上海交通大學

SHANGHAI JIAO TONG UNIVERSITY

上海交通大学

约翰·霍普克罗夫特计算机科学中心

John Hopcroft Center for Computer Science

CS410: Artificial Intelligence

Shuai Li

John Hopcroft Center, Shanghai Jiao Tong University

https://shuaili8.github.io

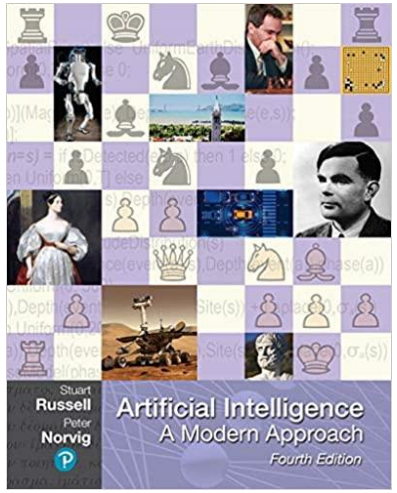
https://shuaili8.github.io/Teaching/CS410/index.html

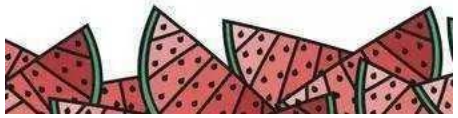
Teaching Assistant

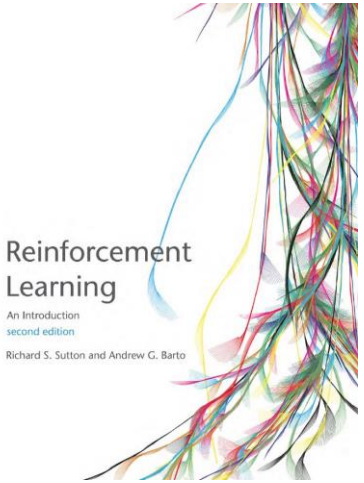
- Fang Kong (孔芳)
  - Email: fangkong@sjtu.edu.cn
  - 1st year PhD student
  - Research on online influence maximization
  - Office hour: Thursday 6-8pm
- Qizhi Li (李奇之)
  - Email: qizhili@sjtu.edu.cn
  - 1st year Master student
  - Research on recommendation systems
  - Office hour: Friday 7-9pm

References (will add more during course)

- Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norvig (4th edition)
- Reinforcement Learning: An Introduction by Richard S. Sutton and Andrew G. Barto
- 周志华《机器学习》清华大学出版社，2016.







Goal

- Know what is AI and what it usually covers
- Familiar and understand popular AI problems and algorithms
- Be able to build AI models in applications
  - Know which algorithms to adopt and when to adopt
- Get a touch of top research

Prerequisites

- Basic computer science principles
  - Big-O notation
  - Comfortably write non-trivial code in Python/numpy
- Probability
  - Random Variables
  - Expectations
  - Distributions
- Linear Algebra & Multivariate/Matrix Calculus
  - Gradients and Hessians
  - Eigenvalue/vector

Slide credit: Anand Avati

Grading

- Attendance and participance: 5%
- Assignments: 35%
- Project 1: 25% (individual project)
- Project 2: 35% (team project)

Honor code

- Discussions are encouraged
- Independently write-up homework and code
- Same reports and homework will be reported

Course Outline

- Search
- CSP problems
- Game trees
- ML: perceptrons and NNs
- HMMs
- MDPs
- Particle filtering

Introduction

What is Artificial Intelligence

- Describe machines (or computers) that mimic "cognitive" functions that humans associate with the human mind, such as "learning" and "problem solving".

  --Russell, S. J., & Norvig, P. (2016). *Artificial intelligence: a modern approach*. Malaysia; Pearson Education Limited.

- Intelligence is the computational part of the ability to achieve goals in the world. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.

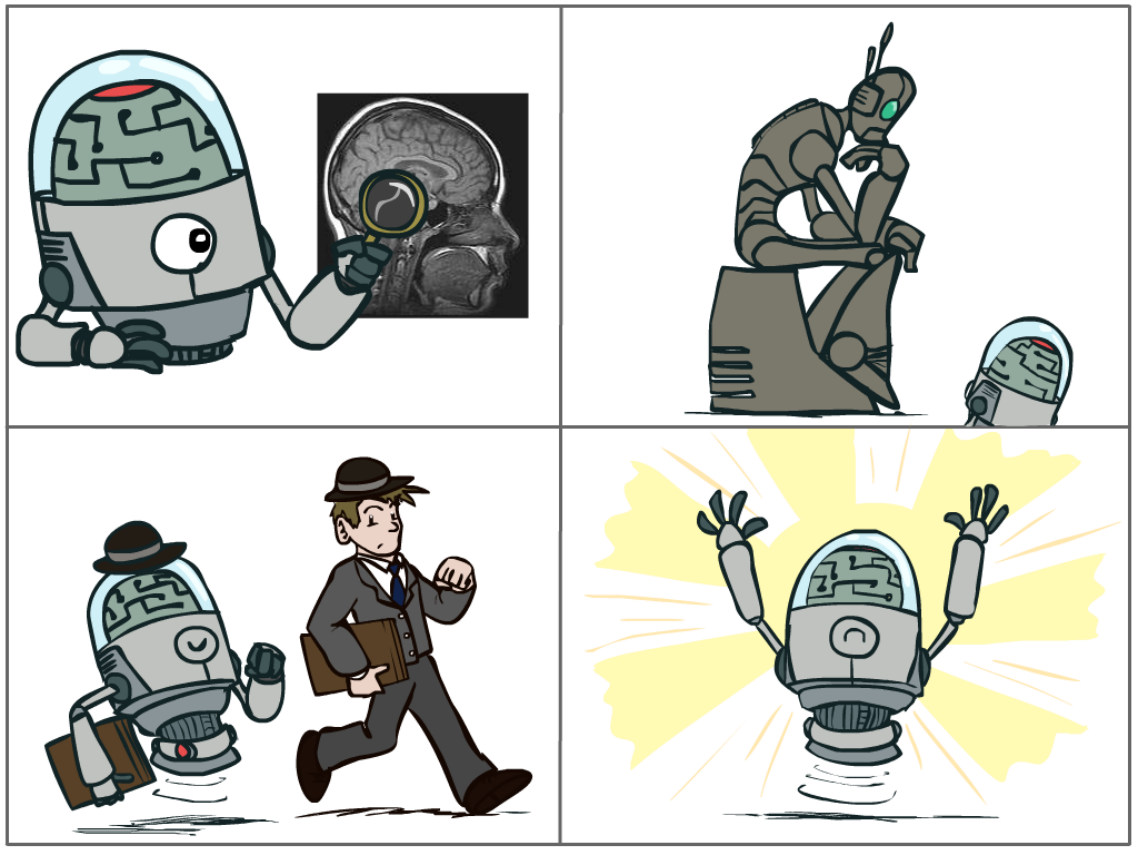
  --By Prof. John McCarthy of Stanford University

  -- http://jmc.stanford.edu/artificial-intelligence/what-is-ai/index.html

What is AI?

The science of making machines that:

Think like people

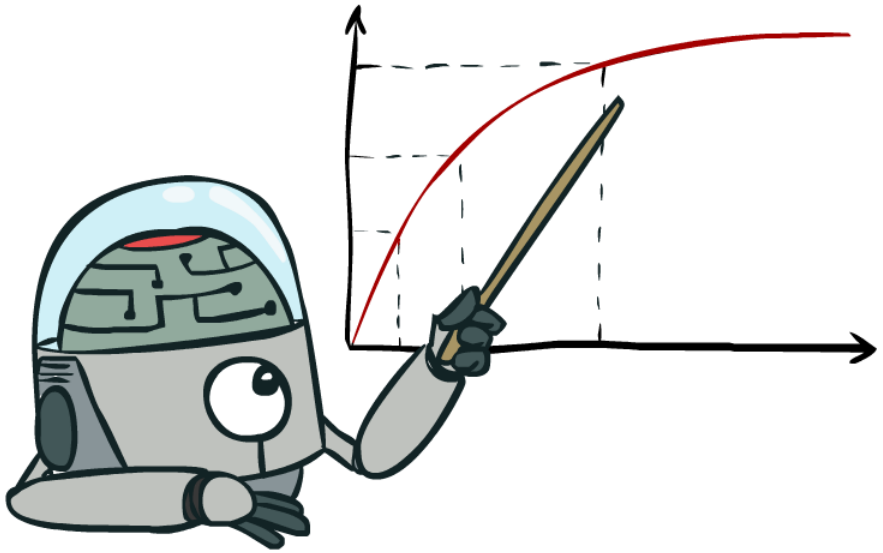


Think rationally

Act like people

Act rationally

Maximize Your Expected Utility

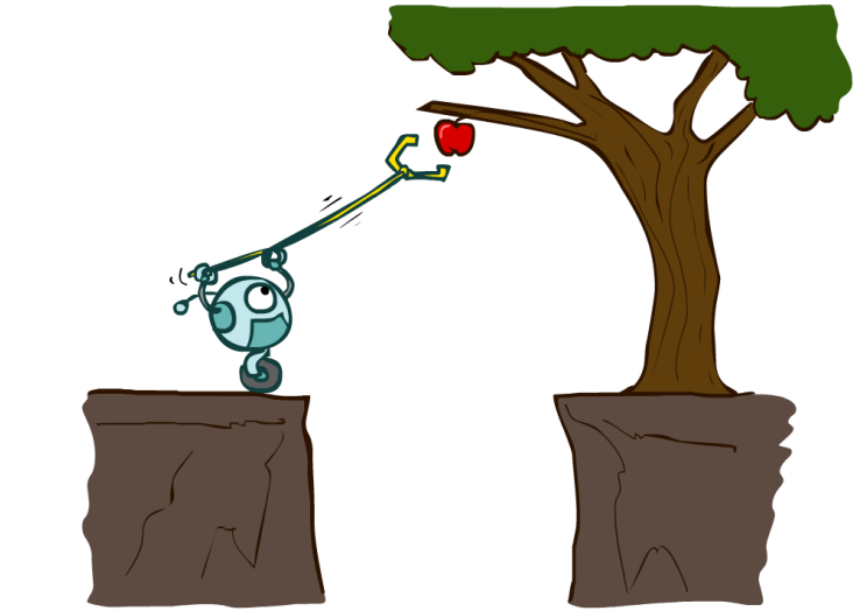


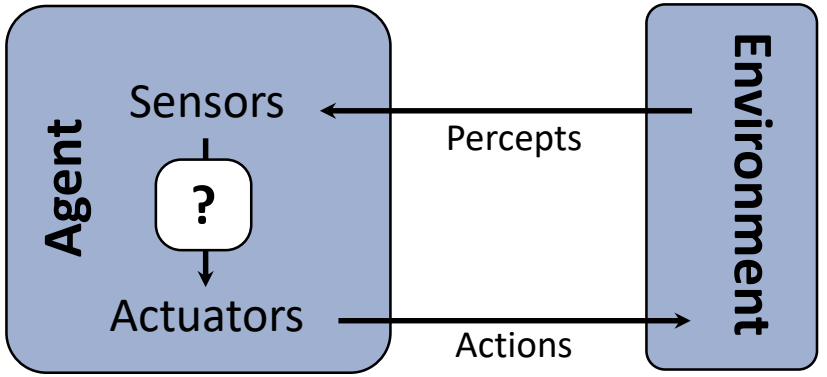
What About the Brain?

- Brains (human minds) are very good at making rational decisions, but not perfect
- Brains aren't as modular as software, so hard to reverse engineer!
- "Brains are to intelligence as wings are to flight"
- Lessons learned from the brain: memory and simulation are key to decision making

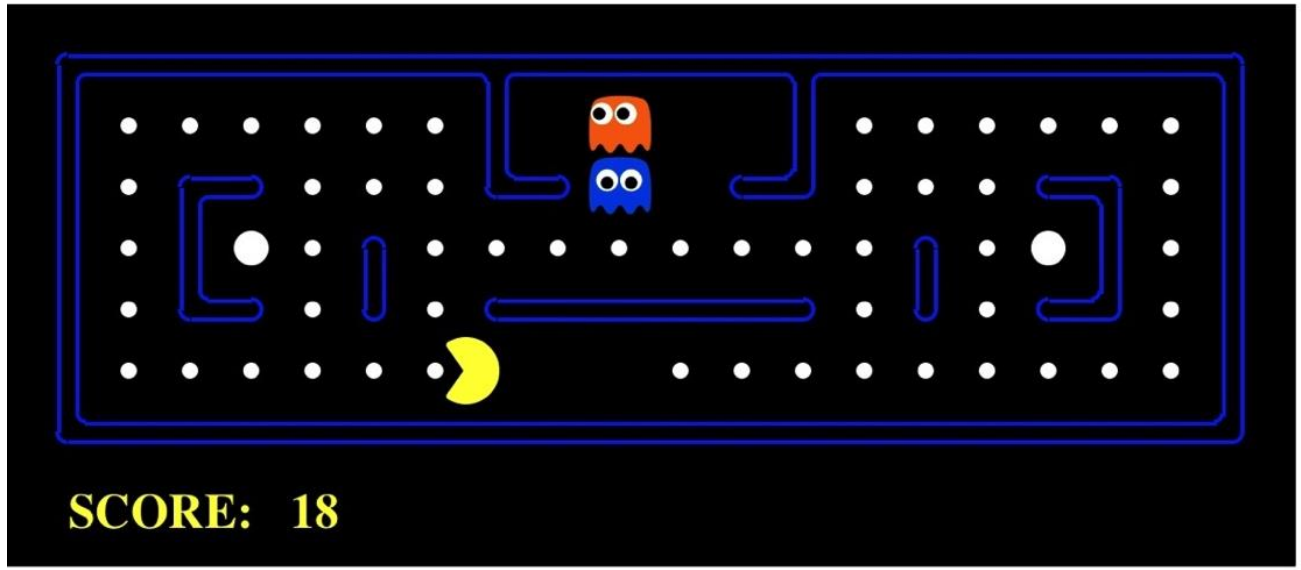
Designing Rational Agents

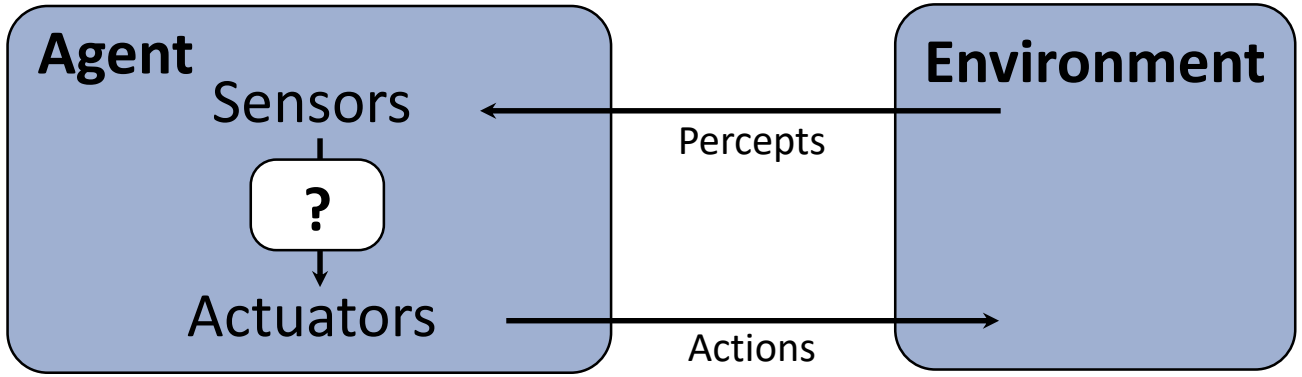
- An **agent** is an entity that *perceives* and *acts*.
- A **rational agent** selects actions that maximize its (expected) **utility**.
- Characteristics of the **percepts, environment,** and **action space** dictate techniques for selecting rational actions
- **This course** is about:
  - General AI techniques for a variety of problem types
  - Learning to recognize when and how a new problem can be solved with an existing technique





Pac-Man as an Agent





Pac-Man is a registered trademark of Namco-Bandai Games, used here for educational purposes

Demo1: pacman-l1.mp4

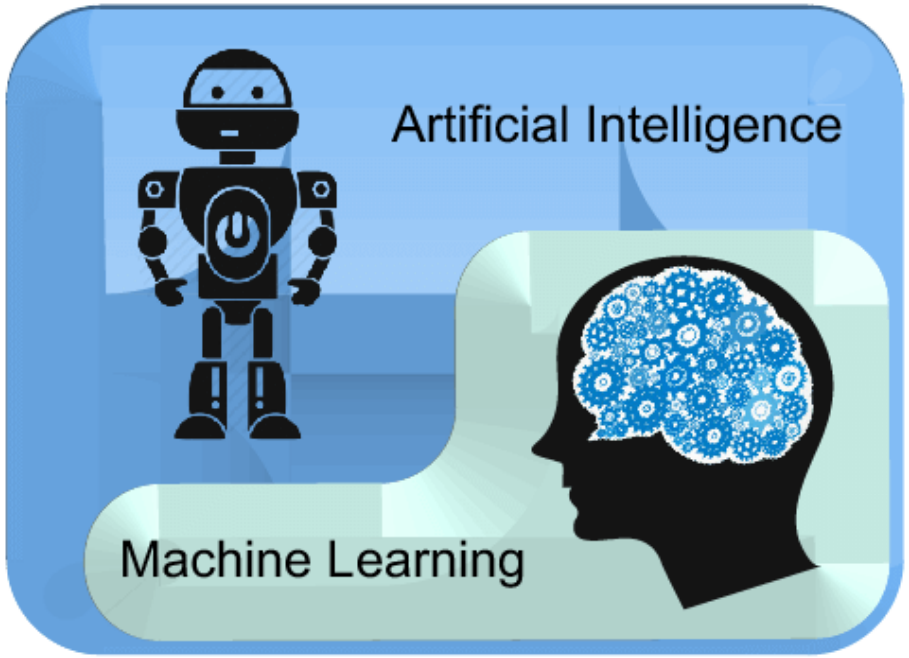
What is Machine Learning

- Term “Machine Learning” coined by Arthur Samuel in 1959.
  - Samuel Checkers-playing Program
- Common definition (by Tom Mitchell):
  - ***Machine Learning is the study of computer algorithms that improve automatically through experience***
- Subfield of Artificial Intelligence (AI)
  - The hottest subfield - reinvigorated interest in AI due to deep learning!

Slide credit: Anand Avati

Difference between AI and ML

- AI is a bigger concept to create intelligent machines that can simulate human thinking capability and behavior, whereas, machine learning is an application or subset of AI that allows machines to learn from data without being programmed explicitly.



