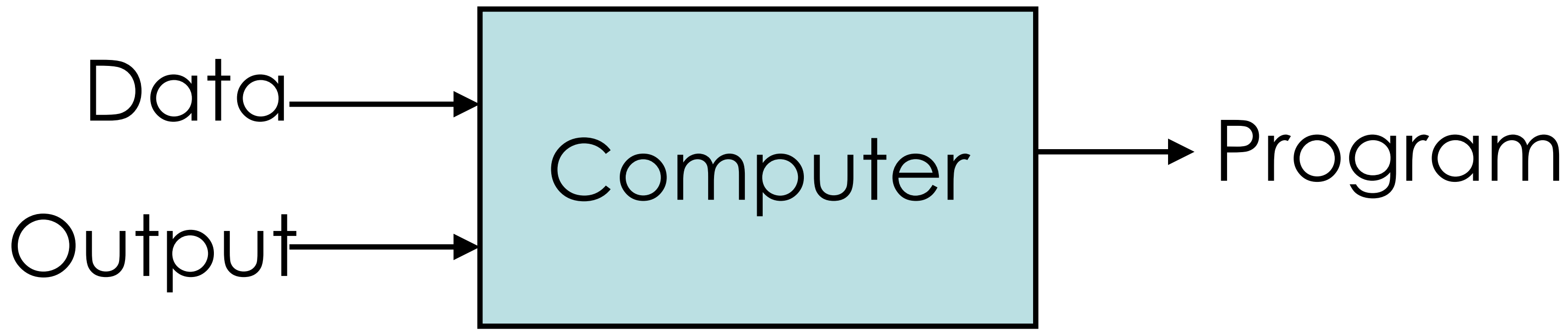
- “Learning is any process by which a system improves performance from experience.”
  - Herbert Simon

- Definition by Tom Mitchell (1998):
  - Machine Learning is the study of algorithms that
    - improve their performance *P*
    - at some task *T*
    - with experience *E*
  - A well-defined learning task is given by <*P*, *T*, *E*>.

Traditional Programming



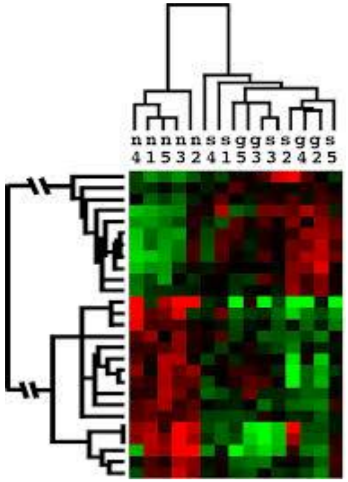
Machine Learning



When Do We Use Machine Learning?

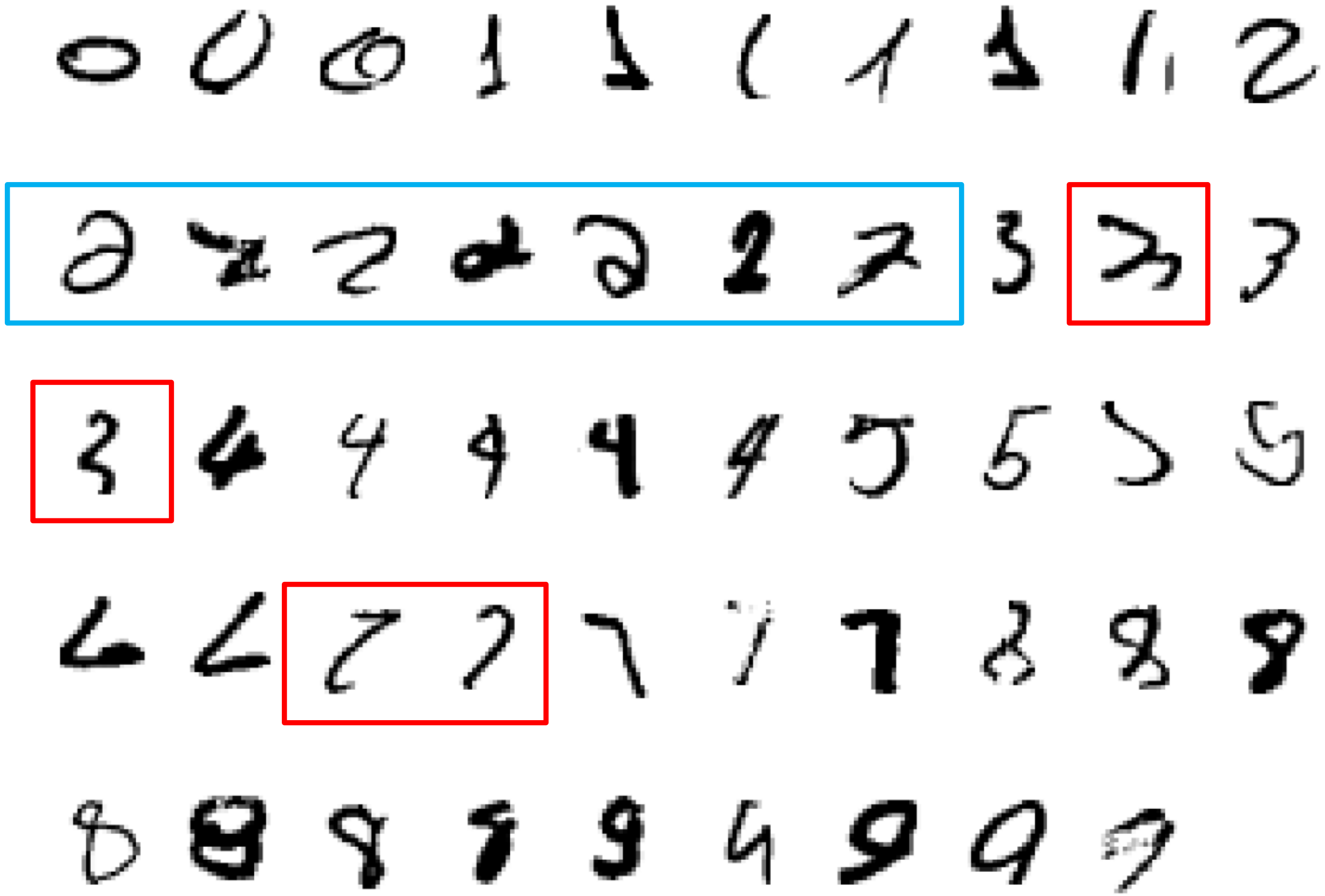
- ML is used when:
  - Human expertise does not exist (navigating on Mars)
  - Humans can’t explain their expertise (speech recognition)
  - Models are based on huge amounts of data (genomics)