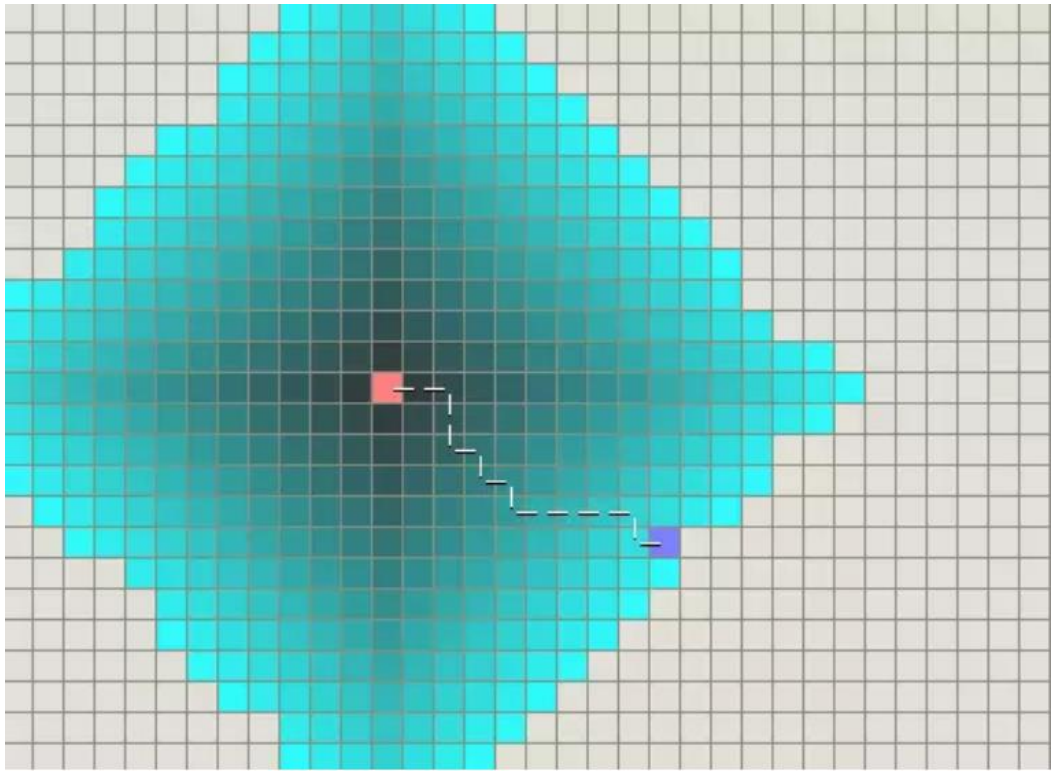
An example of AI but is not machine learning

- A* search algorithm
  - Objective: Find the shortest path between two nodes of a weighted graph
  - Use heuristic information

- Compare with Breadth First Searching and Greedy Searching

Breadth First Searching

- Pink: start point, Purple: end point;
- Blue: visited points, the darker the earlier



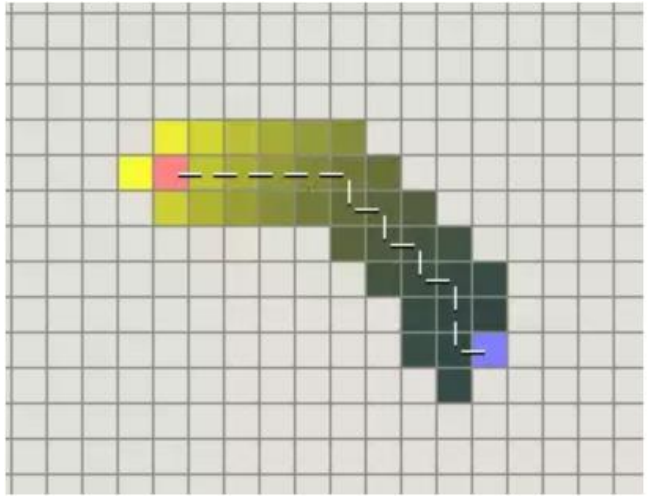
Each time it visits, or expand the point with least $g(n)$ value

- $g(n)$ is the distance from start point to point n.

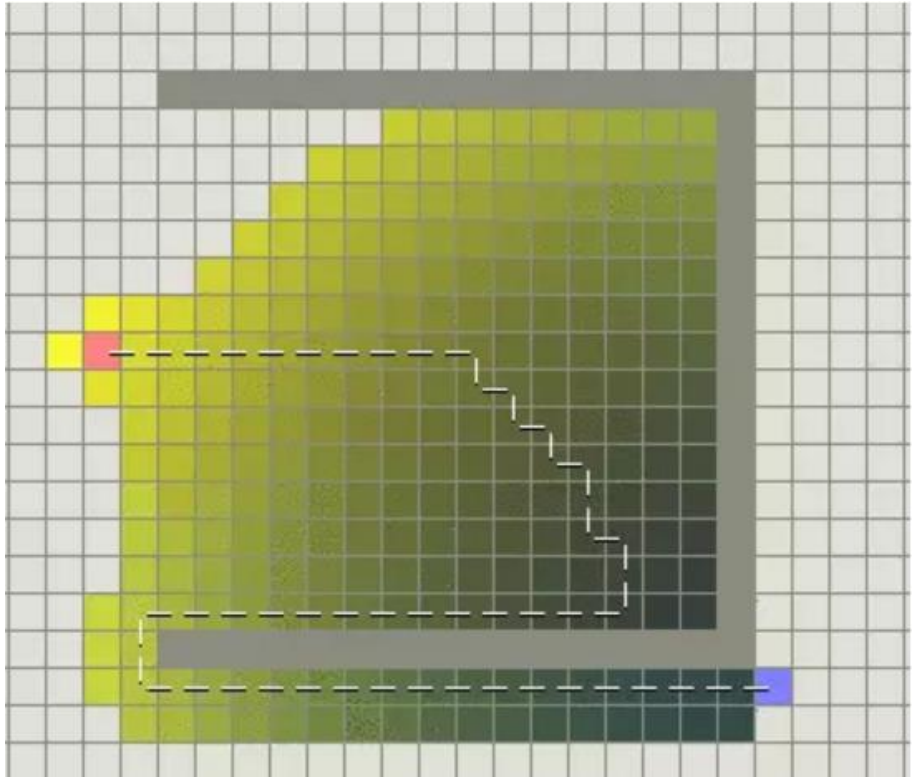
Short comings: computing burden is too high, it visited too many points before getting the end point.

Greedy Searching

- Each time it visit or expand the point with least $h(n)$ value
  - $h(n)$ is the distance from point n to end point. It works fine when there is no obstacles.

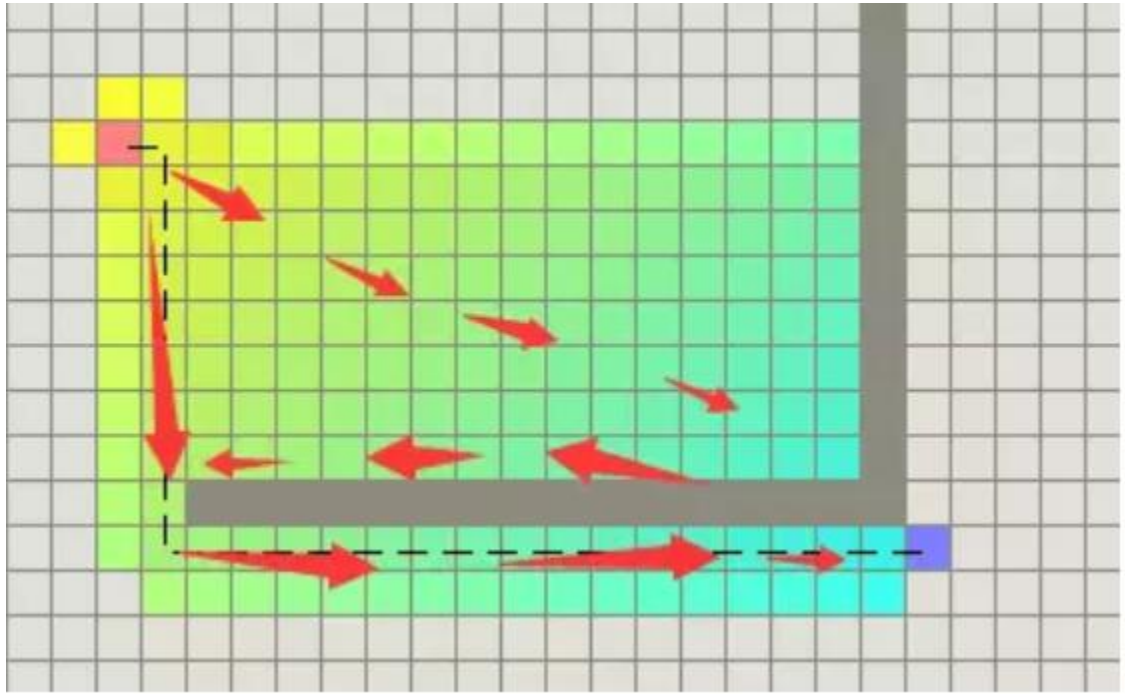


- The cost doubles when there is obstacles



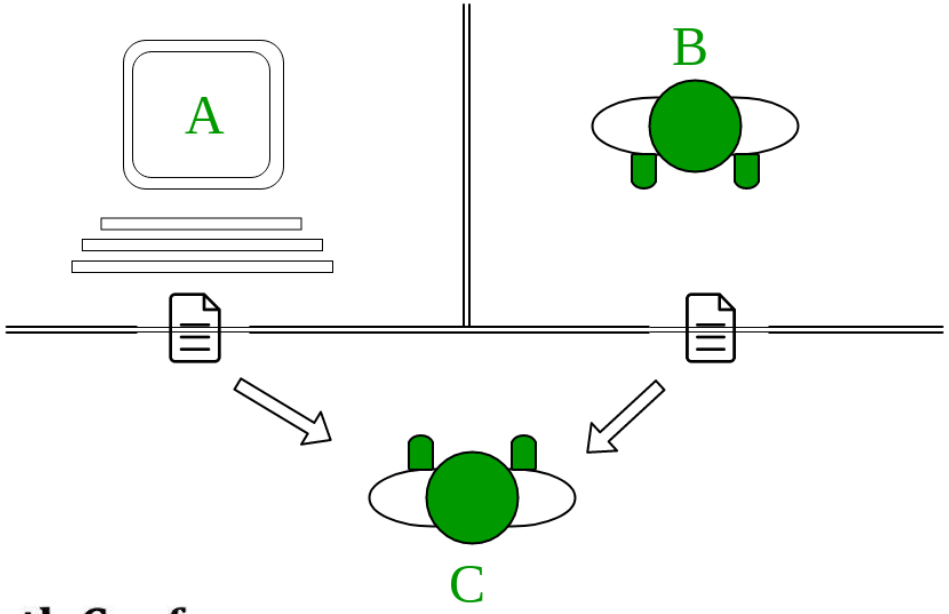
A* algorithm

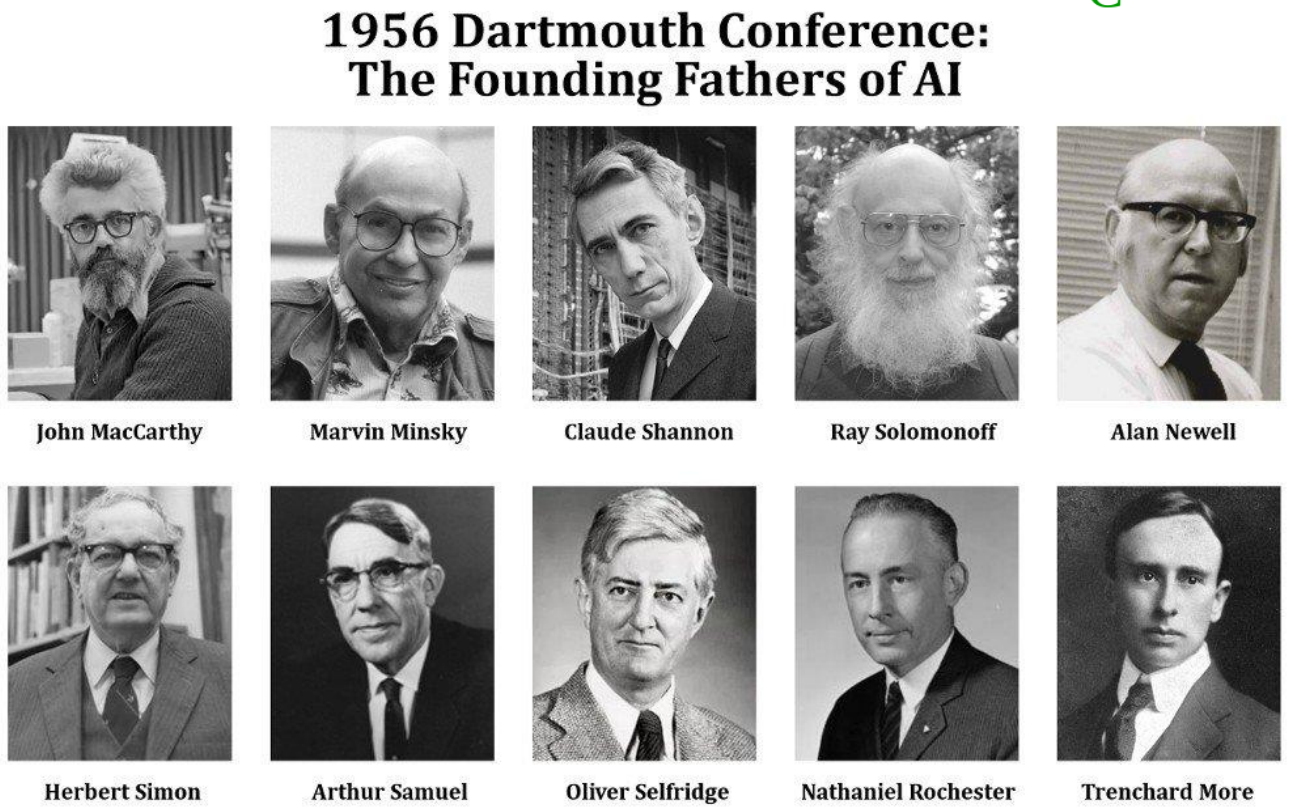
- It combines the stability of BFS and the heuristics in greedy searching.
- Each time it visits point with the least $f(n) = g(n) + h(n)$ value.



History of AI

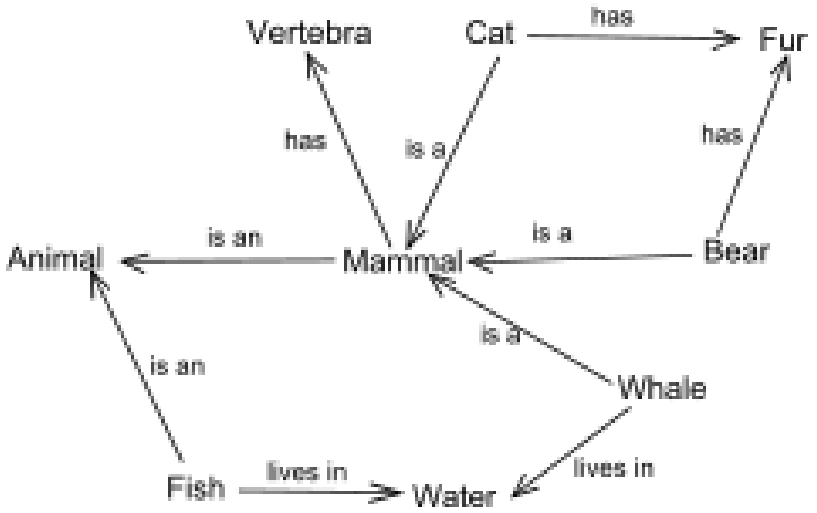
- 1950s
  - Turing's test
  - Dartmouth Conference 1956: the birth of AI





History of AI (cont.)

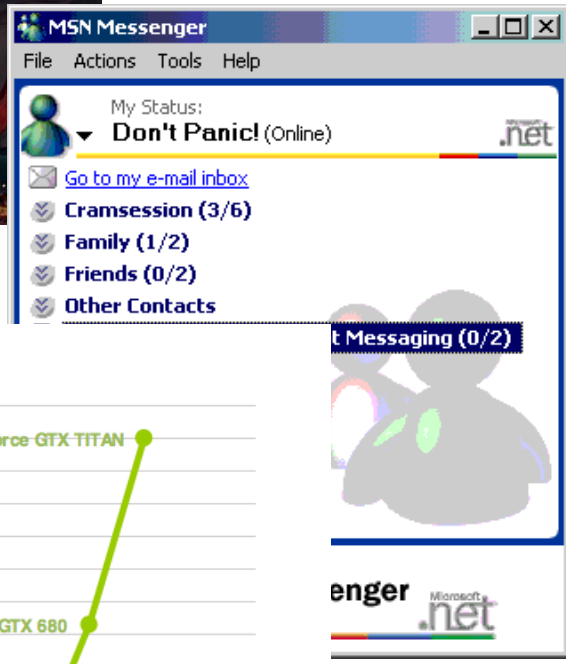
- 1960s
  - Reasoning as search
  - Natural language
    - STUDENT by Daniel Bobrow
      - Can solve high school algebra word problems
      - Semantic net
  - Micro-worlds
    - Marvin Minsky and Seymour Papert of the MIT AI Lab
    - Basic principles, simplified models



History of AI (cont.)

- 1970s - first AI winter
  - Limited computer power
  - Intractability and the combinatorial explosion
  - Commonsense knowledge and reasoning
    - Hard to encode so many concepts and rules
    - Didn’t know how to teach computers to learn these
- 1980s - Boom
  - Expert system
    - Specific domains to limit knowledge requirements
- 1990s - second AI winter
  - Expectations are far beyond reality

History of AI (cont.)



- 2000s
  - Deep Blue
    - first computer chess-playing system to beat a reigning world chess champion, Garry Kasparov
  - Intelligent agents
    - e.g. detect spam emails
- 2010-now
  - Deep learning
  - Big data
  - Artificial general intelligence (AGI)

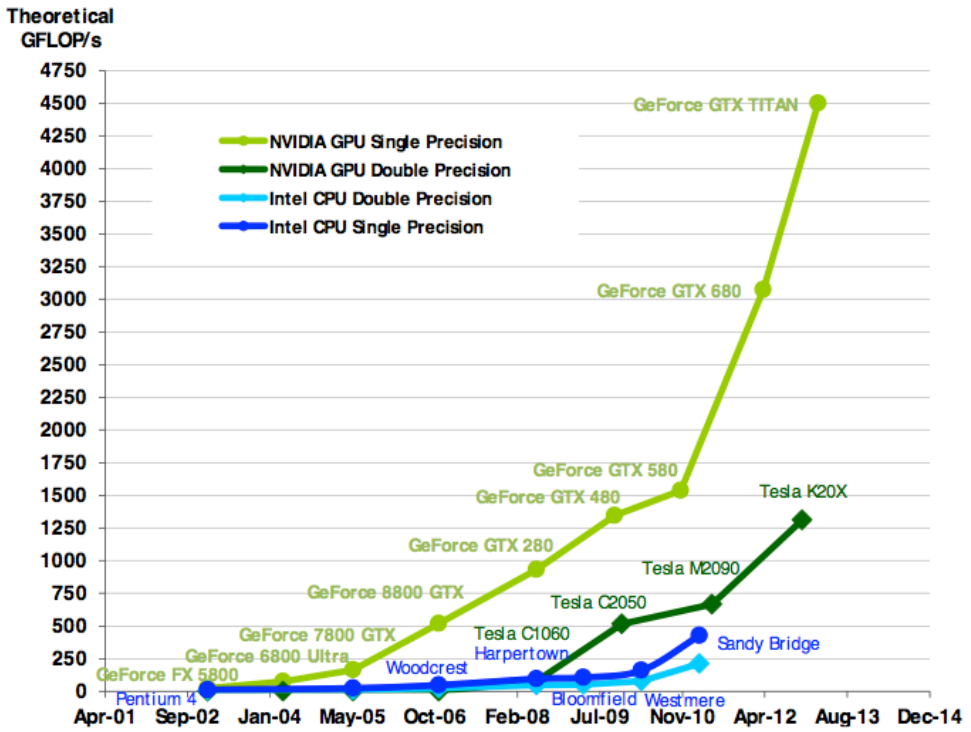
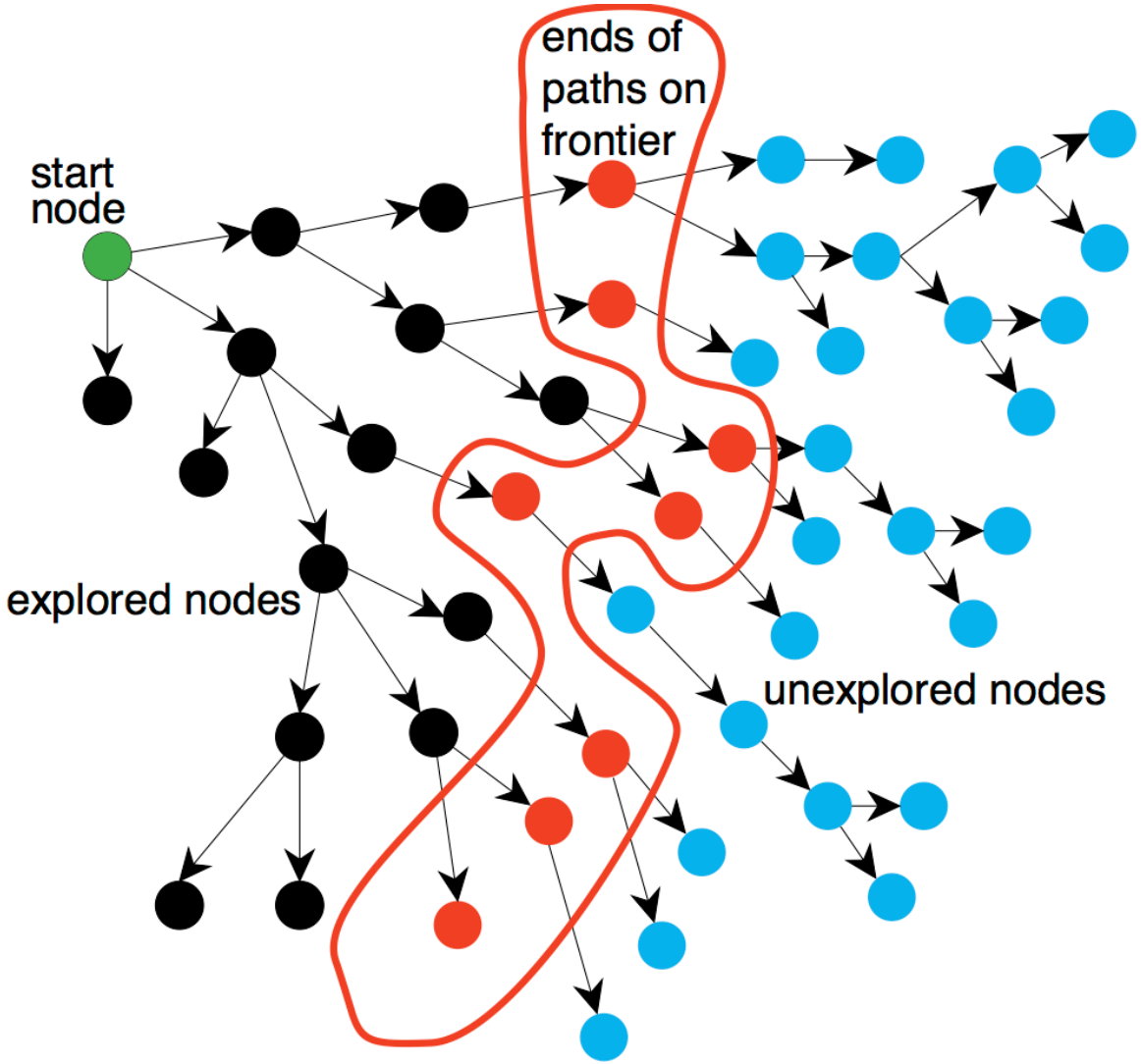


Figure 1 Floating-Point Operations per Second for the CPU and GPU

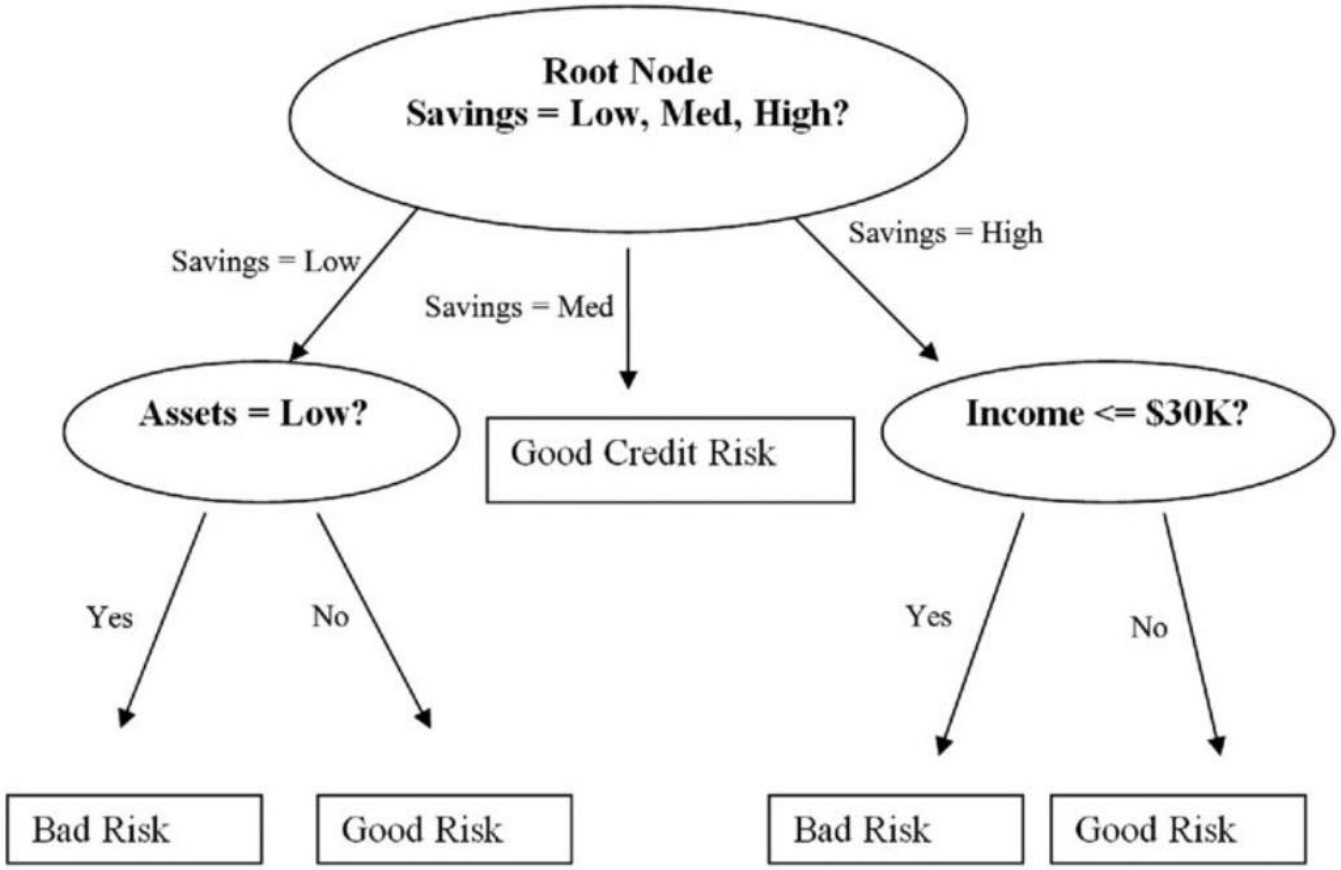
Examples

Search problems



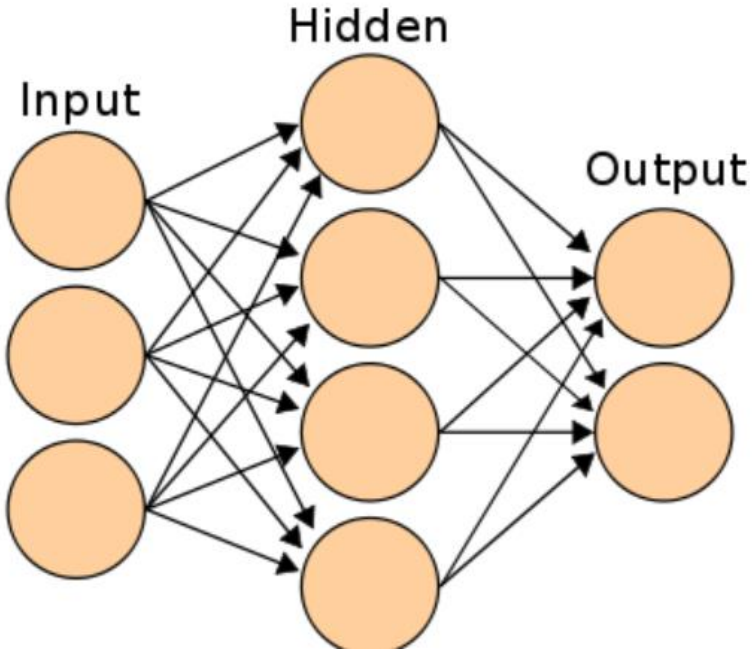
Decision Tree

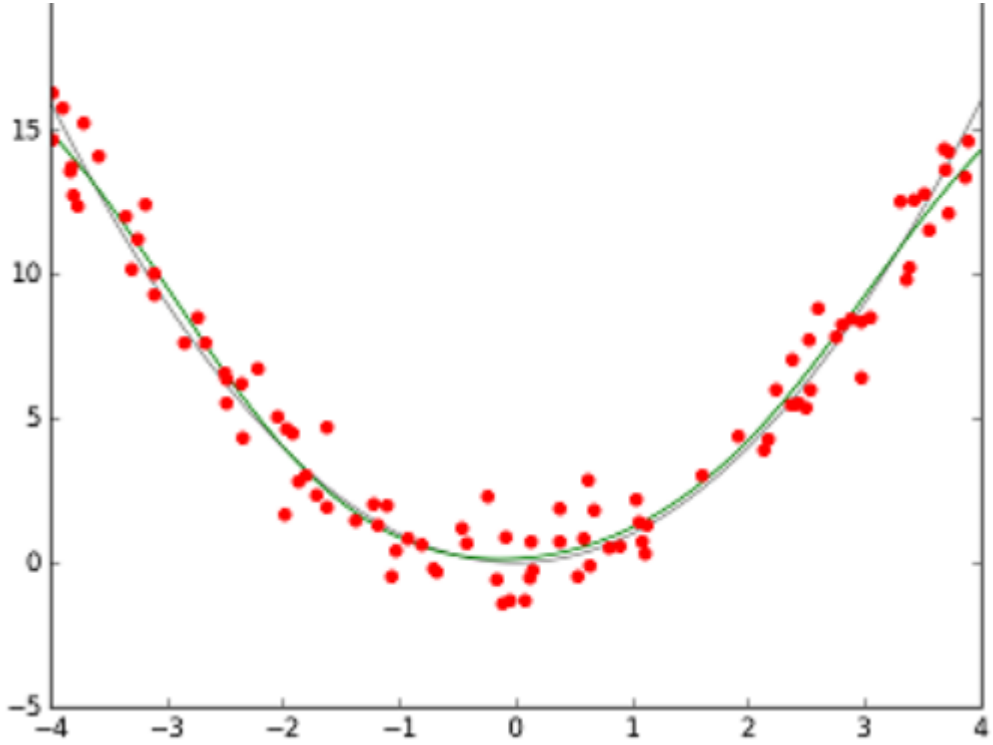
- Split the data by informative questions.



Neural Network

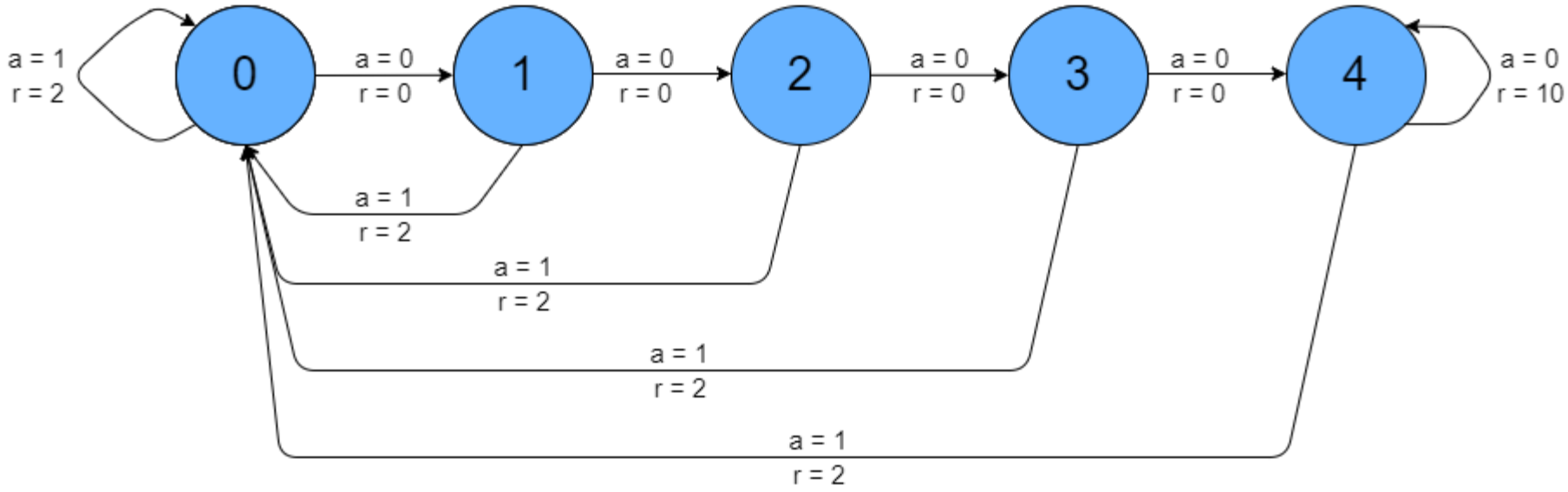
- It approximates the function in high dimensional space.



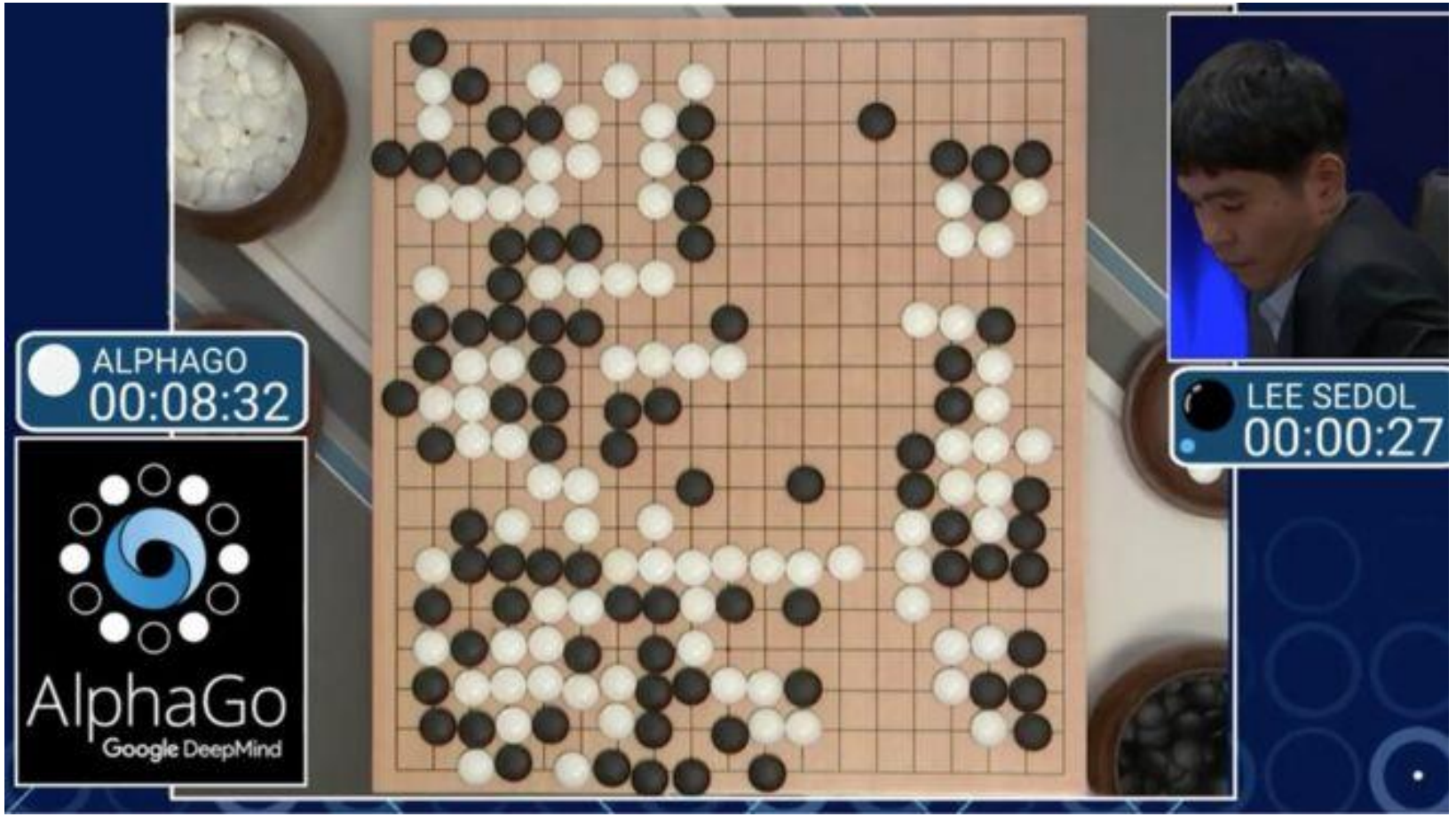


Reinforcement Learning

- Learn which action brings the highest reward at each state, based on your experience.