- Learning isn’t always useful:
  - There is no need to “learn” to calculate payroll

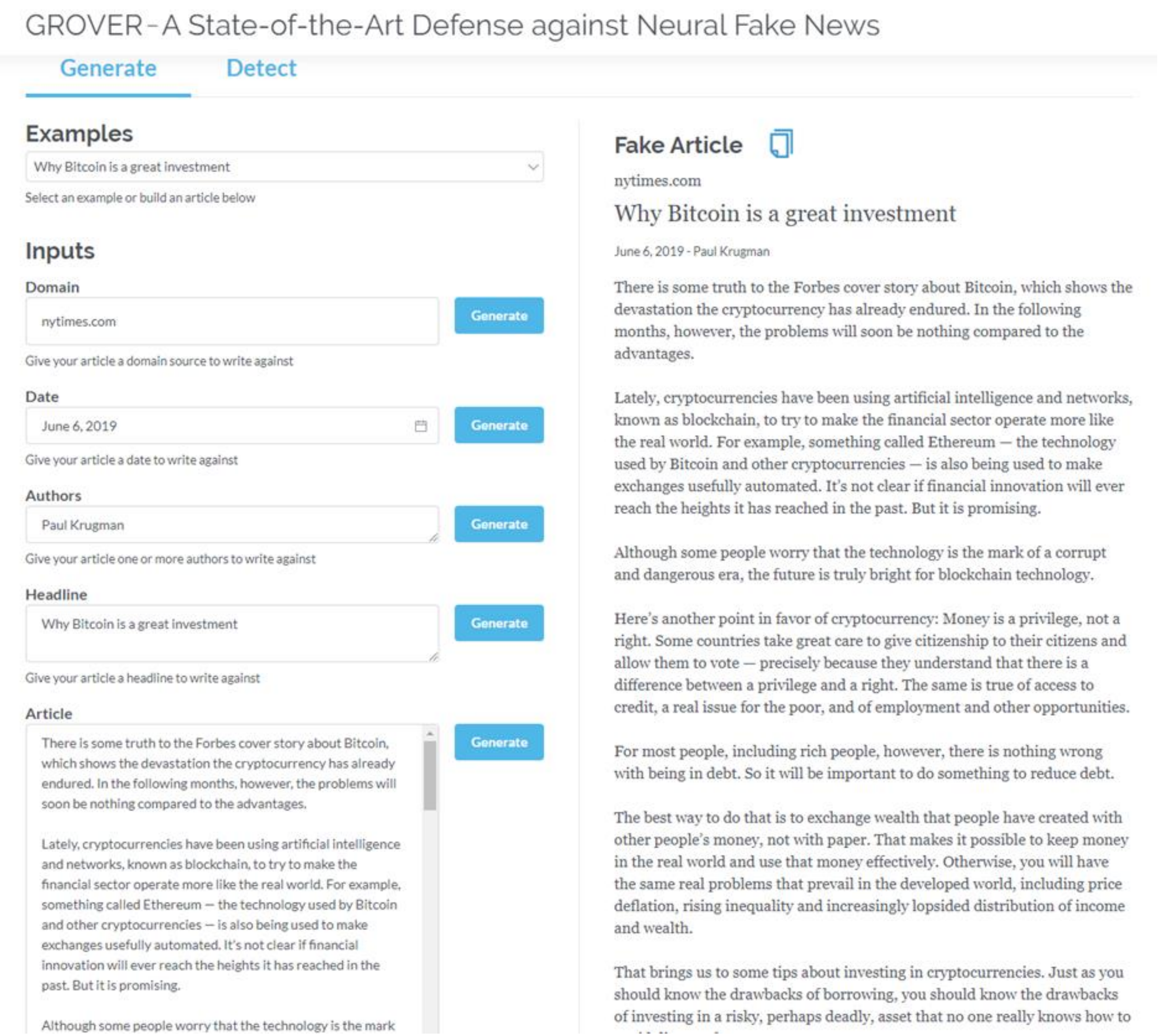
- A classic example of a task that requires machine learning:
  - It is very hard to say what makes a 2



Some more examples of tasks that are best solved by using a learning algorithm

- Recognizing patterns:
  - Facial identities or facial expressions
  - Handwritten or spoken words
  - Medical images
- Generating patterns:
  - Generating images or motion sequences
  - Generating texts

Generated bedrooms. Source: "Unsupervised Representation Learning with Deep Convolutional Generative Adversarial Networks" https://arxiv.org/abs/1511.06434v2



Paper: https://arxiv.org/abs/1905.12616   Demo: https://grover.allenai.org/

Any other ML examples/applicaitons?

Some more examples of tasks that are best solved by using a learning algorithm

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

Sample Applications

- Web search
- Computational biology
- Finance
- E-commerce
- Space exploration
- Robotics
- Information extraction
- Social networks
- Debugging software
- [Your favorite area]

Samuel’s Checkers-Player

- “Machine Learning: Field of study that gives computers the ability to learn without being explicitly programmed.” -Arthur Samuel (1959)

Defining the Learning Task

Improve on task T, with respect to
performance metric P, based on experience E

T: Playing checkers
P: Percentage of games won against an arbitrary opponent
E: Playing practice games against itself