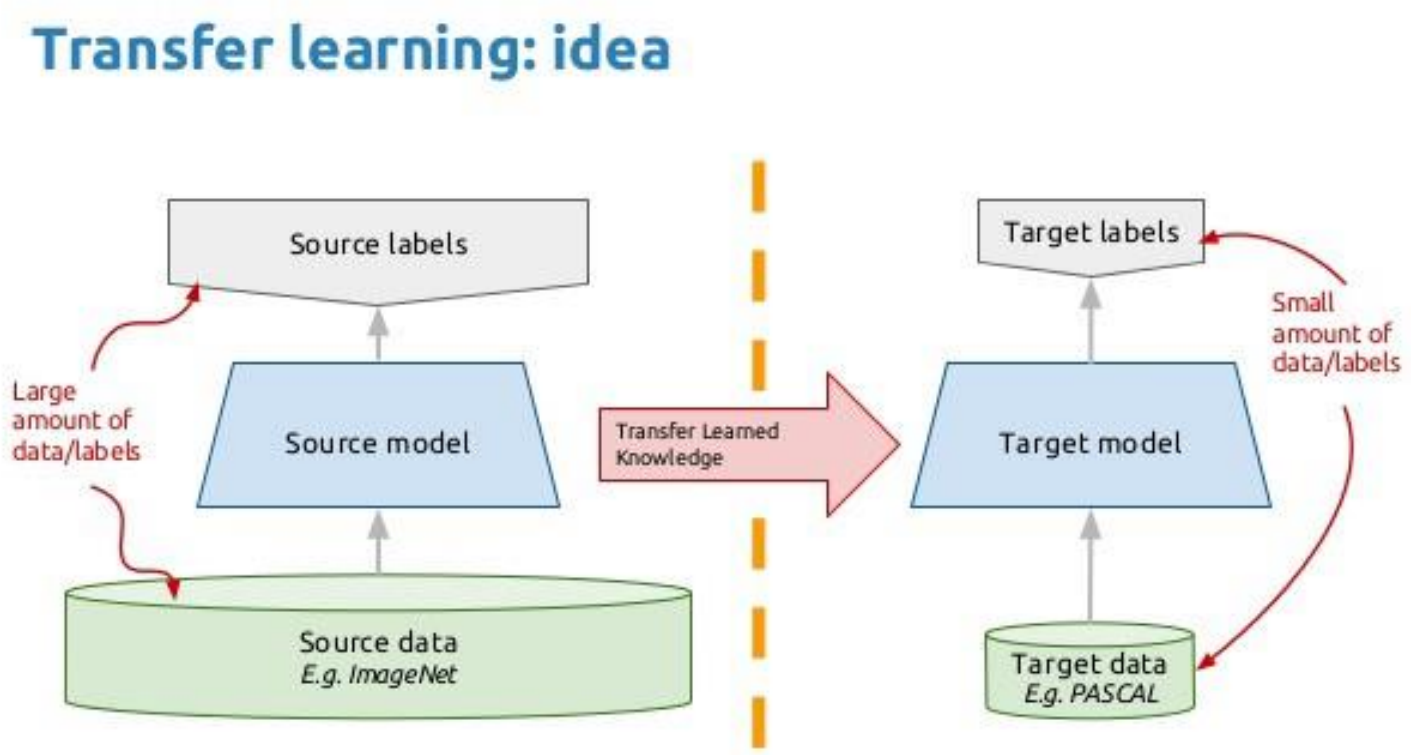


Breaking through by DRL

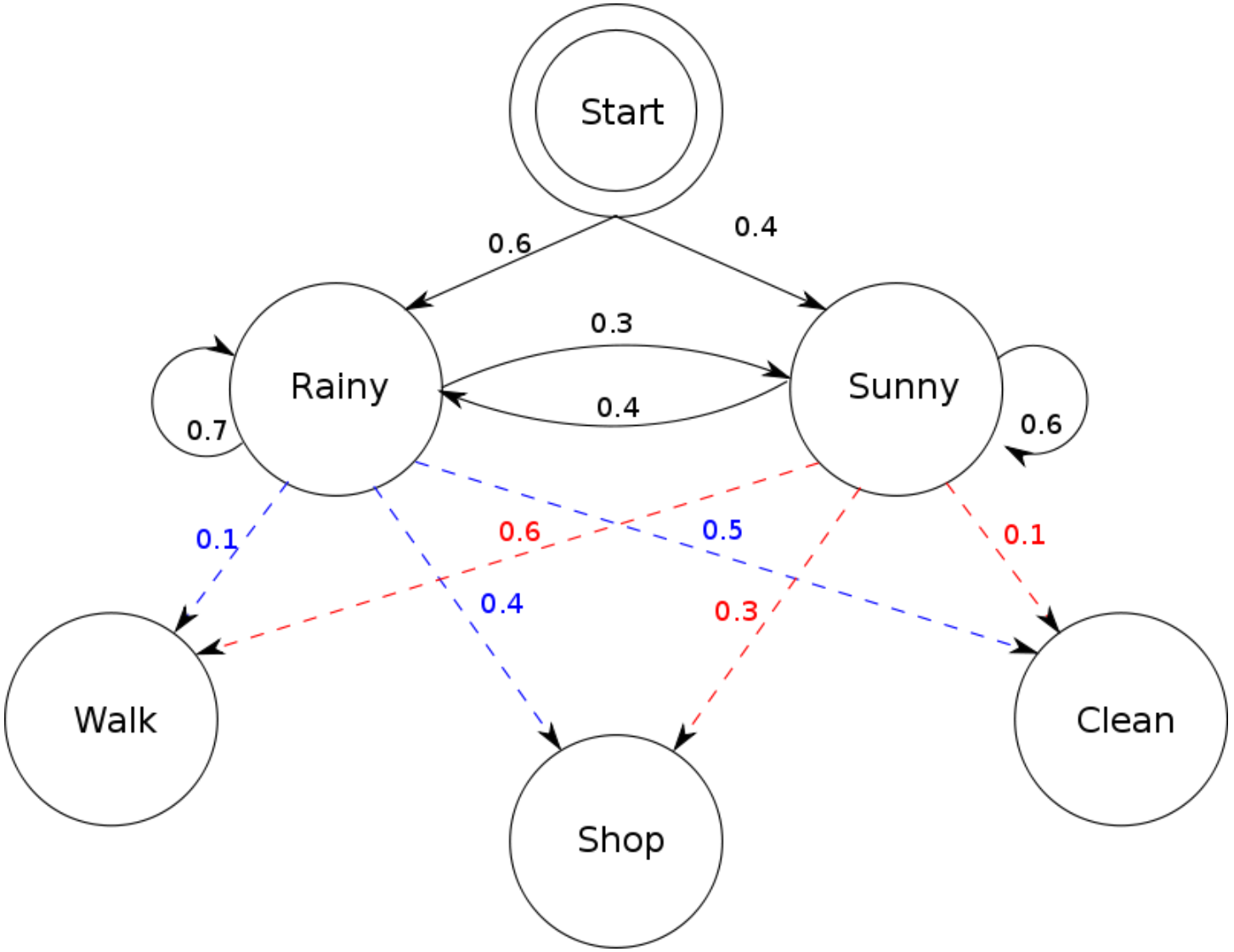


Transfer Learning

- Learn from source data and apply the knowledge on target data



Hidden Markov models



Particle filtering

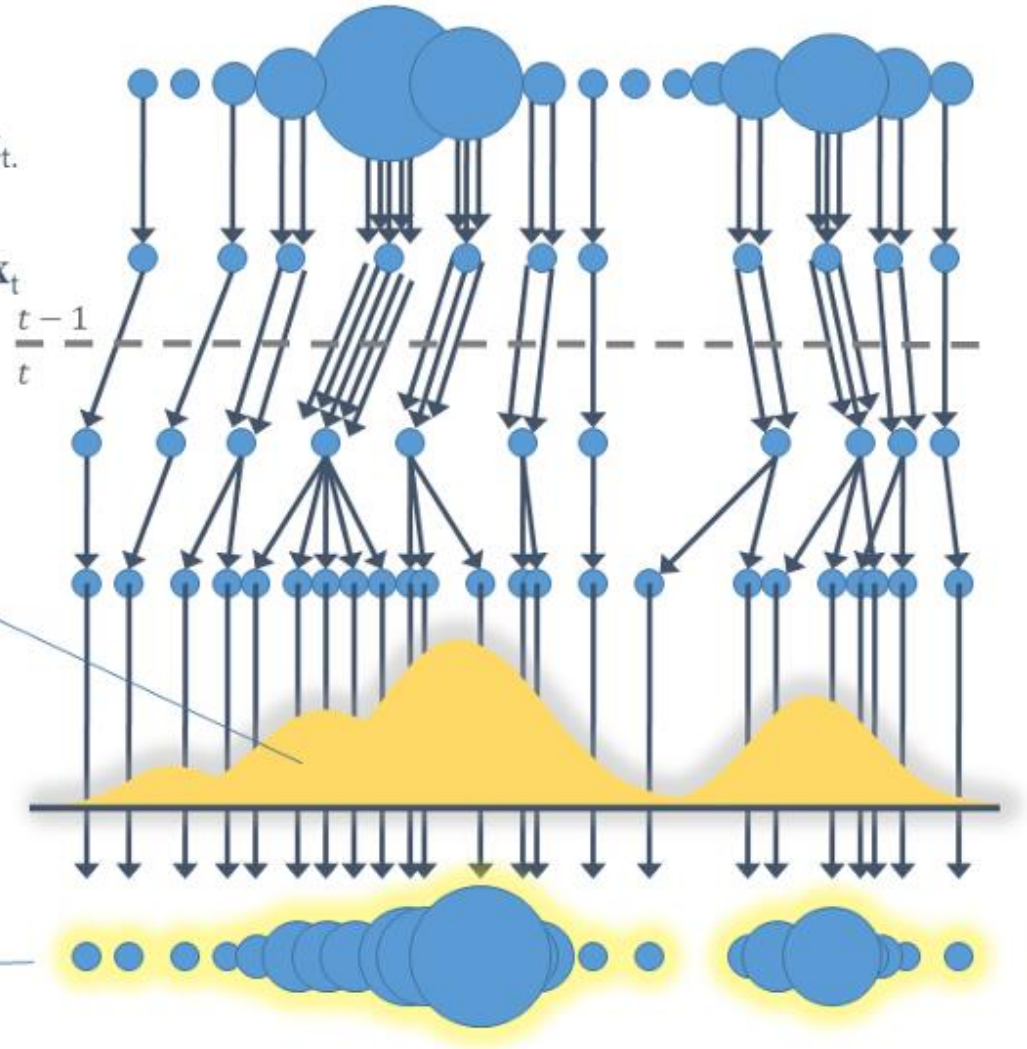
Obtain an observation $\mathbf{z}_t$ for each state estimate $\mathbf{x}_t$.

Evaluate likelihood that $\mathbf{x}_t$ gave rise to $\mathbf{z}_t$ using observation model.

$$p(\mathbf{z}_t \mid \mathbf{x}_t)$$

- **Measure:** weights are proportional to the observation likelihood

$$p(\mathbf{x}_t \mid Z_t)$$

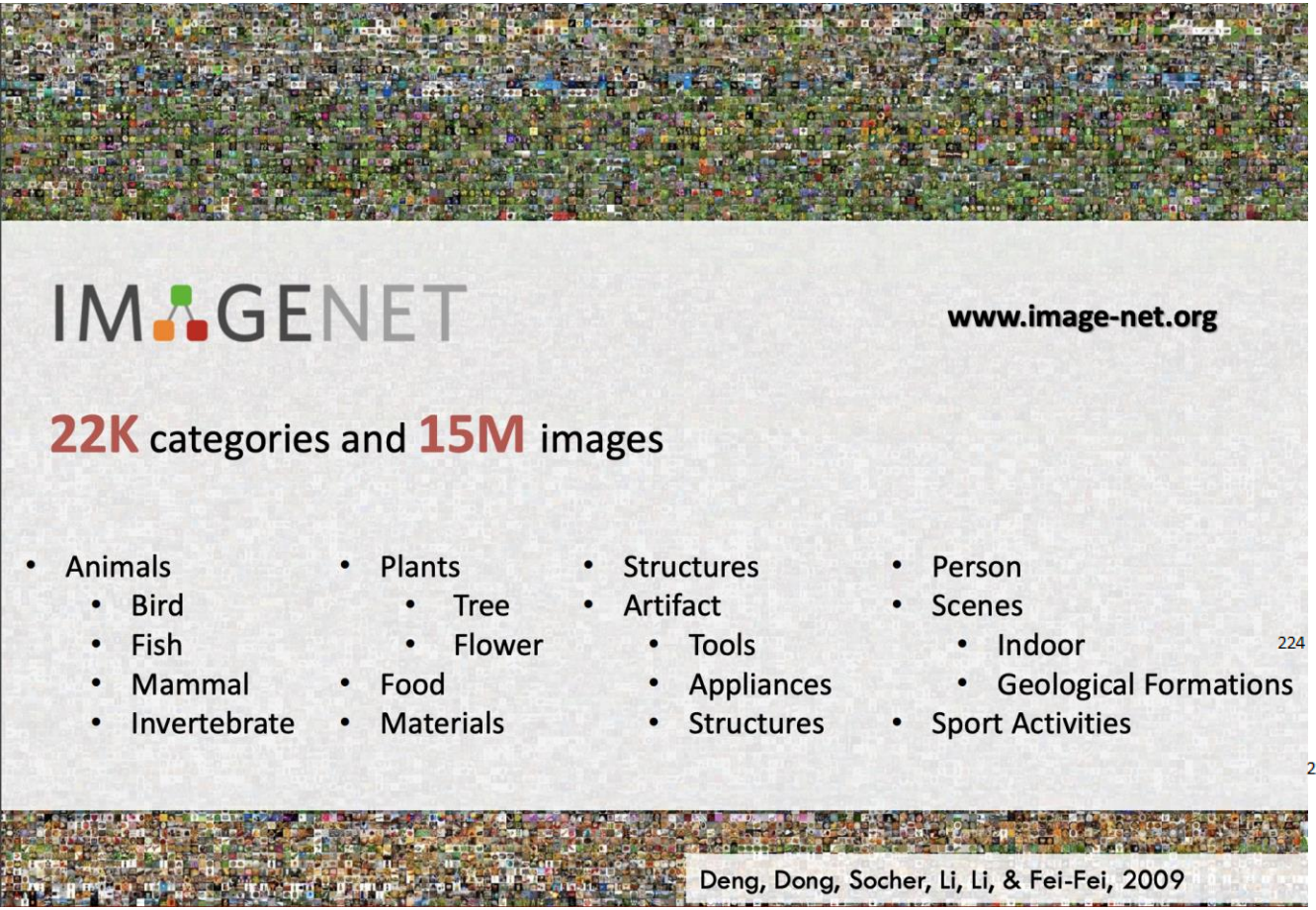


AI and ML Trend

https://www.google.com/trends

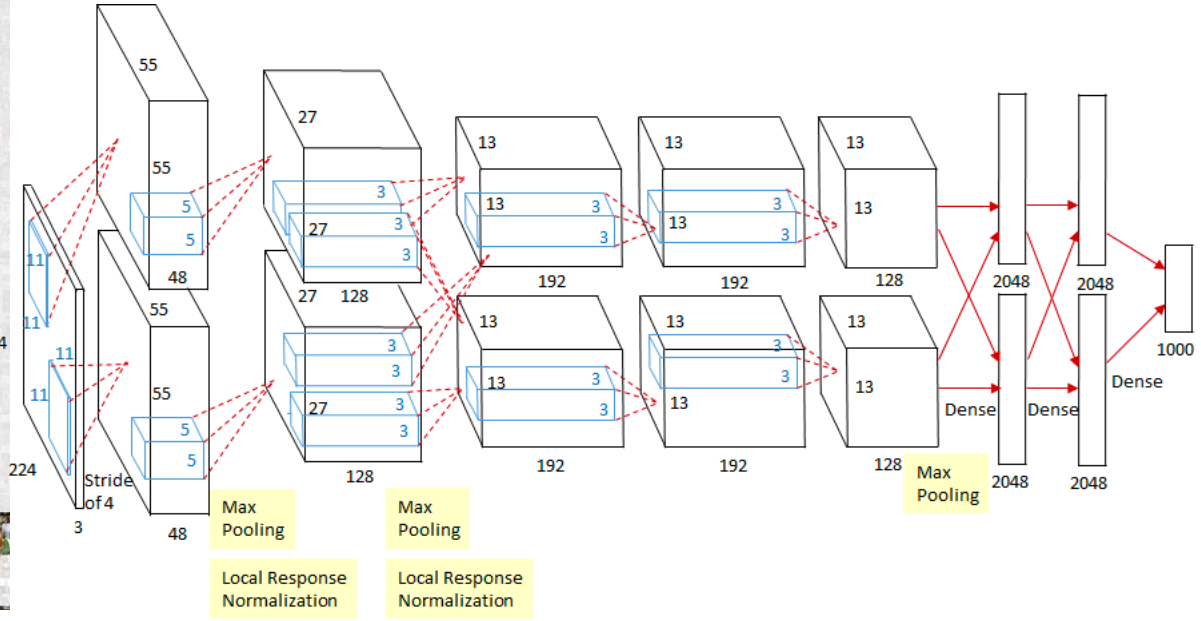
Recent Progress

Computer Vision (CV) -- ImageNet, AlexNet



Deng, J., Dong, W., Socher, R., Li, L. J., Li, K., & Fei-Fei, L. (2009, June). Imagenet: A large-scale hierarchical image database. In *2009 IEEE conference on computer vision and pattern recognition* (pp. 248-255). IEEE.

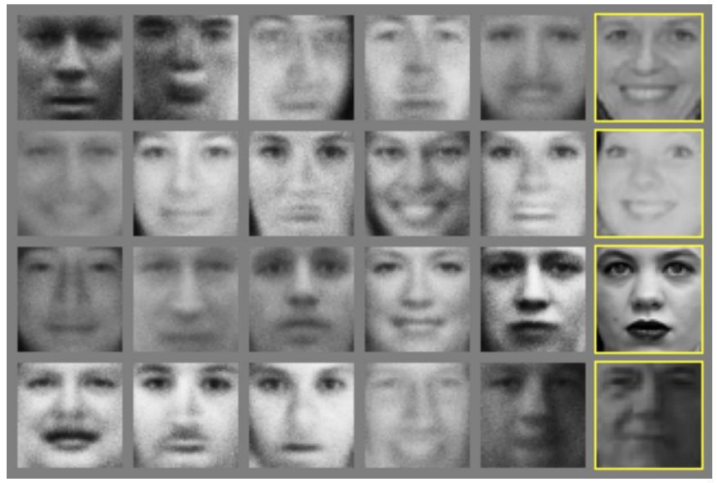
AlexNet, CNN



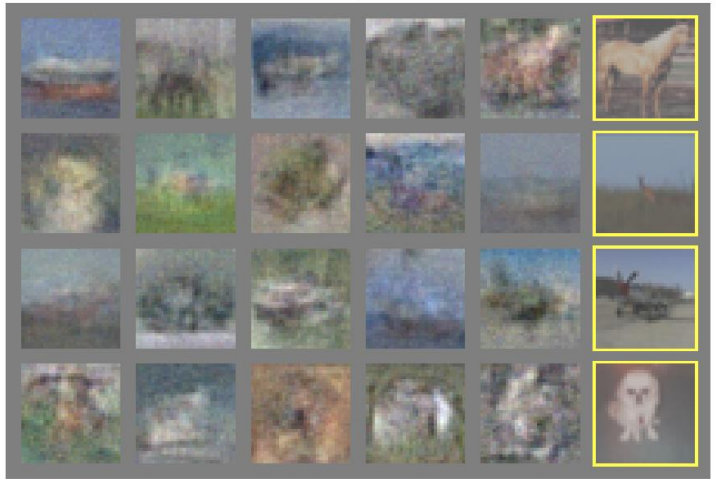
Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. In *Advances in neural information processing systems* (pp. 1097-1105).

CV -- GAN

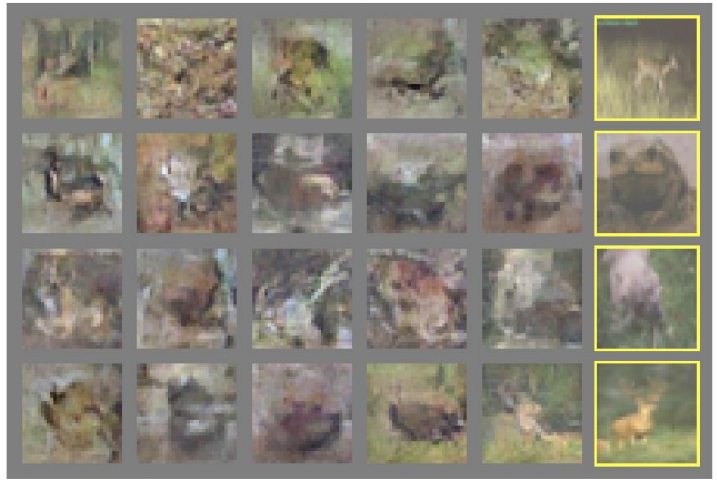
a)



b)



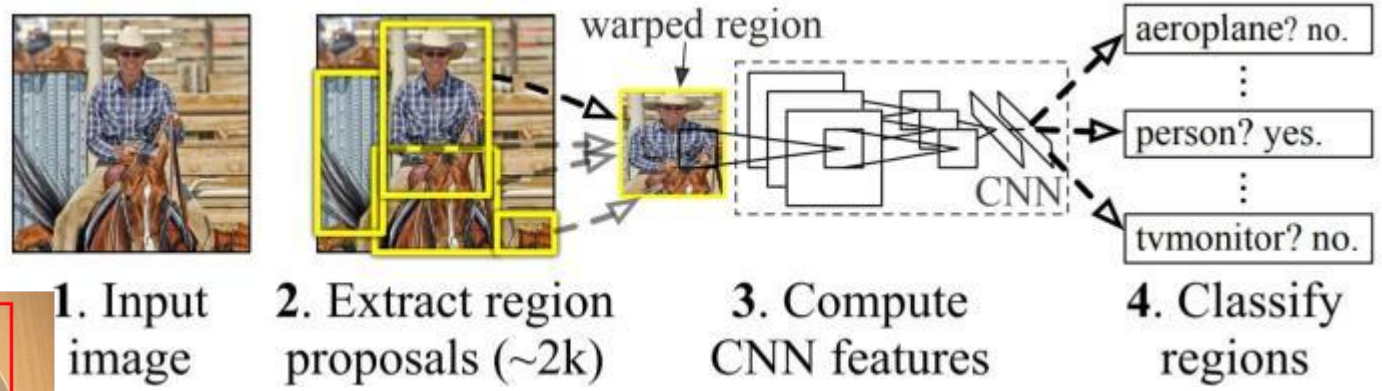
c)

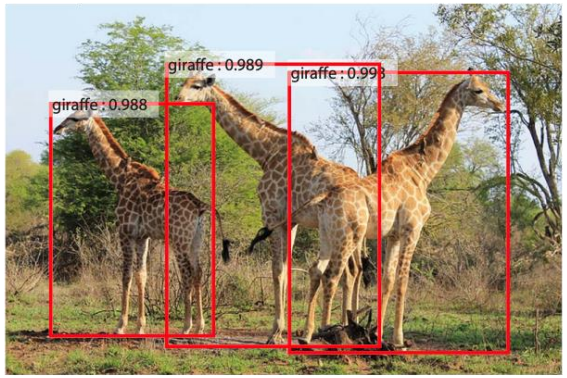


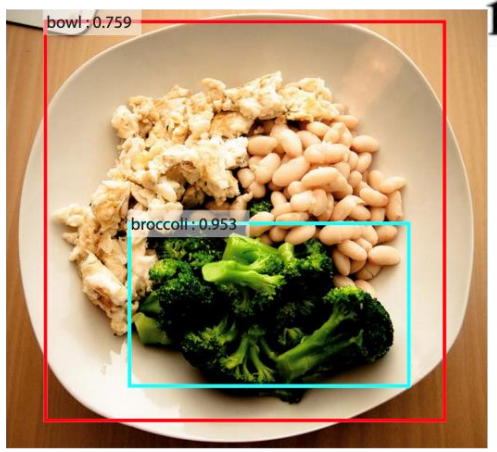
d)

Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., ... & Bengio, Y. (2014). Generative adversarial nets. In *Advances in neural information processing systems* (pp. 2672-2680).