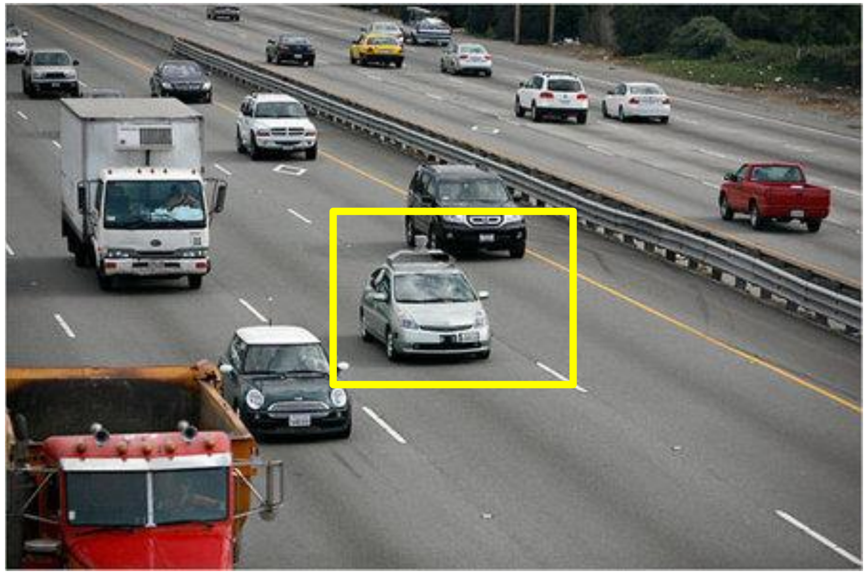
T: Recognizing hand-written words
P: Percentage of words correctly classified
E: Database of human-labeled images of handwritten words

T: Driving on four-lane highways using vision sensors
P: Average distance traveled before a human-judged error
E: A sequence of images and steering commands recorded while observing a human driver.

T: Categorize email messages as spam or legitimate.
P: Percentage of email messages correctly classified.
E: Database of emails, some with human-given labels

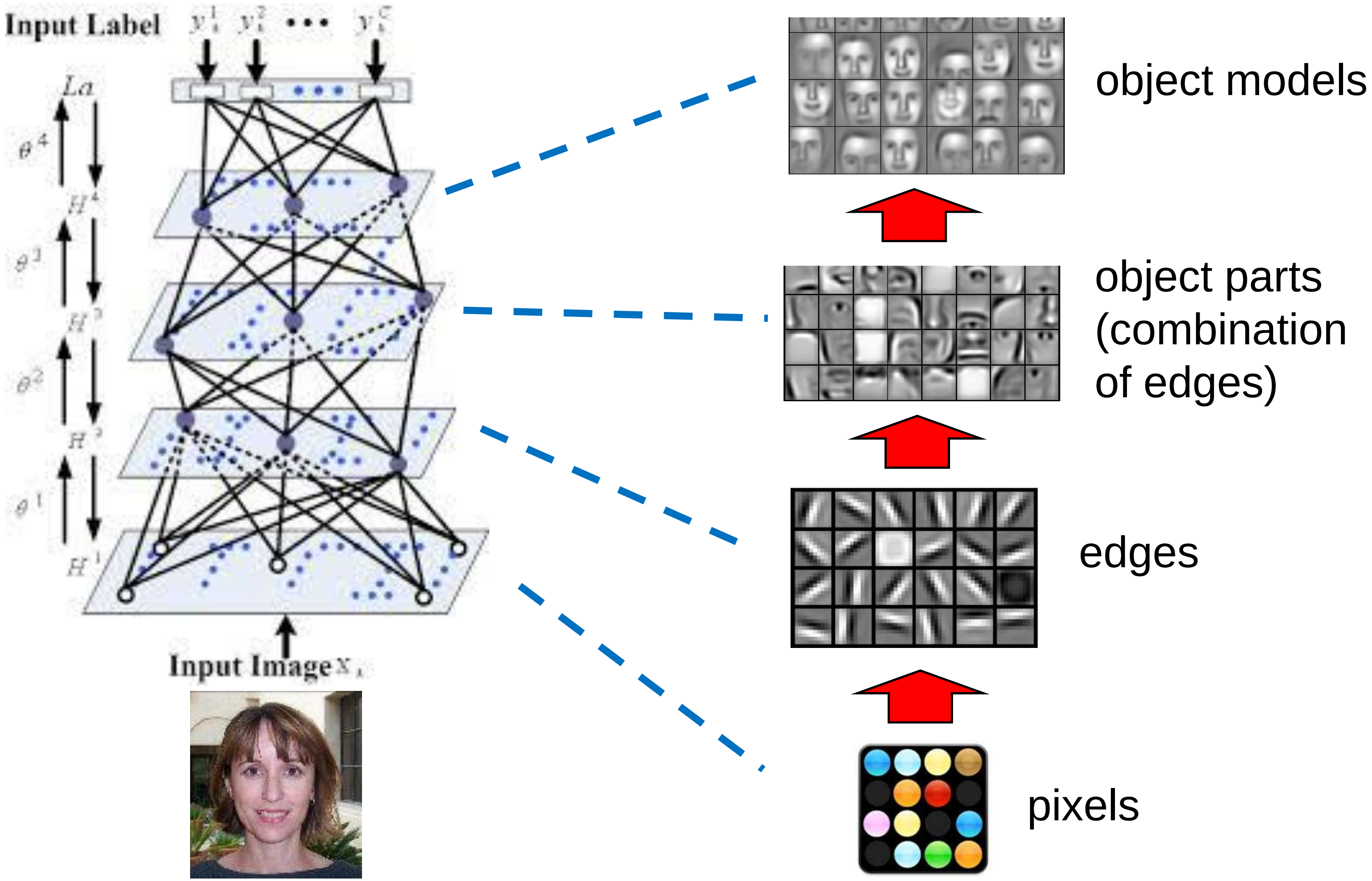
State of the Art Applications of Machine Learning

Autonomous Cars



- Nevada made it legal for autonomous cars to drive on roads in June 2011
- As of 2018, twenty-nine states have legalized autonomous cars

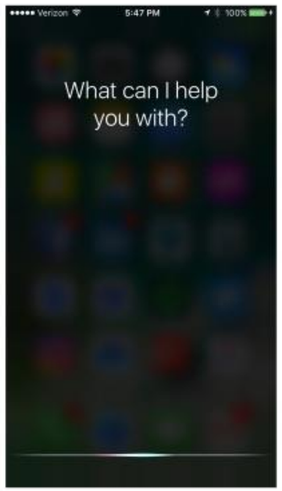
Deep Belief Net on Face Images



Digital Assistant

AMAZON'S ALEXA

GOOGLE'S ASSISTANT



APPLE'S SIRI

MICROSOFT'S CORTANA

AI/Machine Learning/Deep Learning

Forbes

EDITORS' PICK | 3,752 views | Aug 20, 2020, 01:01am EDT

Chatbots Are Machine Learning Their Way To Human Language

Adrian Bridgwater Senior Contributor

Cloud

I track enterprise software application development & data management.