CV (Detection) -- R-CNN, Fast R-CNN, Faster R-CNN







1.Girshick, R., Donahue, J., Darrell, T., & Malik, J. (2014). Rich feature hierarchies for accurate object detection and semantic segmentation. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 580-587).

2. Girshick, R. (2015). Fast r-cnn. In *Proceedings of the IEEE international conference on computer vision* (pp. 1440-1448).

3. Ren, S., He, K., Girshick, R., & Sun, J. (2015). Faster r-cnn: Towards real-time object detection with region proposal networks. In *Advances in neural information processing systems* (pp. 91-99).

Speech recognition (Unsupervised, ICA)

Mixed

Separated

Speech recognition (Unsupervised, ICA, cont.)

Mixed

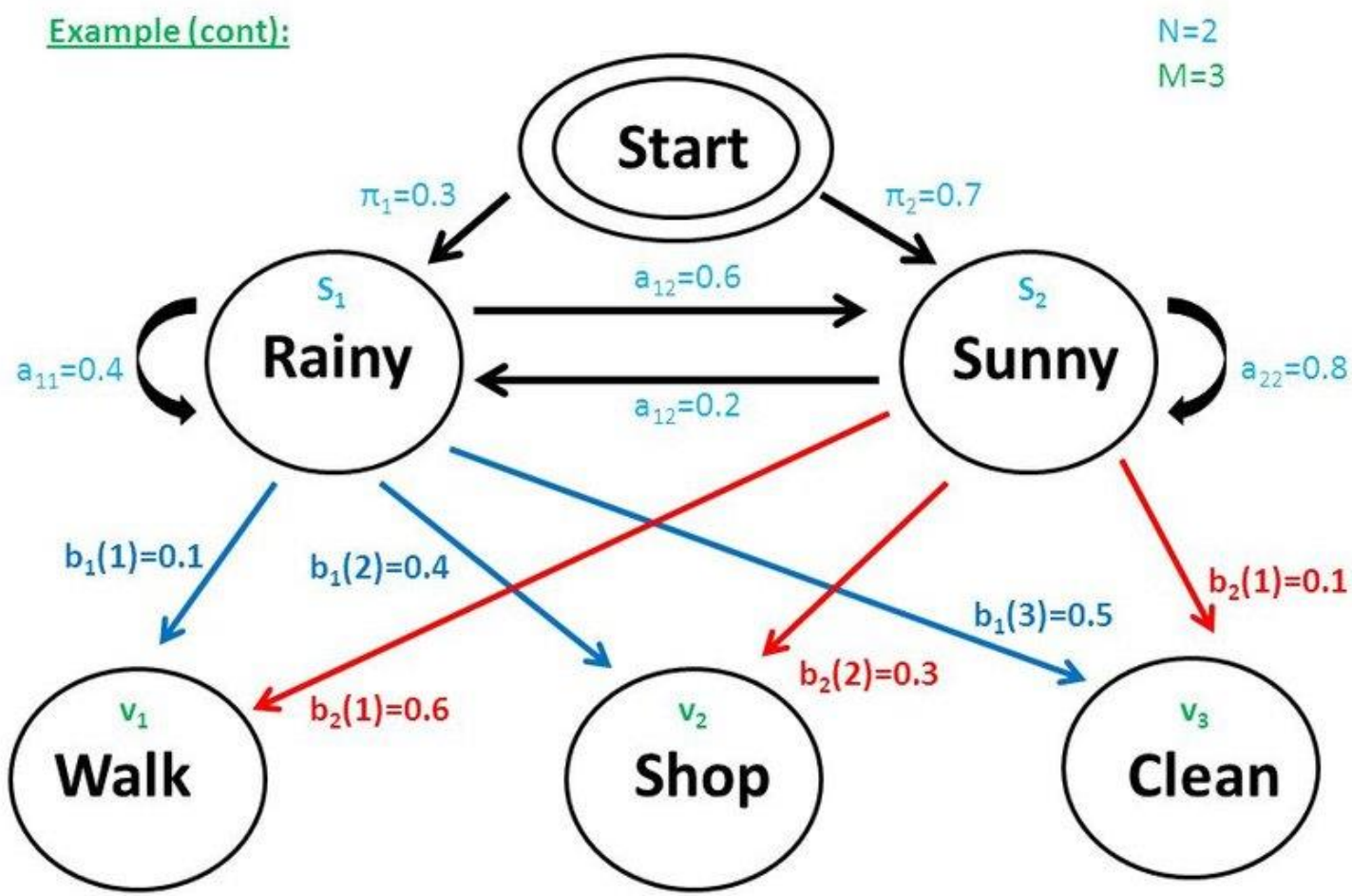
Separated

Speech recognition

- Previous works use
  - Hidden Markov models (HMMs)
    - Deal with the temporal variability of speech
  - Gaussian mixture models (GMMs)
    - Determine how well each state of each HMM fits a frame or a short window of frames of coefficients that represents the acoustic input
- New
  - Feed-forward neural network
    - Takes several frames of coefficients as input and produces posterior probabilities over HMM states as output

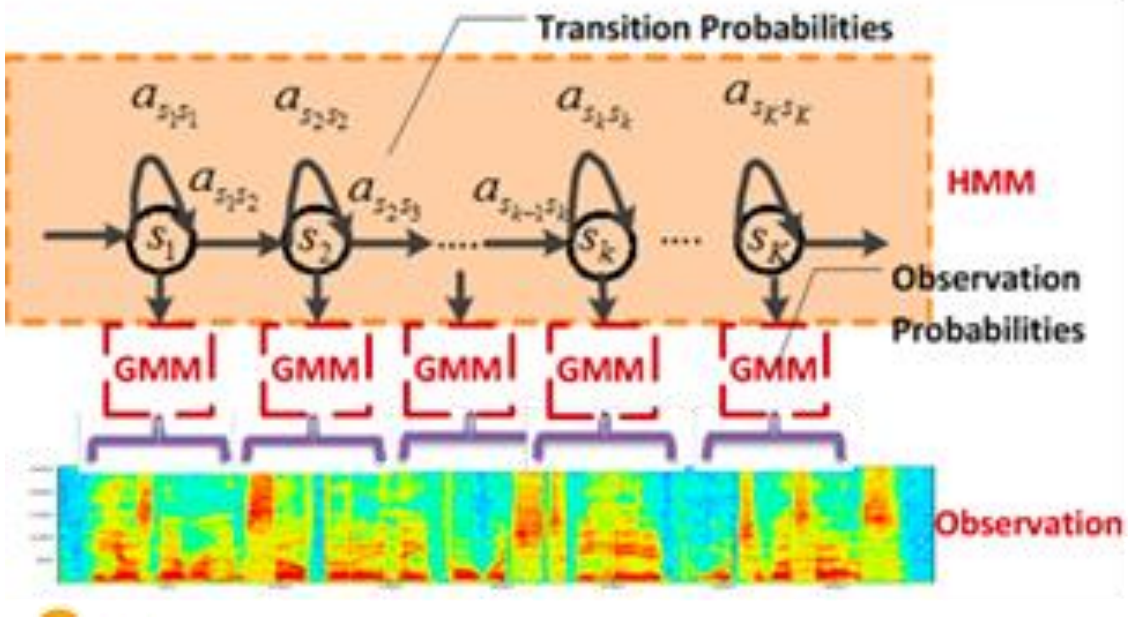
Hinton, G., Deng, L., Yu, D., Dahl, G., Mohamed, A. R., Jaitly, N., ... & Sainath, T. (2012). Deep neural networks for acoustic modeling in speech recognition. *IEEE Signal processing magazine*, *29*.

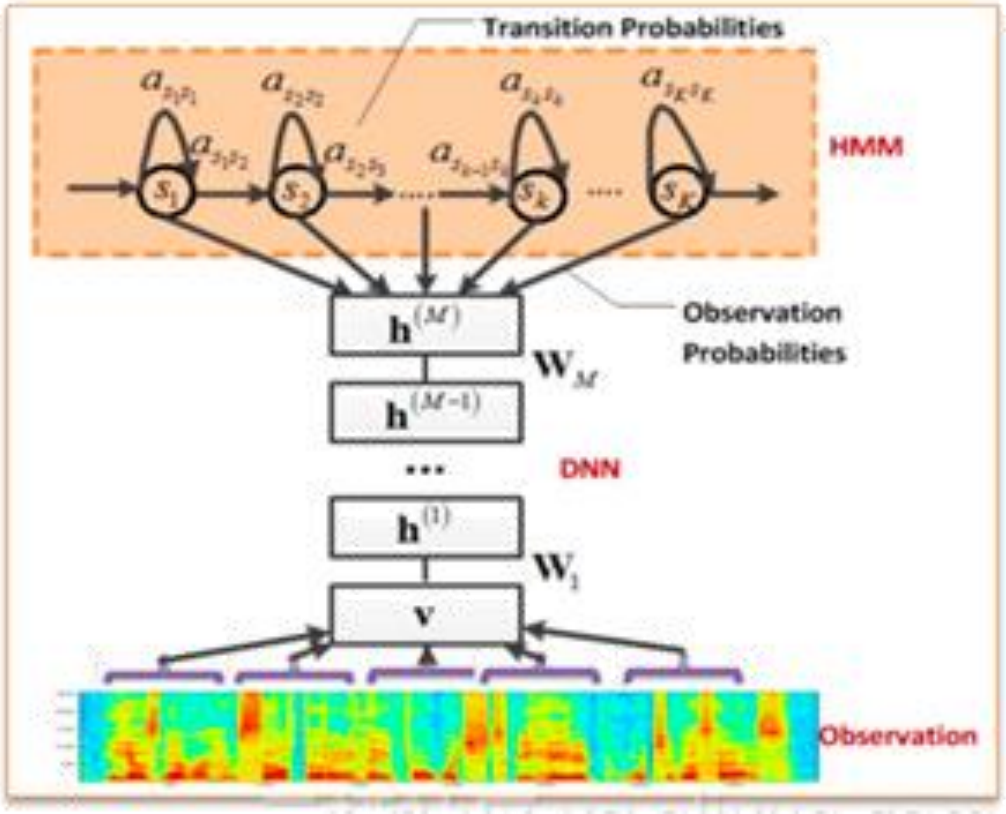
Hidden Markov Model



Speech recognition

- Deep Learning: From GMM-HMM to DNN-HMM

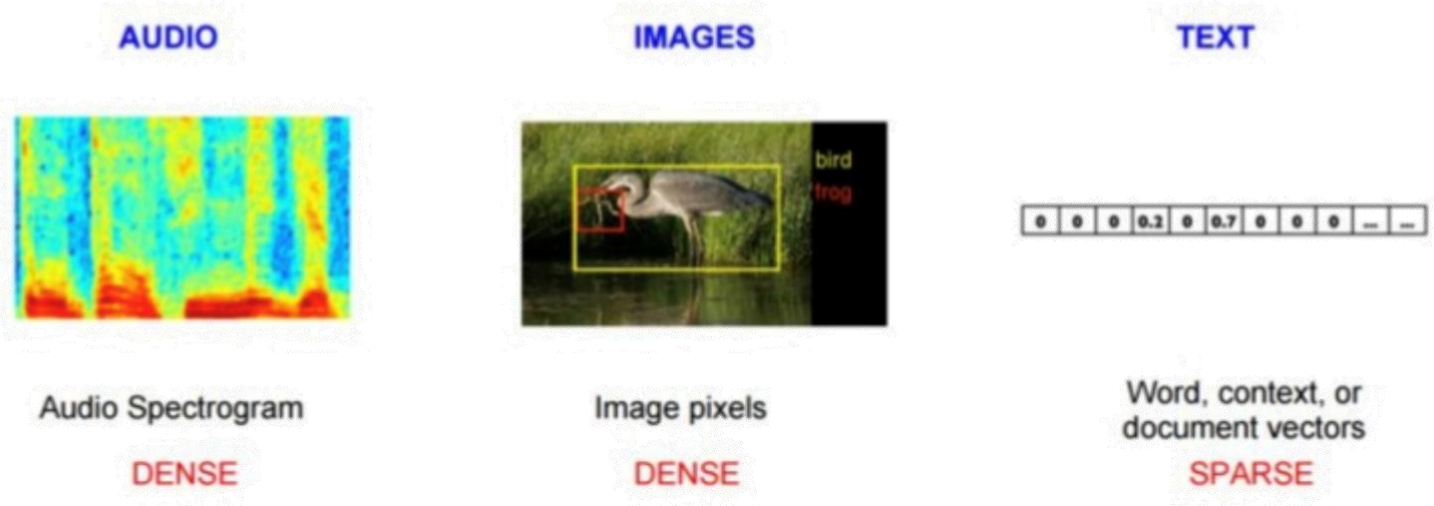




Hinton, G., Deng, L., Yu, D., Dahl, G., Mohamed, A. R., Jaitly, N., ... & Sainath, T. (2012). Deep neural networks for acoustic modeling in speech recognition. *IEEE Signal processing magazine*, *29*.

Natural Language Processing (NLP) -- Word2Vec

Image and audio processing systems work with rich, high-dimensional datasets encoded as vectors.



Pennington, J., Socher, R., & Manning, C. (2014, October). Glove: Global vectors for word representation. In *Proceedings of the 2014 conference on empirical methods in natural language processing (EMNLP)* (pp. 1532-1543).

Natural Language Processing (NLP) -- Word2Vec (cont.)

Word Analogies

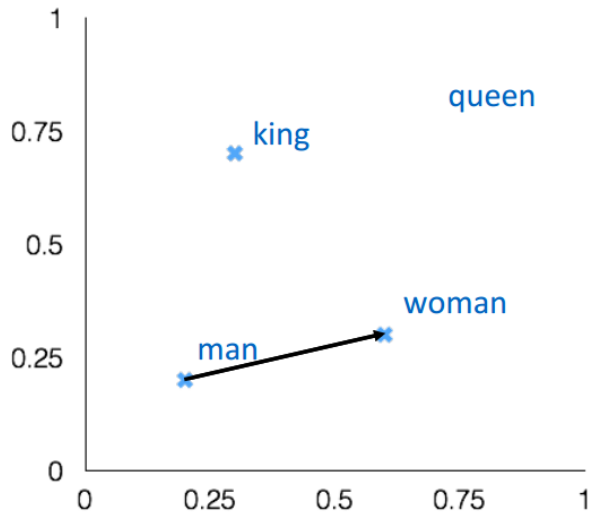
Test for linear relationships, examined by Mikolov et al. (2014)

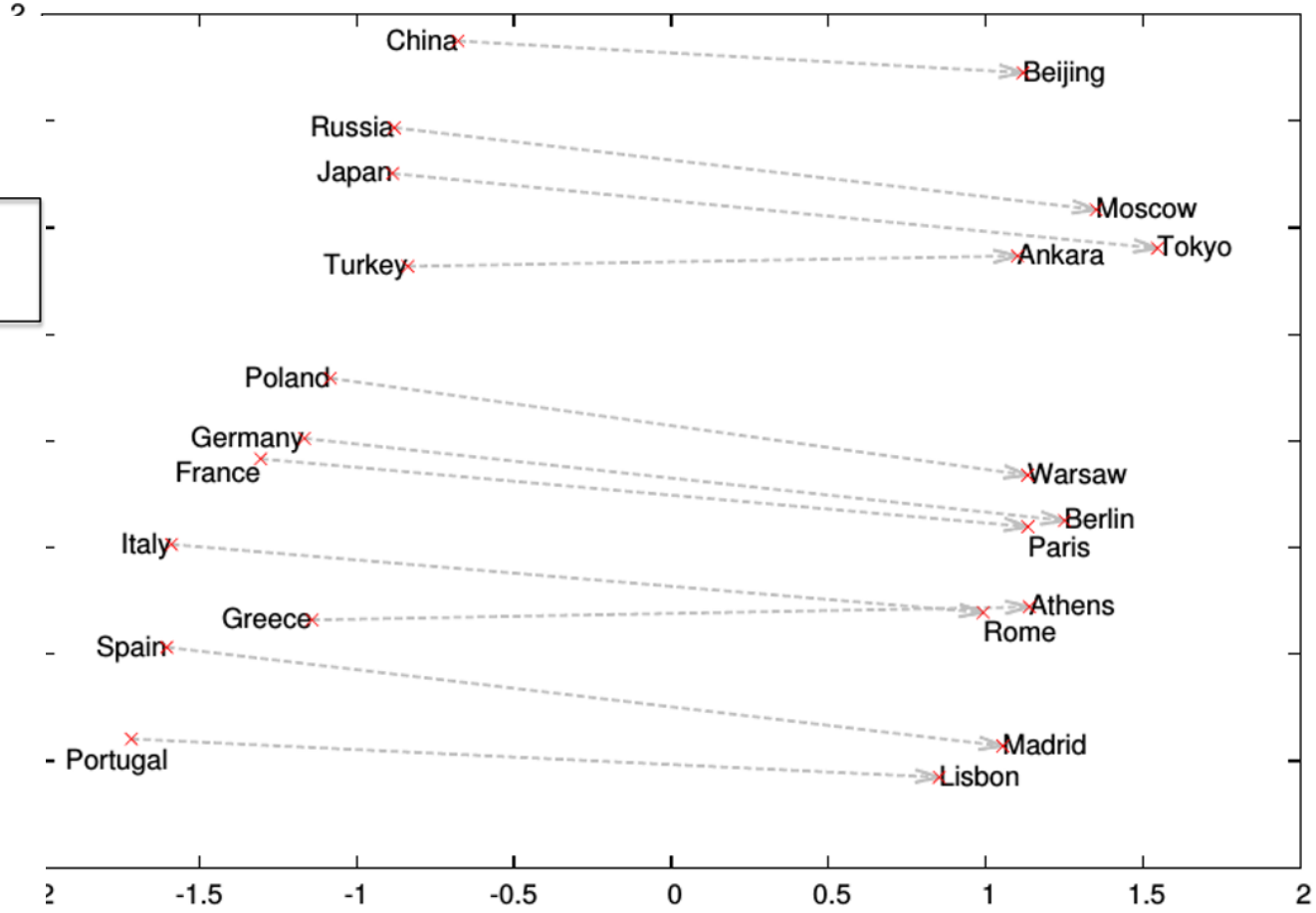
a:b :: c:?

$$d = \arg\max_x \frac{(w_b - w_a + w_c)^T w_x}{||w_b - w_a + w_c||}$$

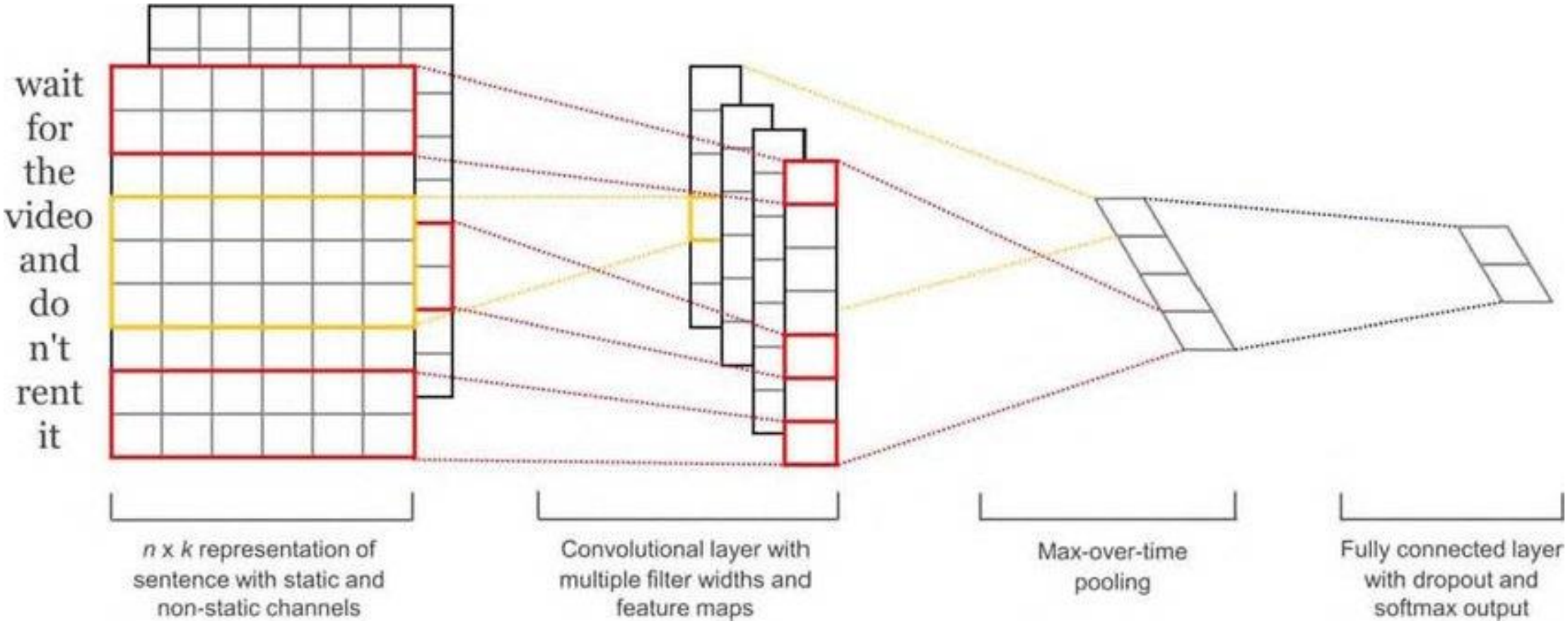
man:woman :: king:?

+	king	[0.30 0.70]
-	man	[0.20 0.20]
+	woman	[0.60 0.30]
	queen	[0.70 0.80]





NLP -- CNN



Kim, Y. (2014, October). Convolutional Neural Networks for Sentence Classification. In *Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing (EMNLP)* (pp. 1746-1751).

NLP -- BERT

- BERT
  - Bidirectional Encoder Representations from Transformers
  - The pre-train deep bidirectional representations from unlabeled text by jointly conditioning on both left and right context in all layers
  - The pre-trained BERT model can be finetuned with just one additional output layer to create state-of-the-art models for a wide range of tasks, such as question answering and language inference, without substantial taskspecific architecture modifications
  - It obtains new state-of-the-art results on eleven natural language processing tasks

Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. (2018). Bert: Pre-training of deep bidirectional transformers for language understanding. *arXiv preprint arXiv:1810.04805*.

NLP -- BERT

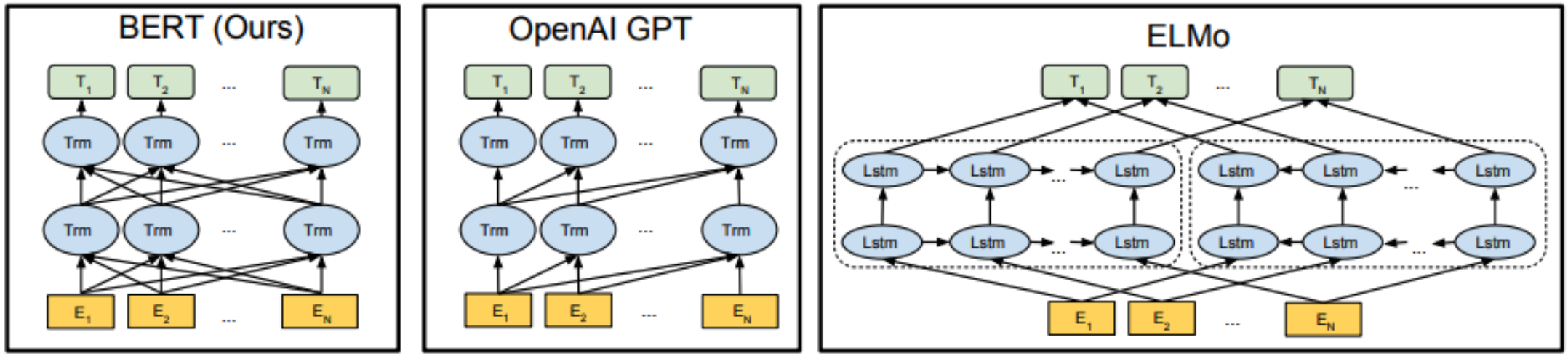


Figure 1: Differences in pre-training model architectures. BERT uses a bidirectional Transformer. OpenAI GPT uses a left-to-right Transformer. ELMo uses the concatenation of independently trained left-to-right and right-to-left LSTM to generate features for downstream tasks. Among three, only BERT representations are jointly conditioned on both left and right context in all layers.

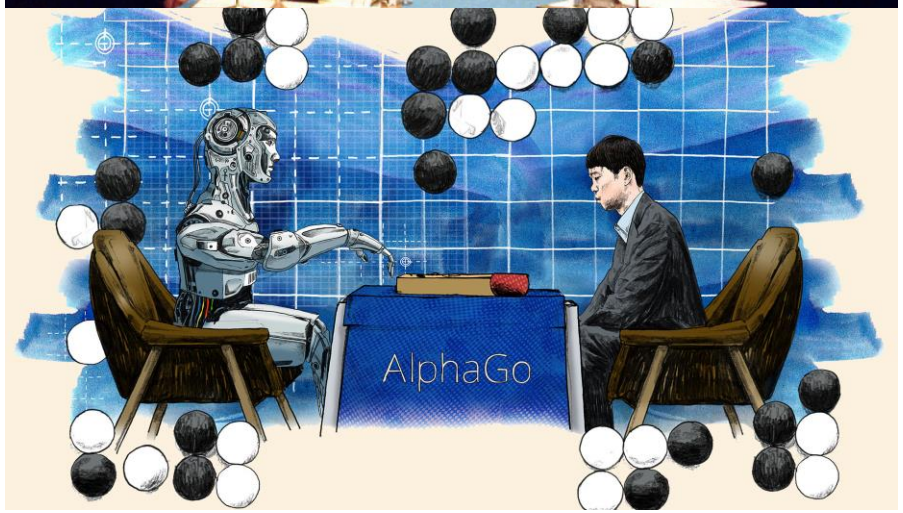
Game Playing -- Atari

Deep Reinforcement Learning

Trained separate DQN agents for 50 different Atari games, without any prior knowledge of the game rules

Mnih, V., Kavukcuoglu, K., Silver, D., Rusu, A. A., Veness, J., Bellemare, M. G., ... & Petersen, S. (2015). Human-level control through deep reinforcement learning. *Nature*, *518*(7540), 529.

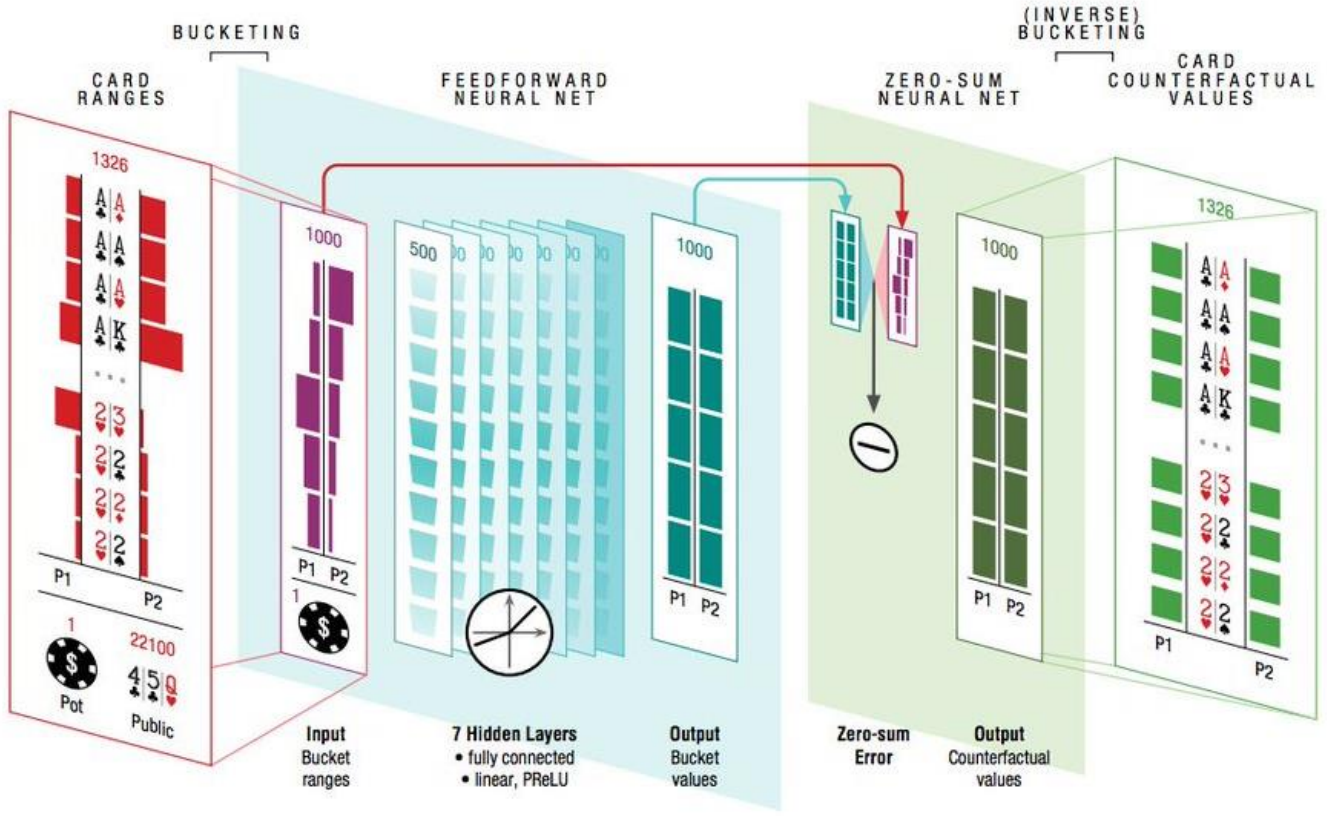
Game Playing



- IBM Deep Blue (1996)
  - Win Garry Kasparov by 3.5:2.5 on Chess
  - Search over 12 following steps
- AlphaGo (2016)
  - Win Lee Sedol by 4:1 on Go
  - Efficient search on large solution space

Silver, D., Huang, A., Maddison, C. J., Guez, A., Sifre, L., Van Den Driessche, G., ... & Dieleman, S. (2016). Mastering the game of Go with deep neural networks and tree search. *nature*, *529*(7587), 484.

Game Playing -- Texas hold'em



DeepStack

- In a study involving 44,000 hands of poker, DeepStack defeated with statistical significance professional poker players in heads-up no-limit Texas hold'em
- Imperfect information setting

Moravčík, M., Schmid, M., Burch, N., Lisý, V., Morrill, D., Bard, N., ... & Bowling, M. (2017). Deepstack: Expert-level artificial intelligence in heads-up no-limit poker. *Science*, *356*(6337), 508-513.