Moveworks founding team from left to right Vaibhav Nivargi, CTO; Bhavin Shah, CEO; Varun Singh, VP ... [+]

MOVEWORKS

Computers and humans have never spoken the same language. Over and above speech recognition, we also need computers to understand the semantics of written

The New York Times

The Machines Are Learning, and So Are the Students

Artificial intelligence is starting to take over repetitive tasks in classrooms, like grading, and is optimizing coursework and revolutionizing the preparation for college entrance exams.

DISCOVER

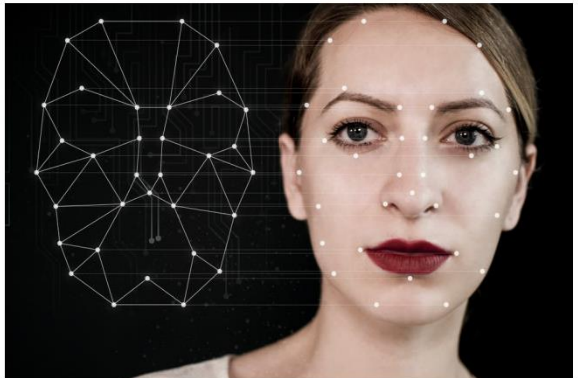
THE SCIENCES | MIND | TECHNOLOGY | HEALTH | ENVIRONMENT | PLANET EARTH

TECHNOLOGY

Deepfakes: The Dark Origins of Fake Videos and Their Potential to Wreak Havoc Online

The presence of videos and images altered with artificial intelligence are nearly doubling every six months. But the problem might be more than meets the eye.

By Jennifer Walter | August 13, 2020 12:05 PM

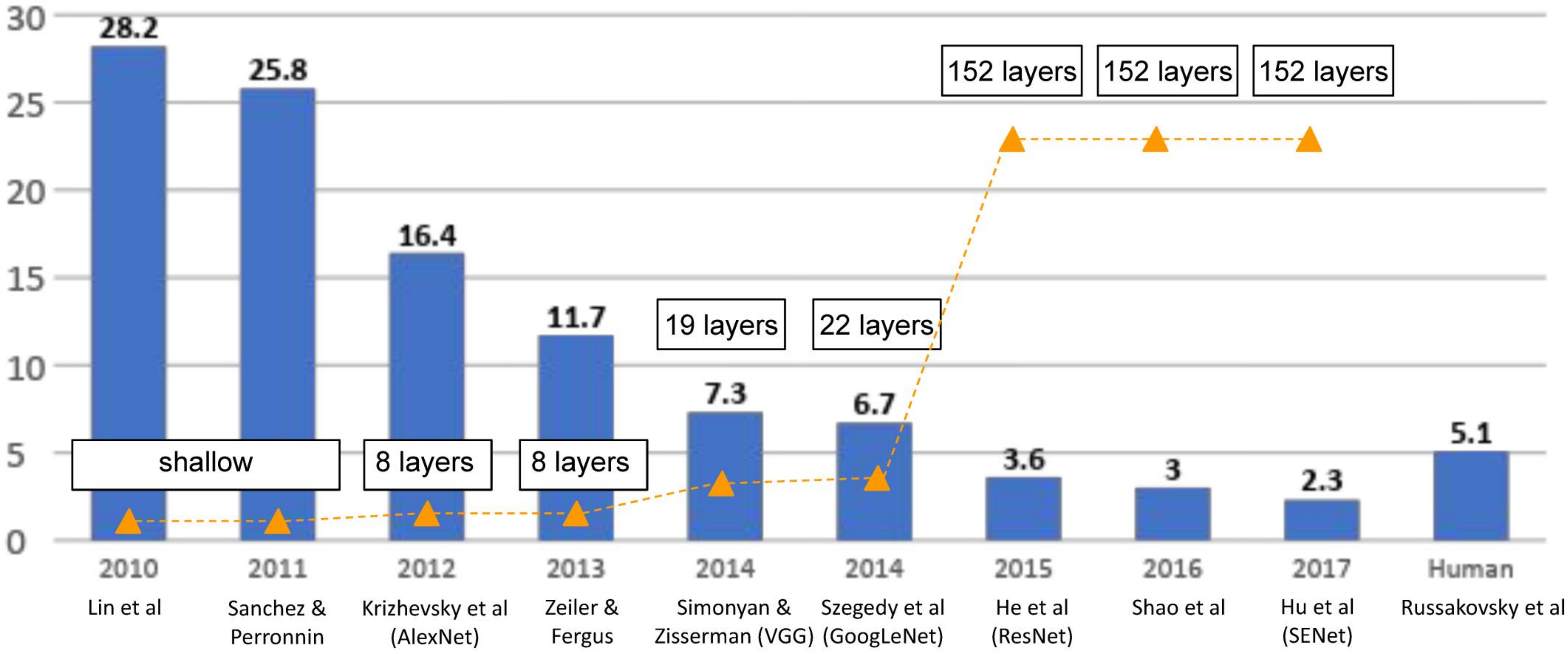


AI/Machine Learning/Deep Learning

EXCLUSIVE: Korean virtual influencer Rozy dishes on her global popularity, making "humane" connections and Hollywood plans

Rozy is Korea's first virtual influencer (Image via Sidus Studio X)

ImageNet Large Scale Visual Recognition Challenge (ILSVRC) winners



GLUE SuperGLUE Paper Code Tasks Leaderboard FAQ Diagnostics S

Rank	Name	Model	URL	Score	CoLA	SST-2	MRPC	STS-B	QQP	MNLI-m	MNLI-mm	QNL
1	Microsoft Alexander v-team	Turing ULR v6		91.3	73.3	97.5	94.2/92.3	93.5/93.1	76.4/90.9	92.5	92.1	96.7
2	JDExplore d-team	Vega v1		91.3	73.8	97.9	94.5/92.6	93.5/93.1	76.7/91.1	92.1	91.9	96.7
3	Microsoft Alexander v-team	Turing NLR v5		91.2	72.6	97.6	93.8/91.7	93.7/93.3	76.4/91.1	92.6	92.4	97.9
4	DIRL Team	DeBERTa + CLEVER		91.1	74.7	97.6	93.3/91.1	93.4/93.1	76.5/91.0	92.1	91.8	96.7
5	ERNIE Team - Baidu	ERNIE		91.1	75.5	97.8	93.9/91.8	93.0/92.6	75.2/90.9	92.3	91.7	97.3
6	AliceMind & DIRL	StructBERT + CLEVER		91.0	75.3	97.7	93.9/91.9	93.5/93.1	75.6/90.8	91.7	91.5	97.4
7	DeBERTa Team - Microsoft	DeBERTa / TuringNLRv4		90.8	71.5	97.5	94.0/92.0	92.9/92.6	76.2/90.8	91.9	91.6	99.2
8	HFL iFLYTEK	MacALBERT + DKM		90.7	74.8	97.0	94.5/92.6	92.8/92.6	74.7/90.6	91.3	91.1	97.8
9	PING-AN Omni-Sinitic	ALBERT + DAAF + NAS		90.6	73.5	97.2	94.0/92.0	93.0/92.4	76.1/91.0	91.6	91.3	97.5
10	T5 Team - Google	T5		90.3	71.6	97.5	92.8/90.4	93.1/92.8	75.1/90.6	92.2	91.9	96.9
11	Microsoft D365 AI & MSR AI & GATECH	MT-DNN-SMART		89.9	69.5	97.5	93.7/91.6	92.9/92.5	73.9/90.2	91.0	90.8	99.2
12	Huawei Noah's Ark Lab	NEZHA-Large		89.8	71.7	97.3	93.3/91.0	92.4/91.9	75.2/90.7	91.5	91.3	96.2
13	LG AI Research	ANNA		89.8	68.7	97.0	92.7/90.1	93.0/92.8	75.3/90.5	91.8	91.6	96.0
14	Zihang Dai	Funnel-Transformer (Ensemble B10-10-10H1024)		89.7	70.5	97.5	93.4/91.2	92.6/92.3	75.4/90.7	91.4	91.1	95.8
23	GLUE Human Baselines	GLUE Human Baselines		87.1	66.4	97.8	86.3/80.8	92.7/92.6	59.5/80.4	92.0	92.8	91.2

https://gluebenchmark.com/leaderboard

Types of Learning

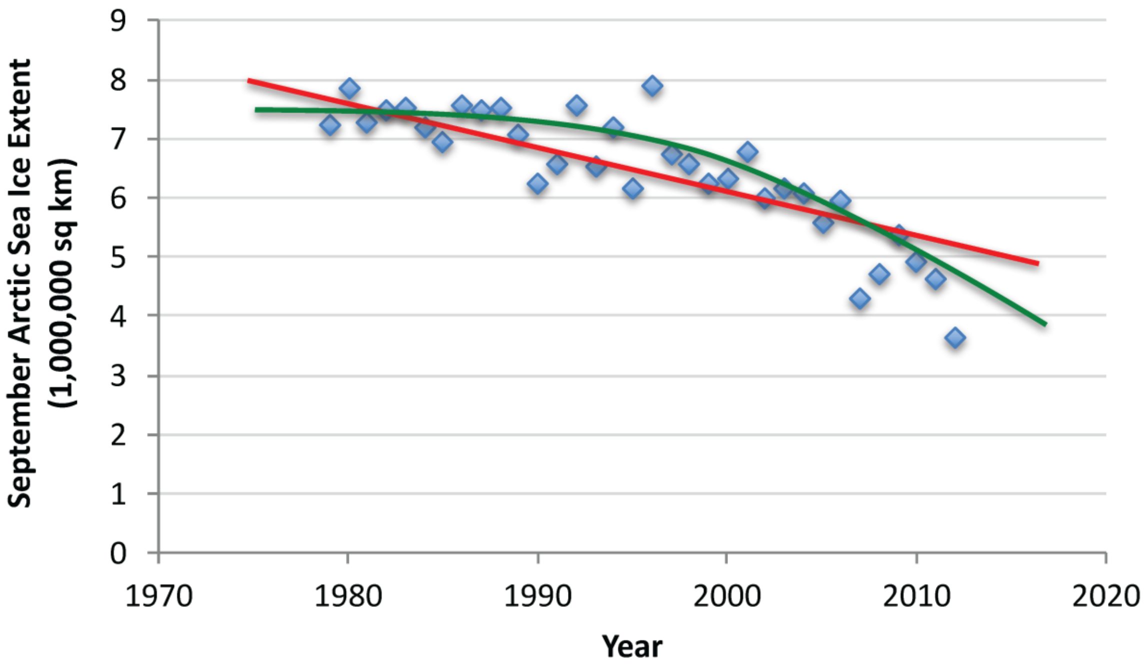
Types of Learning

- **Three Types of Major Learning**
  - **Supervised (inductive) learning**
    - Given: training data + desired outputs (labels)
  - **Unsupervised learning**
    - Given: training data (without desired outputs)
  - **Reinforcement learning**
    - Rewards from sequence of actions

- **Other Types of Learning**
  - **Semi-supervised learning**
    - Given: training data + a few desired outputs
  - **Transfer Learning**
    - A model, which is developed for a task, is reused as the starting point for a model on a second task
      - E.g., Resnet, BERT