History of Game AI

1956 checkers

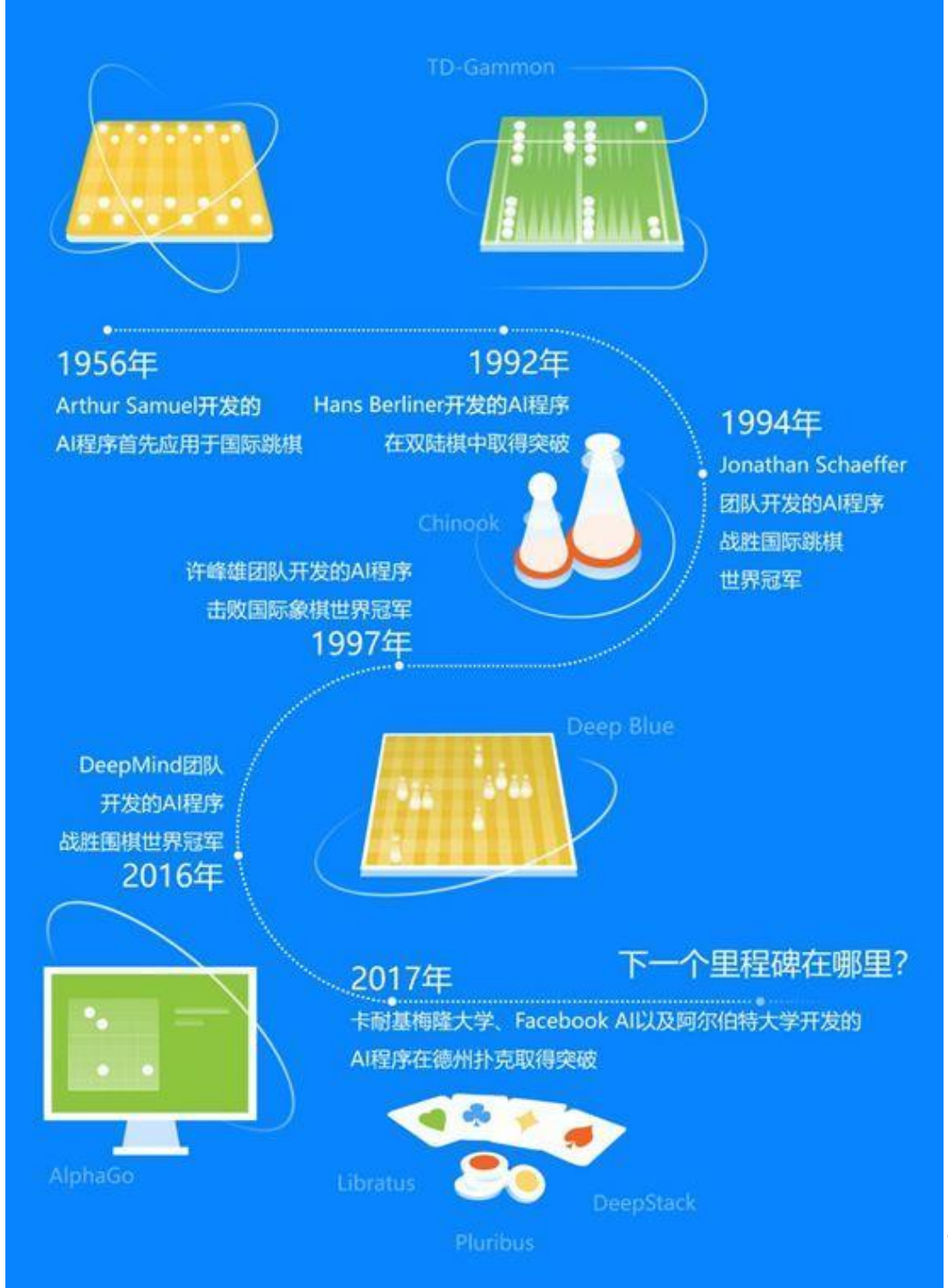
1992 backgammon

1994 checkers

1997 chess

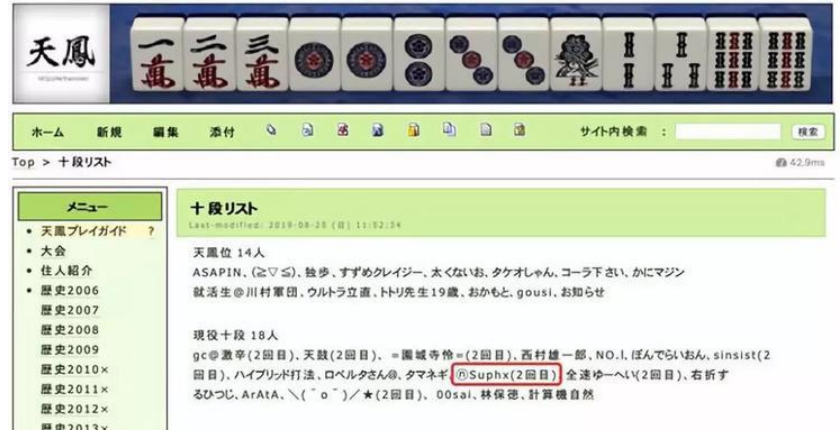
2016 Go

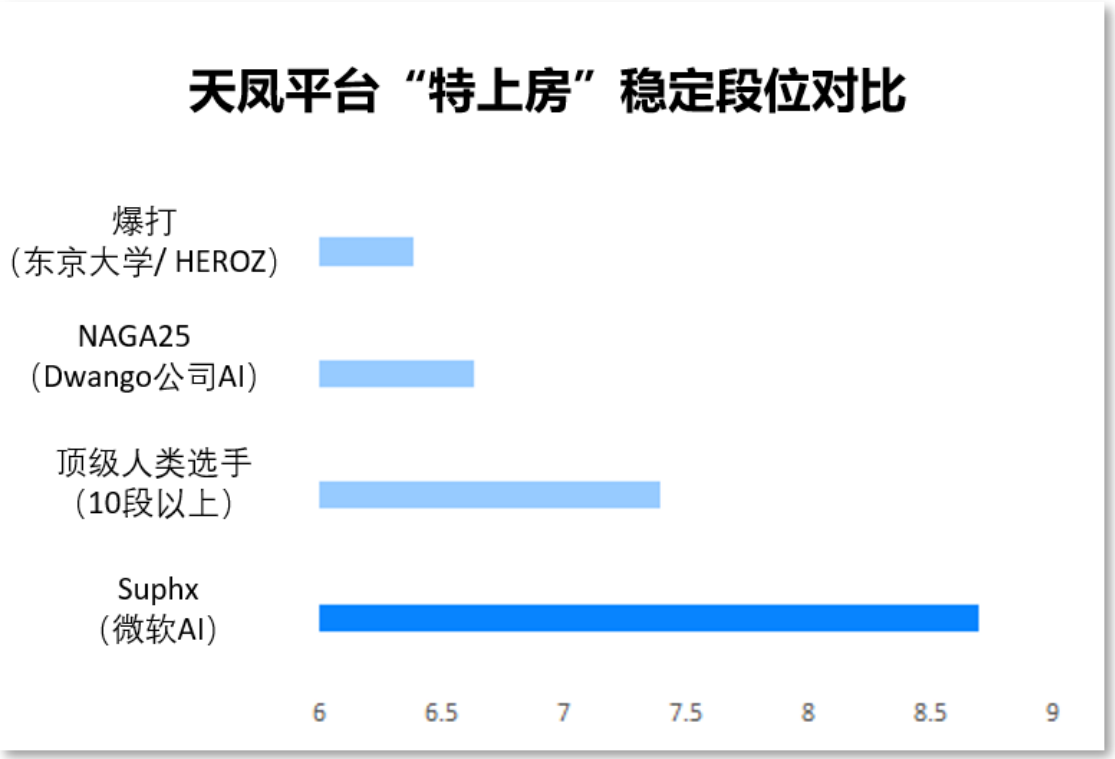
2017 Texas hold’em



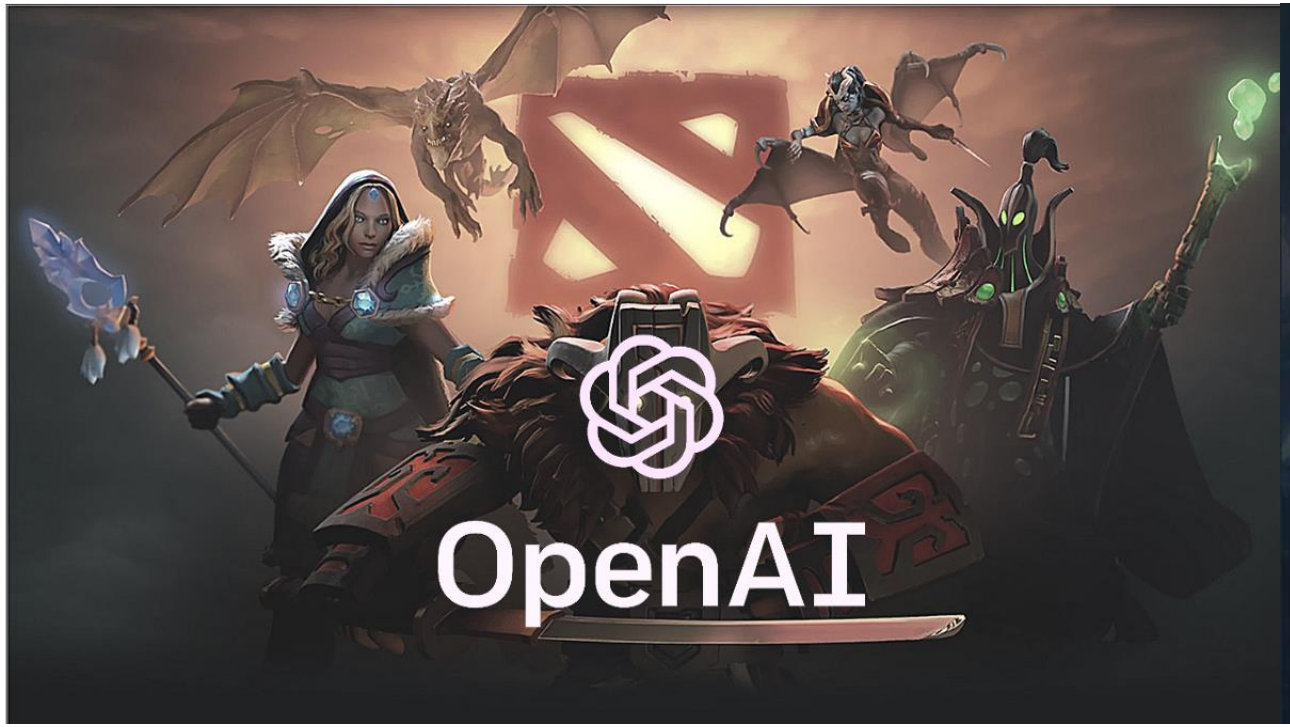
Game Playing -- Majiang

- Microsoft Suphx 2019
  - Professional level





Game playing – state of the art



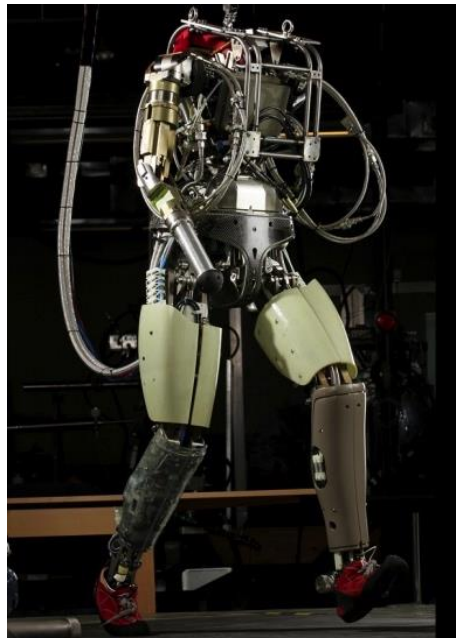
Simulated Agents

[Schulman, Moritz, Levine, Jordan, Abbeel, ICLR 2016]

Robotics

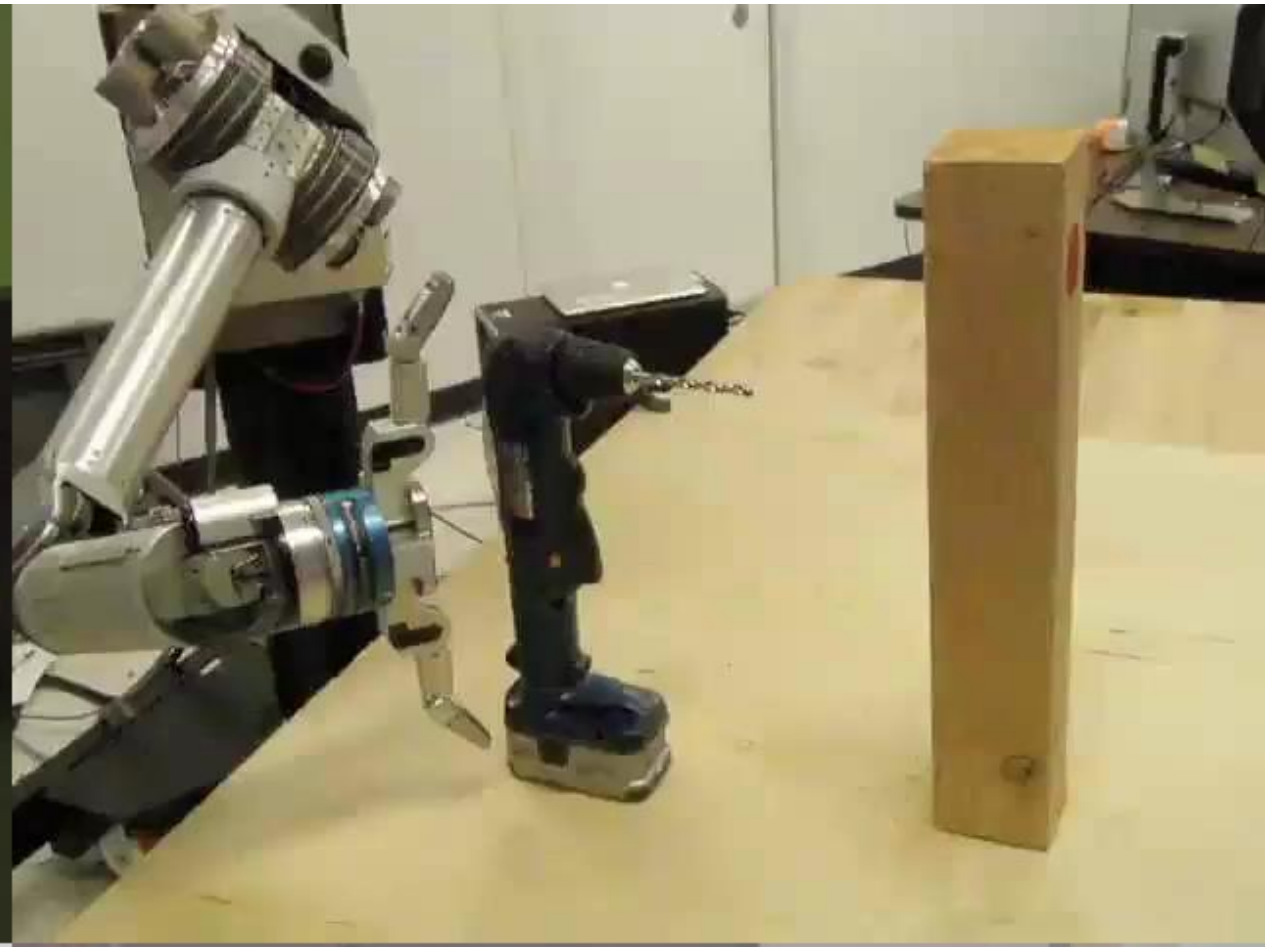
Demo 1: ROBOTICS – soccer.avi
Demo 2: ROBOTICS – soccer2.avi
Demo 3: ROBOTICS – gcar.avi
Demo 4: ROBOTICS – laundry.avi
Demo 5: ROBOTICS – petman.avi

- Robotics
  - Part mech. eng.
  - Part AI
  - Reality much harder than simulations!
- Technologies
  - Vehicles
  - Rescue
  - Help in the home
  - Lots of automation…
- In this class:
  - We ignore mechanical aspects
  - Methods for planning
  - Methods for control



Images from UC Berkeley, Boston Dynamics, RoboCup, Google

Robots



Robots

[Levine*, Finn*, Darrell, Abbeel, JMLR 2016]

Human-AI Interaction

Boston Dynamics: Spot

EXPLORER

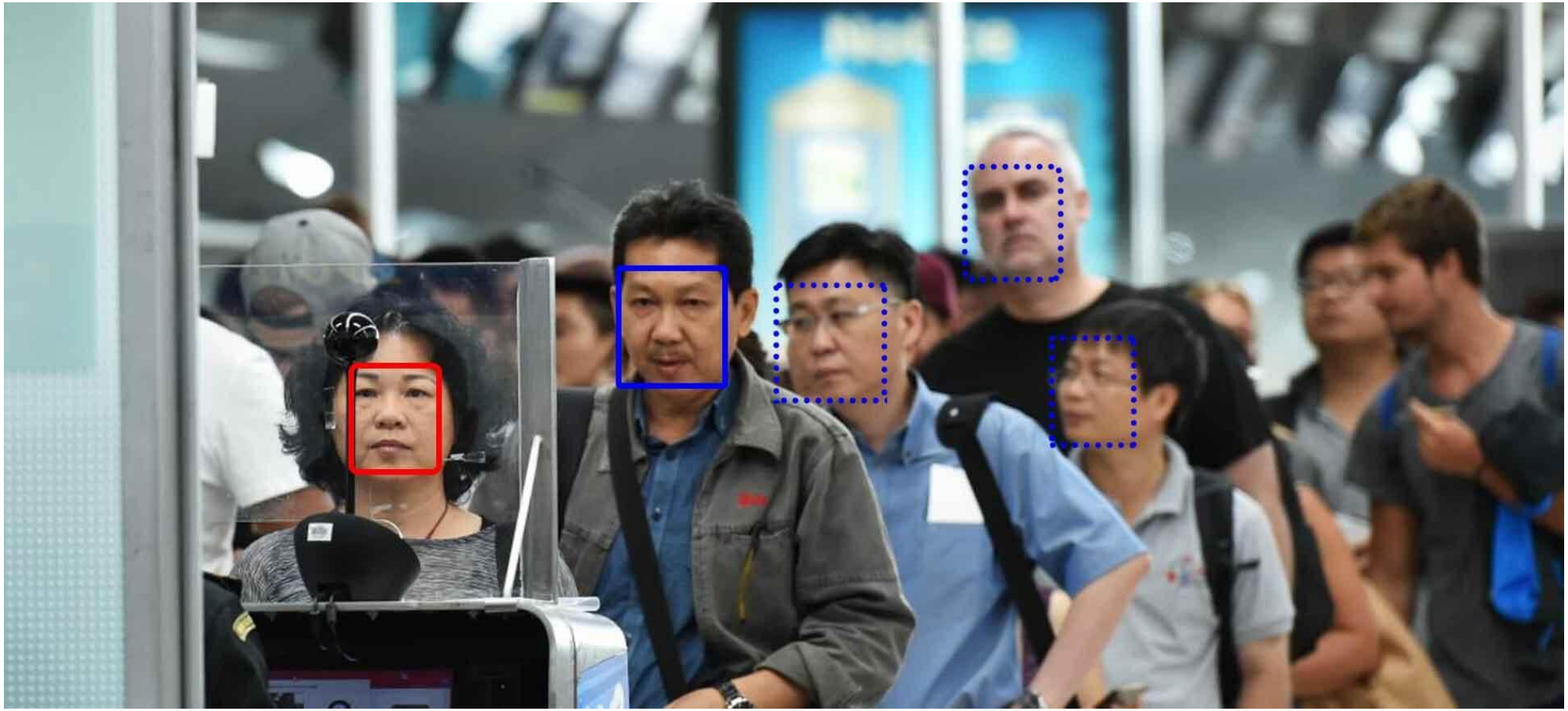
$74,500.00

The Spot Explorer kit puts the power of robotics into your hands and makes robotics easy, so you can focus on building your application.

Exoskeletons

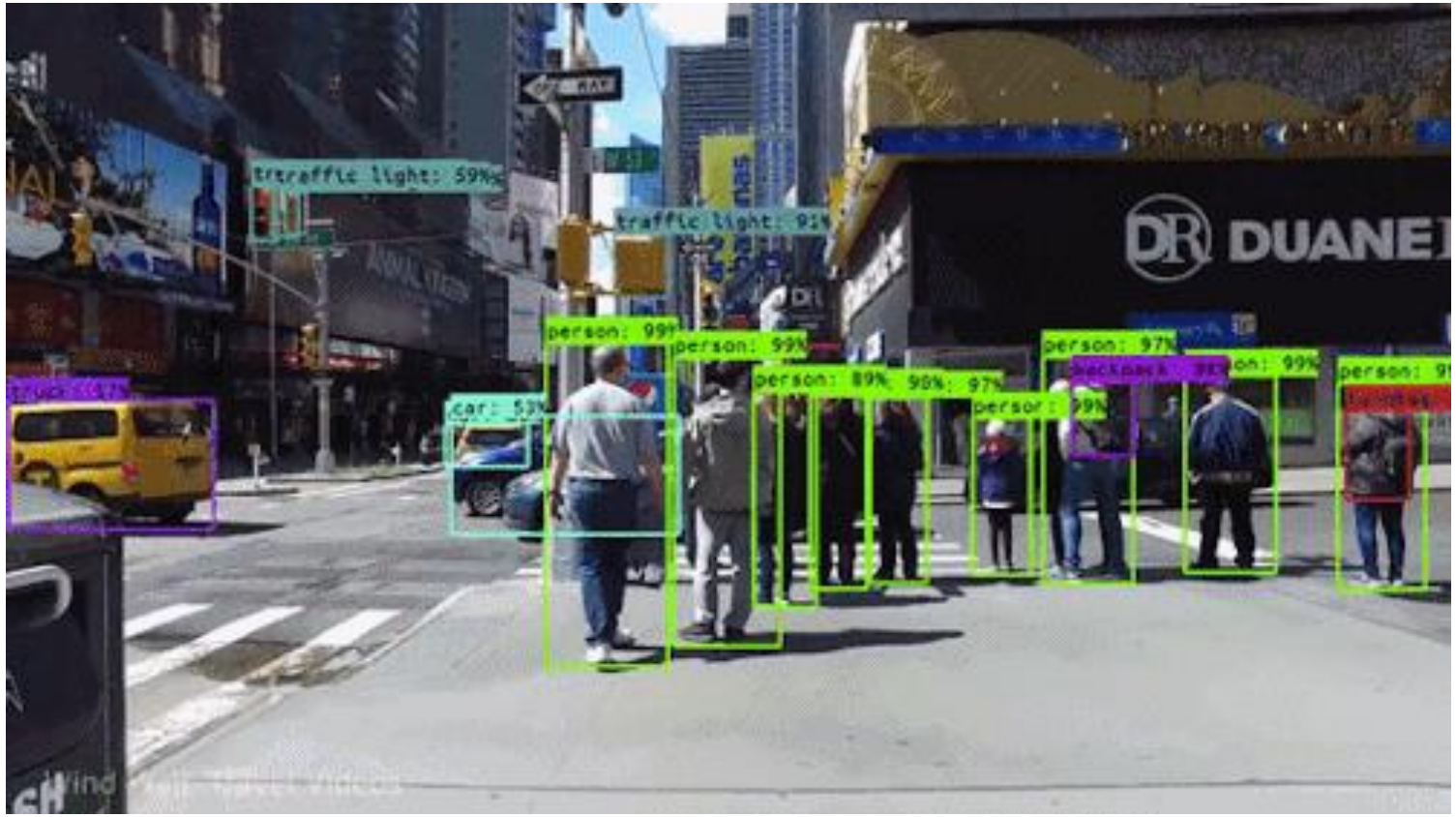
Applications

Face Recognition in Customs



https://bitrefine.group/home/transportation/face-recognition-support-system

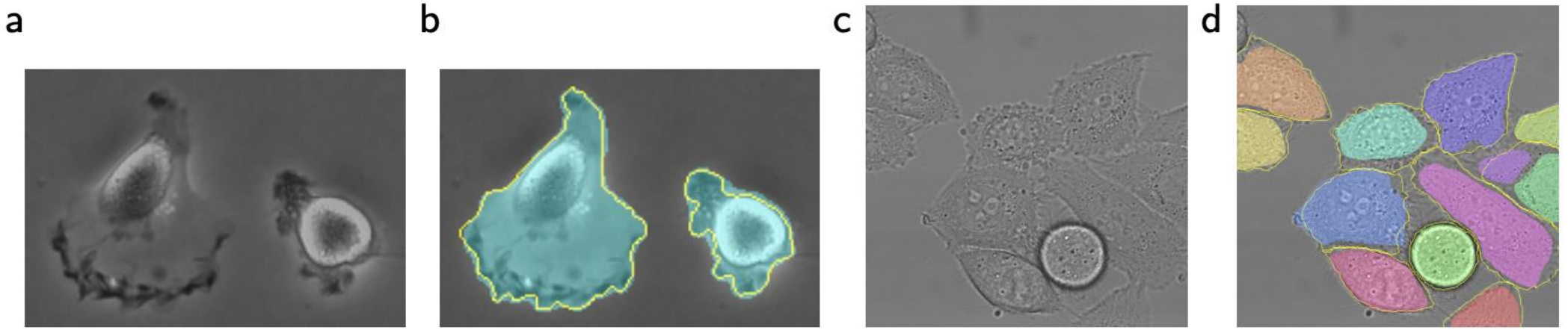
Autonomous Self-driving Cars



https://cdn-images-1.medium.com/max/1600/1*q1uVc-MU-tC-WwFp2yXJow.gif

Medical image analysis

- Segmentation results on ISBI cells and DIC-HeLa cells

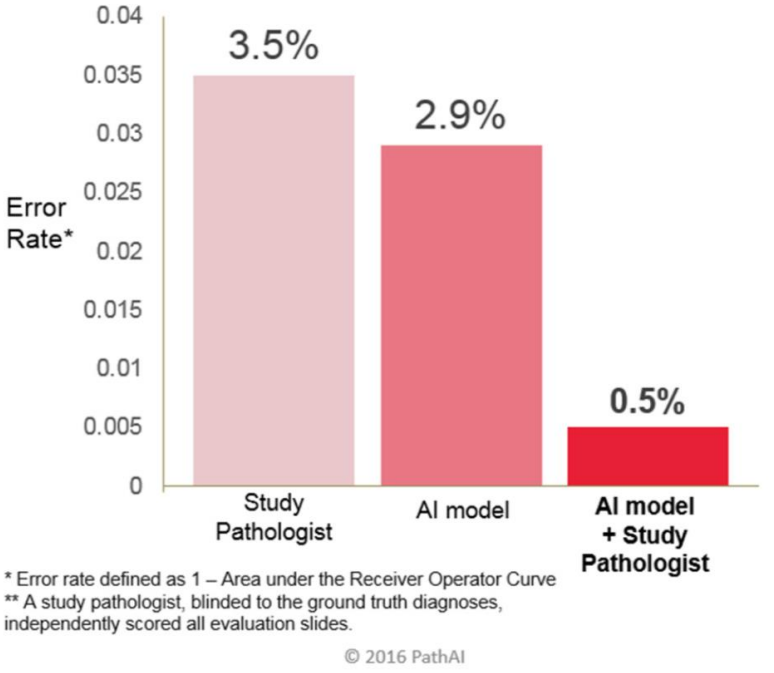


Ronneberger, O., Fischer, P., & Brox, T. (2015, October). U-net: Convolutional networks for biomedical image segmentation. In *International Conference on Medical image computing and computer-assisted intervention* (pp. 234-241). Springer, Cham.