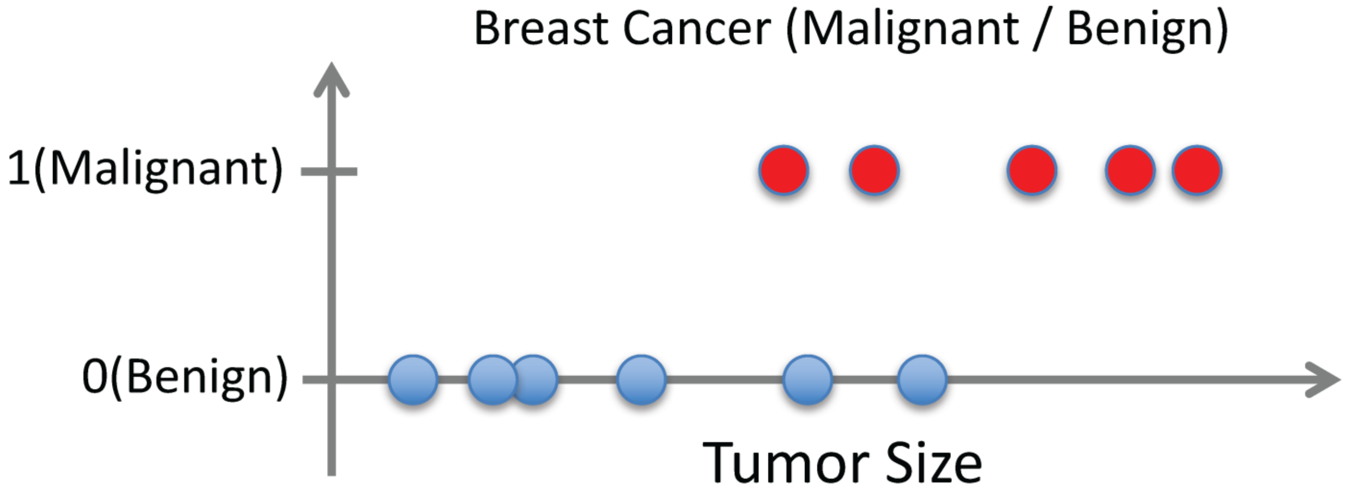
Supervised Learning: Regression

- Given $(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)$
- Learn a function $f(x)$ to predict y given x
  - y is real-valued == regression



Supervised Learning: Classification

- Given $(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)$
- Learn a function $f(x)$ to predict y given x
  - y is categorical == classification



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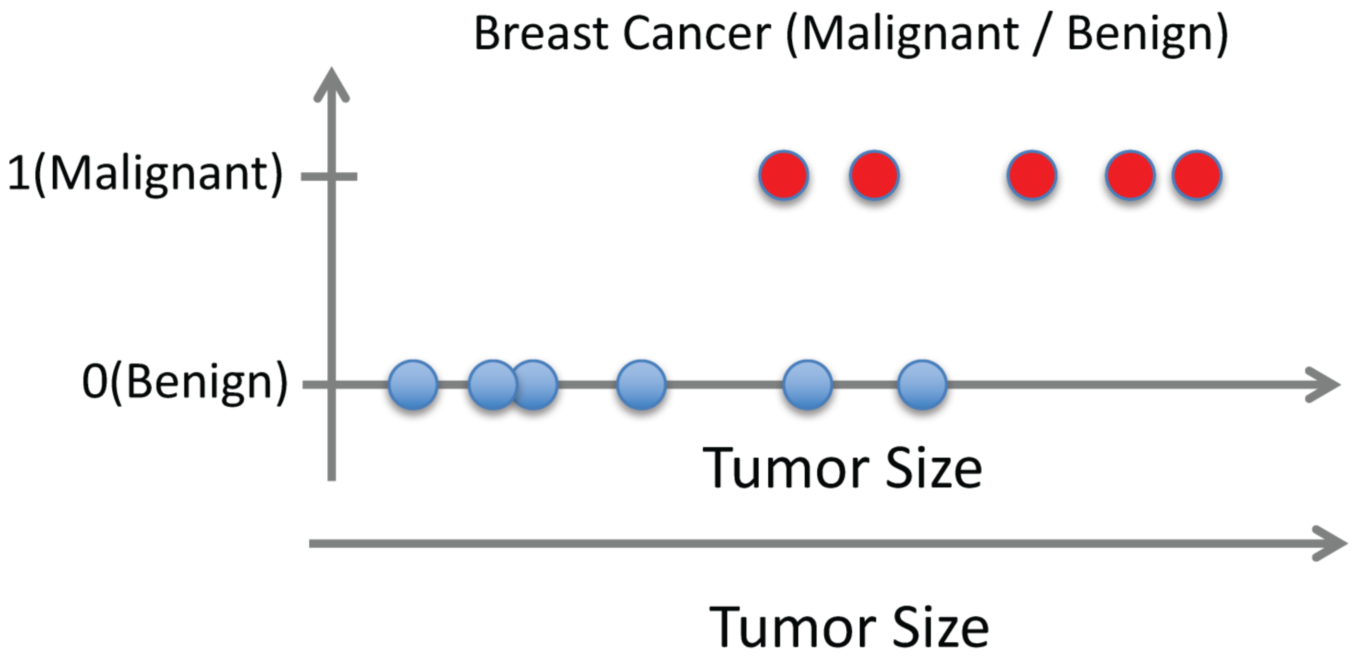

Supervised Learning: Classification

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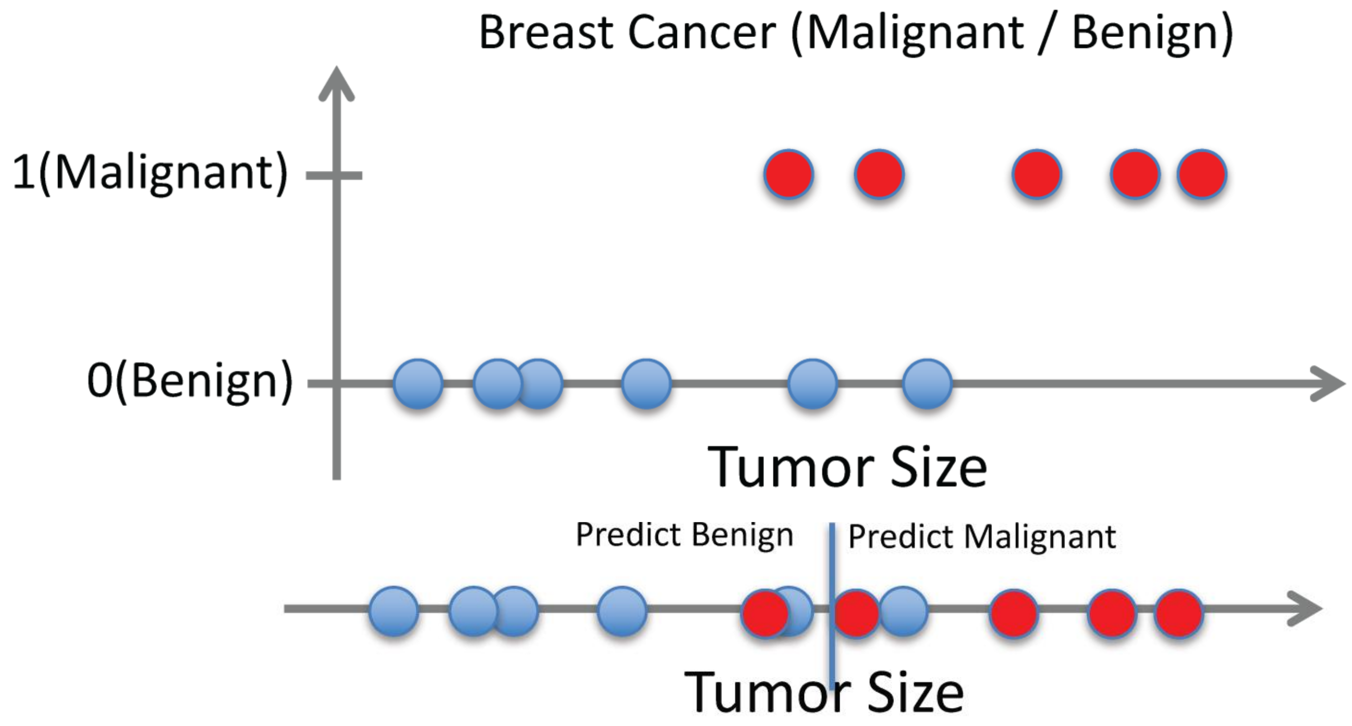
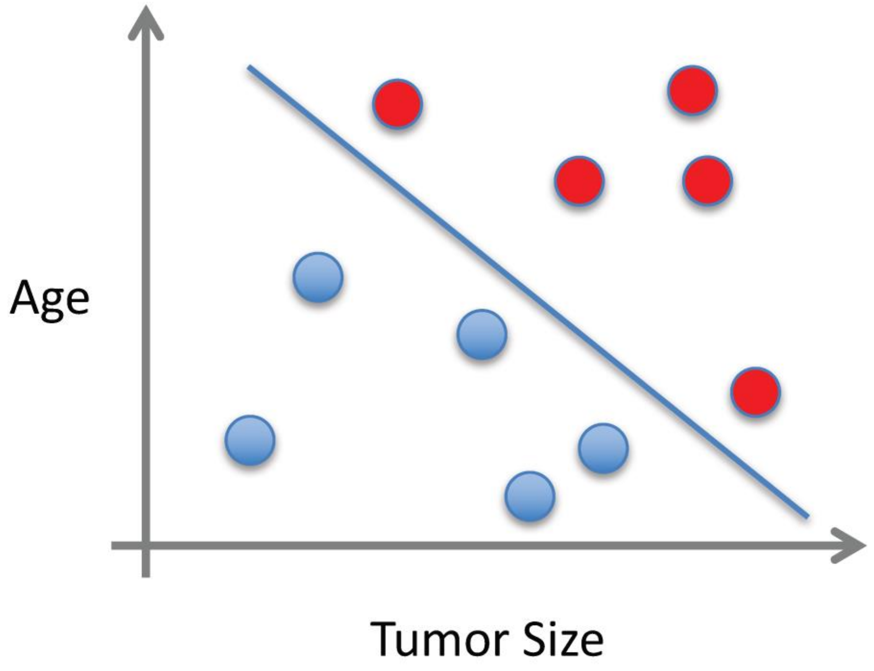