Medical image analysis

- Breast Cancer Diagnoses

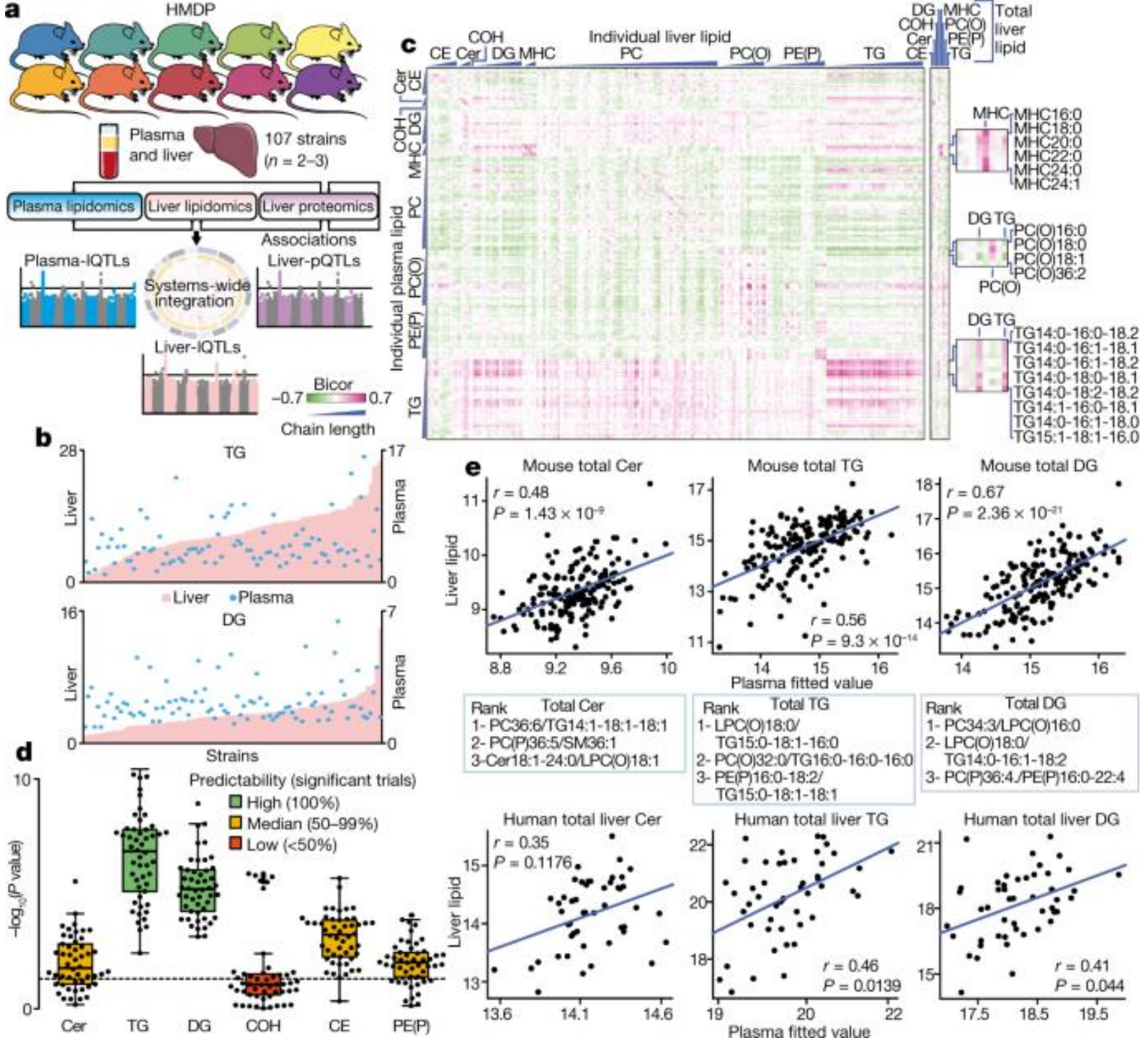
(AI + Pathologist) > Pathologist



Wang, Dayong, et al. "Deep learning for identifying metastatic breast cancer." arXiv preprint arXiv:1606.05718 (2016).

https://blogs.nvidia.com/blog/2016/09/19/deep-learning-breast-cancer-diagnosis/

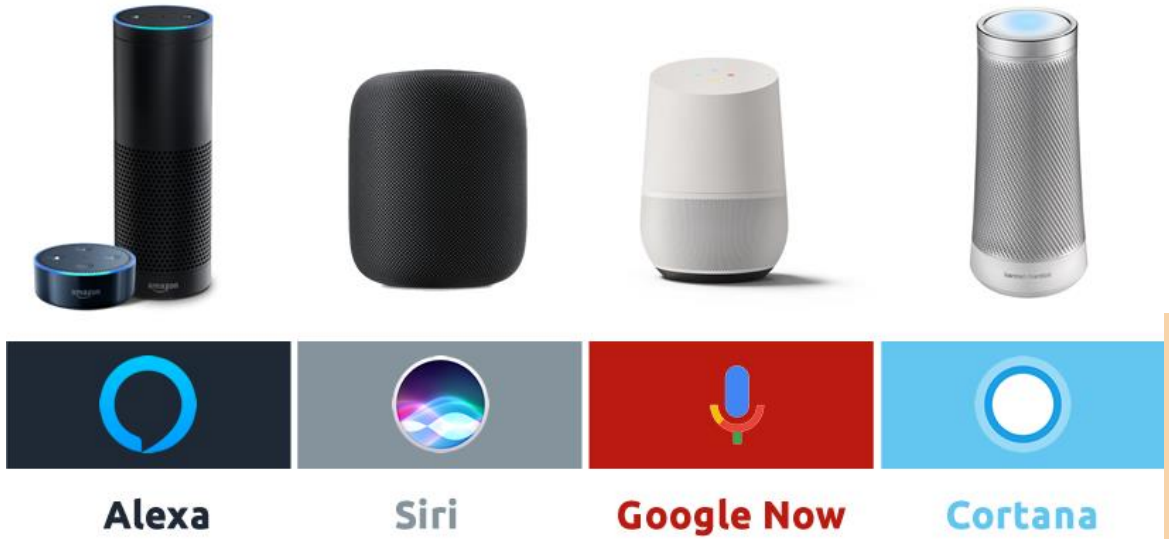
Bioinformatics



Voice assistants

- Google AI can make complete phone calls (2018)

Voice assistants

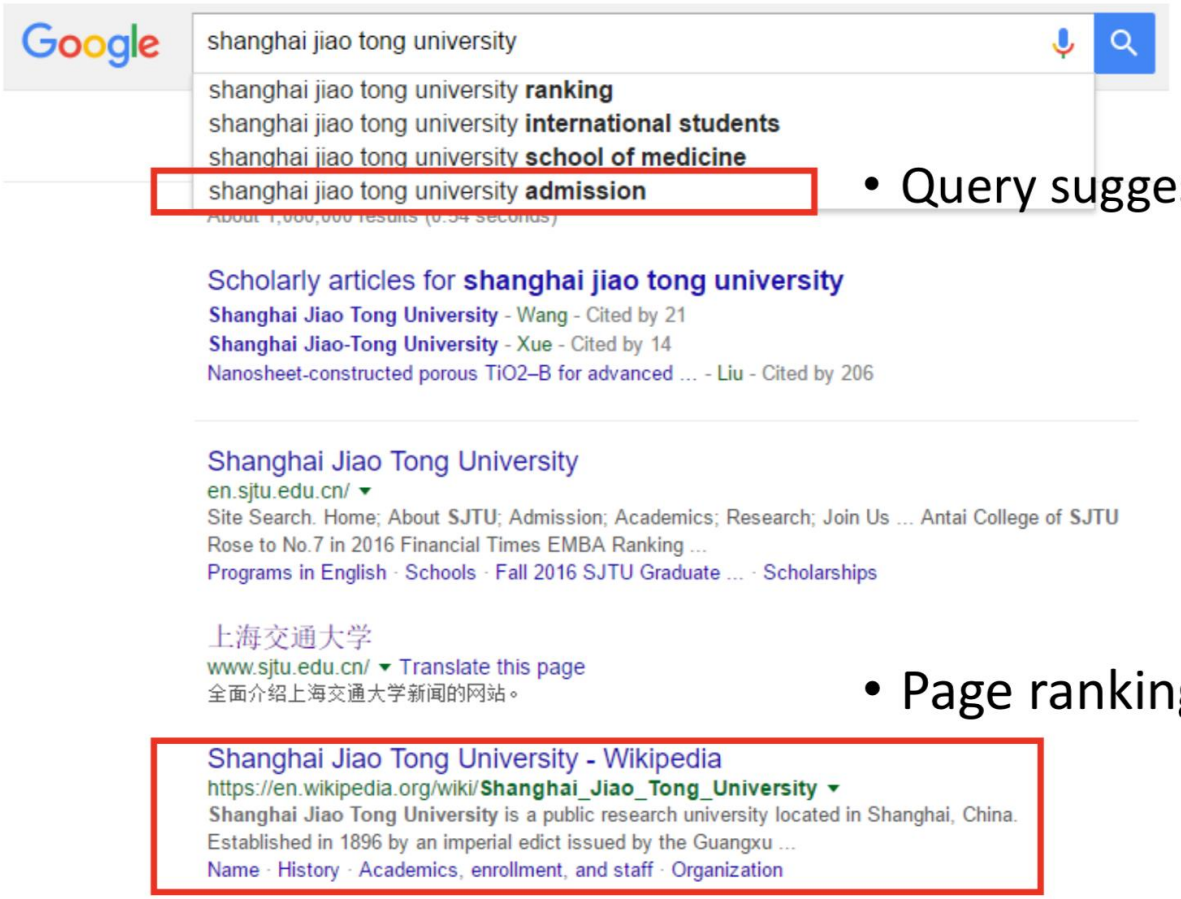


- Alexa/Siri/Google/Cortana
- XiaoAI (Xiaomi)/
  HiAssistant (EMUI)/Siri/
  Bixby (Samsung)/
  Jovi (vivo)

EMUI

Jovi

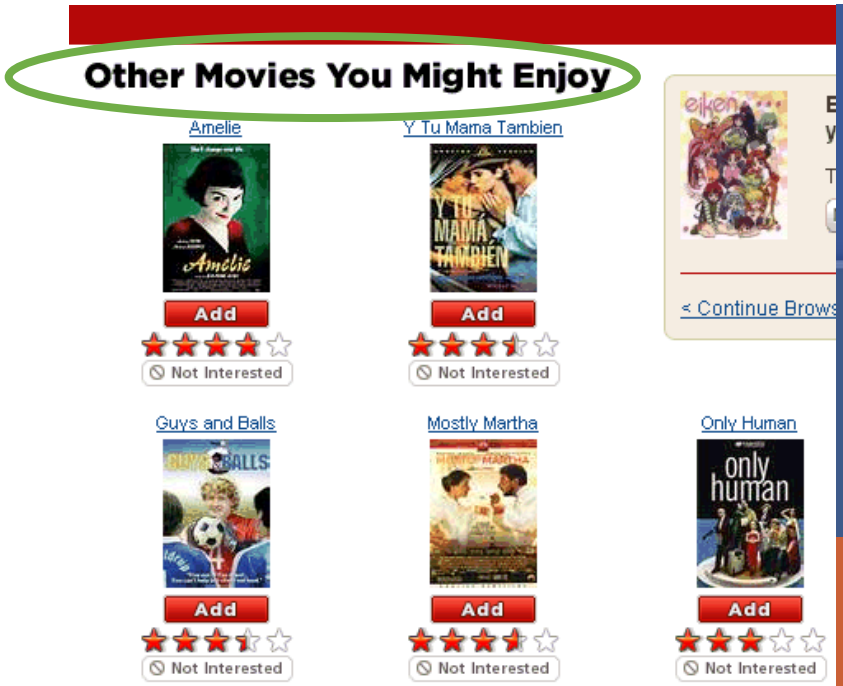
Web search



- Query suggestion
- Page ranking

Slide credit: Weinan Zhang

Web recommendation



Recommend movies/events/products based on history records

Netflex/Facebook/Amazon

Online advertising

Taobao

- Which ad to show
  - Could attract users
- How to set up the bid price
  - for both the platform and the advertisers

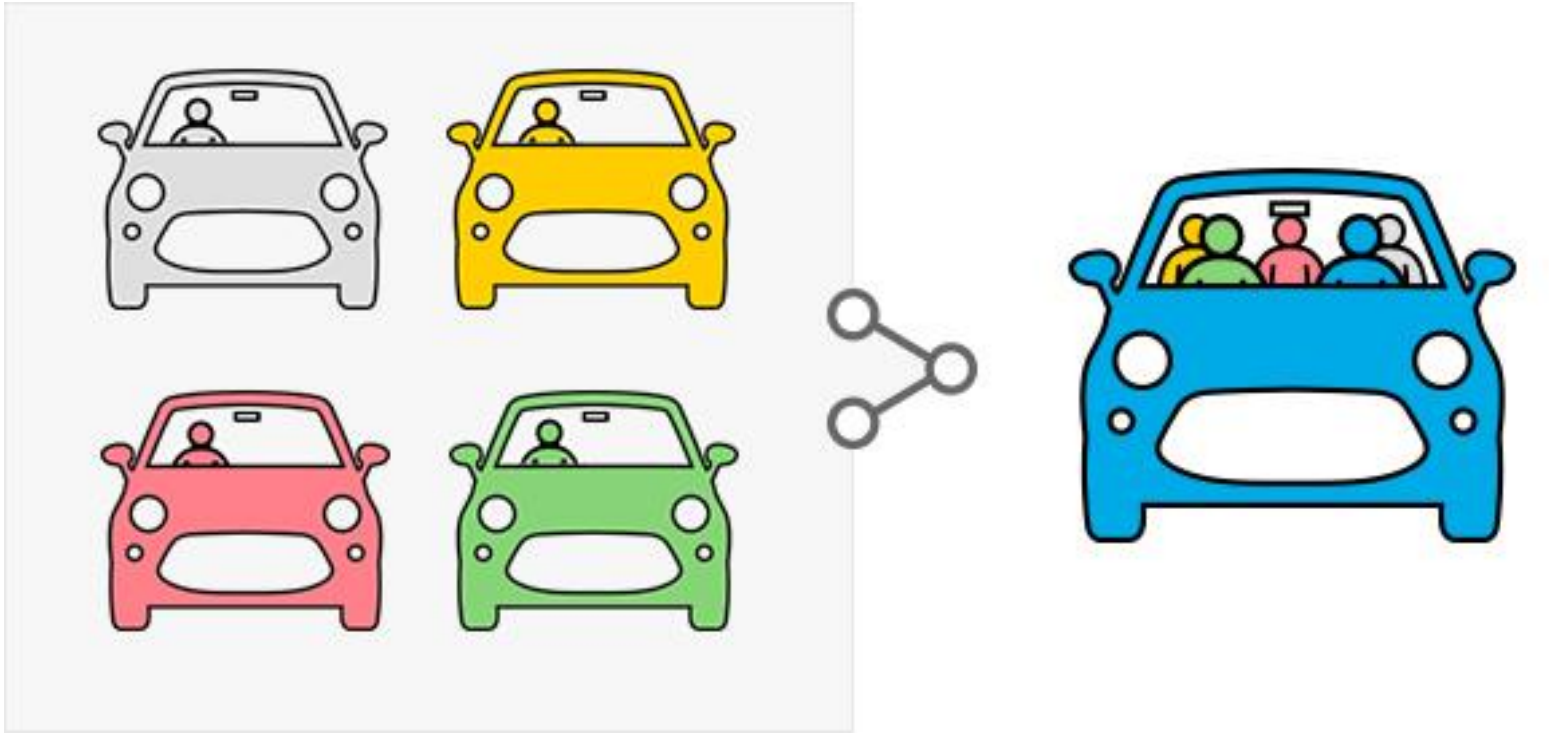
Agriculture: Crop-dusting

- DJI drones (unmanned aerial vehicles)

Sorting parcels

Ride sharing

- Improve traffic

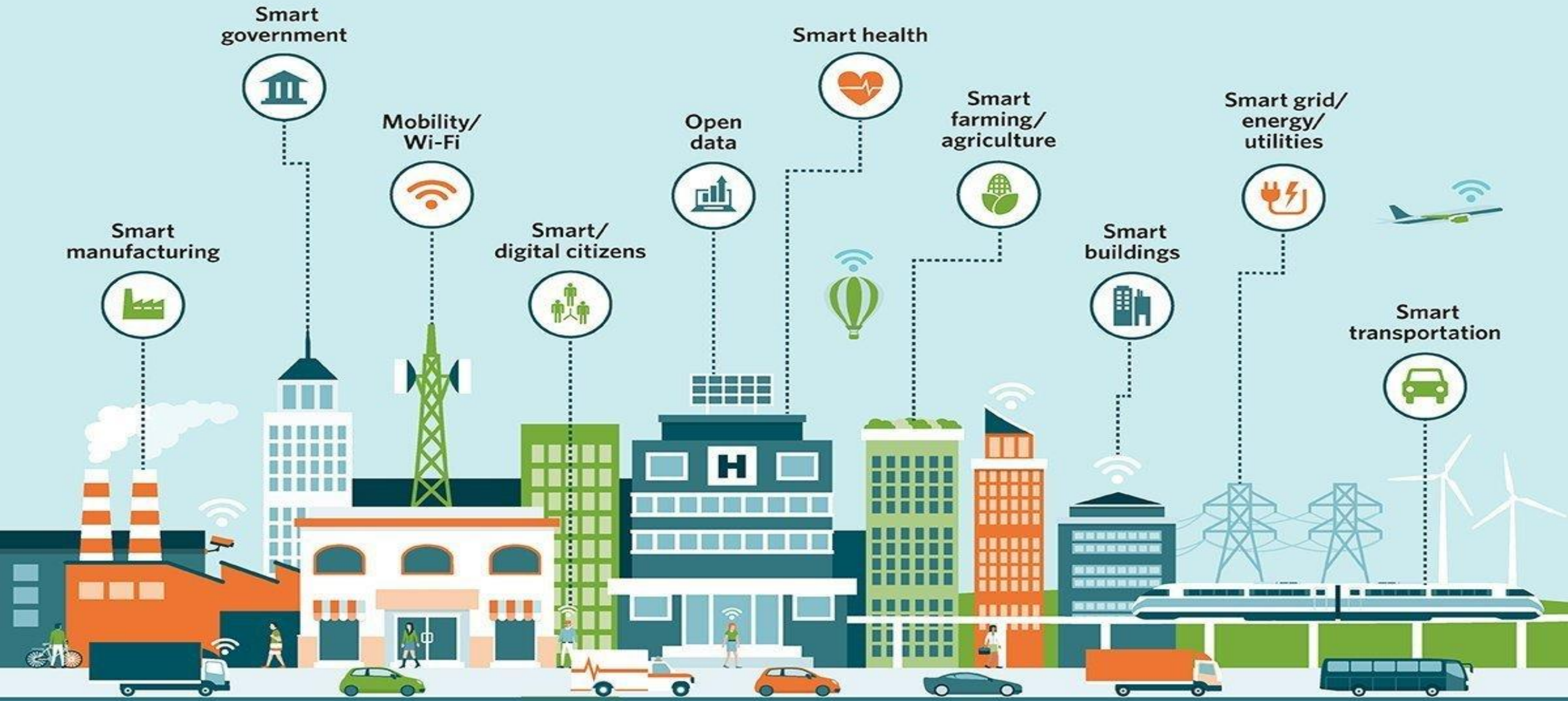


Uber

lyft

DiDi

Smart transportation scheduling



SMART CITY COMPONENTS

Summary

Shuai Li
https://shuaili8.github.io

- What is AI and ML
- An example of AI but not ML
  - A* algorithm
- History of AI
- Recent progress
  - Computer vision/speech recognition/natural language processing/game AI
- Many applications
  - Many industries/many aspects of life

Questions?