Supervised Learning

- x can be multi-dimensional
  - Each dimension corresponds to an attribute

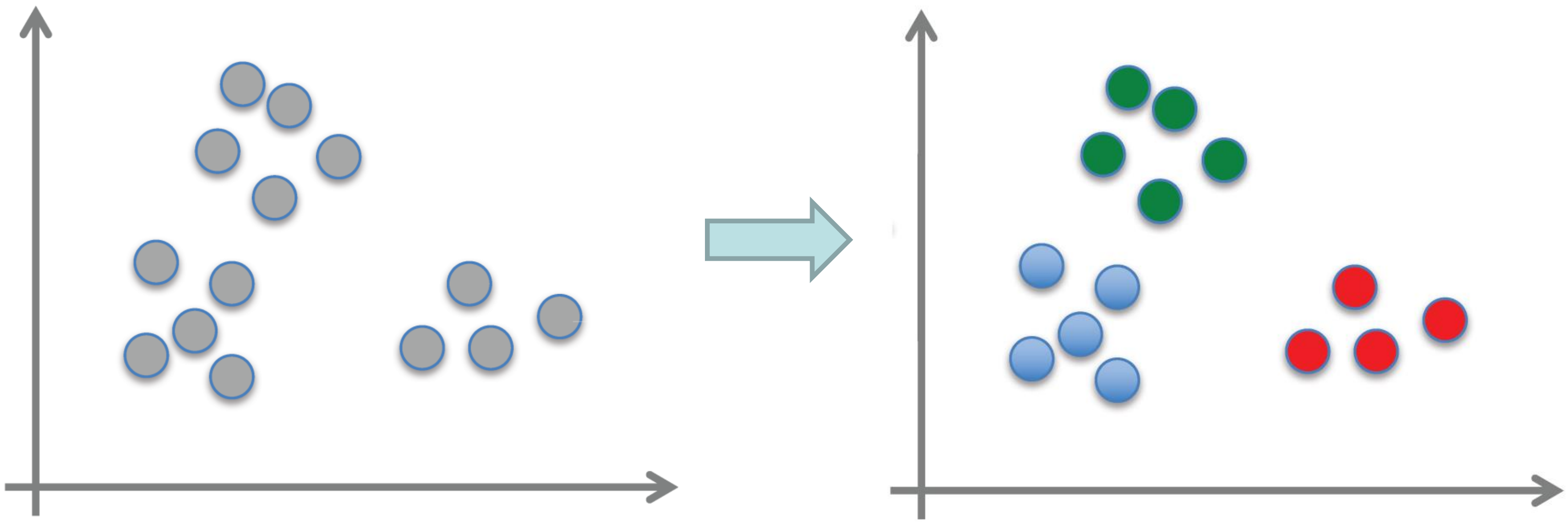


- Clump Thickness
- Uniformity of Cell Size
- Uniformity of Cell Shape

…

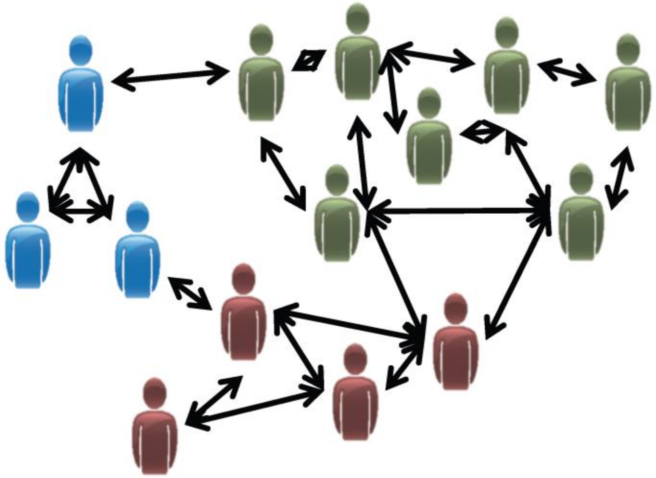
Unsupervised Learning

- Given $x_1, x_2, \ldots, x_n$ (without labels)
- Output hidden structure behind the x's
  - E.g., clustering



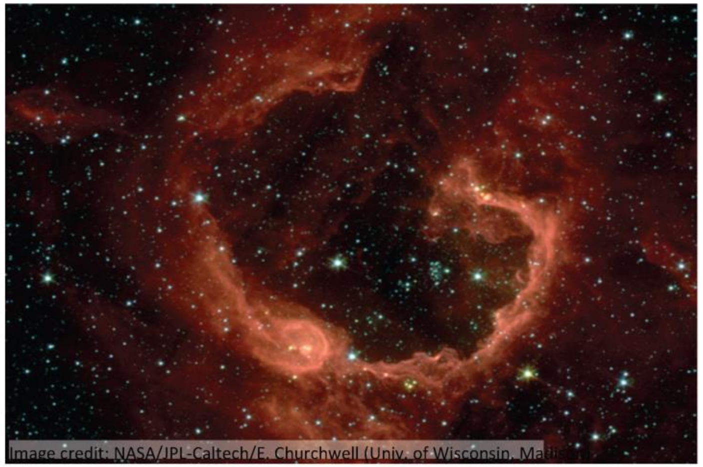
Unsupervised Learning

Organize computing clusters



Social network analysis

Market segmentation

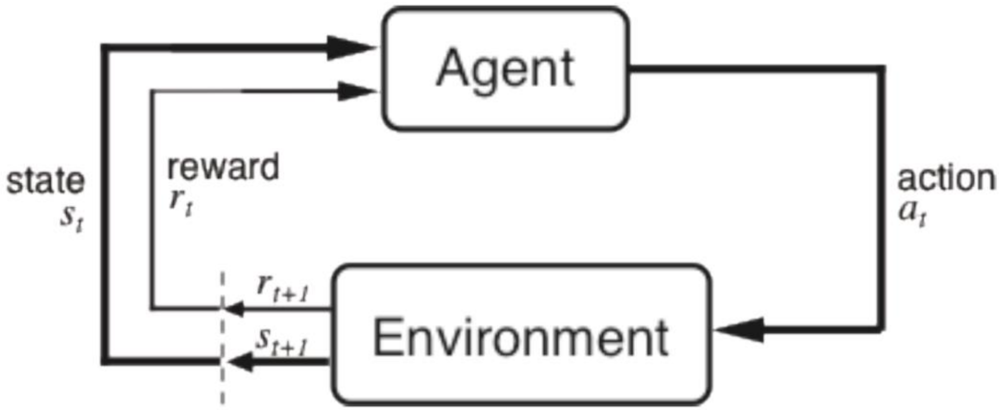


Astronomical data analysis

Reinforcement Learning

- Given a sequence of states and actions with (delayed) rewards, output a policy
  - Policy is a mapping from states → actions that tells you what to do in a given state
- Examples:
  - Game playing (e.g., Go!)
  - Robot in a maze
  - Balance a pole on your hand

The Agent-Environment Interface



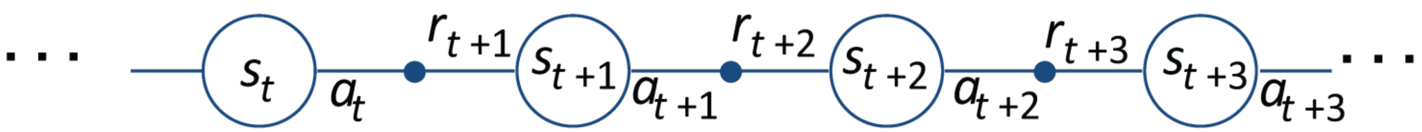
Agent and environment interact at discrete time steps : $t = 0, 1, 2, K$

Agent observes state at step t: $s_t \in S$

produces action at step t: $a_t \in A(s_t)$

gets resulting reward : $r_{t+1} \in \Re$

and resulting next state : s_{t+1}



Reinforcement Learning

https://www.youtube.com/watch?v=4cgWya-wjgY