CS410: Artificial Intelligence

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https://shuaili8.github.io

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

Part of slide credits: CMU AI & http://ai.berkeley.edu

Teaching Assistant

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  - Research interests on bandit algorithms and optimization
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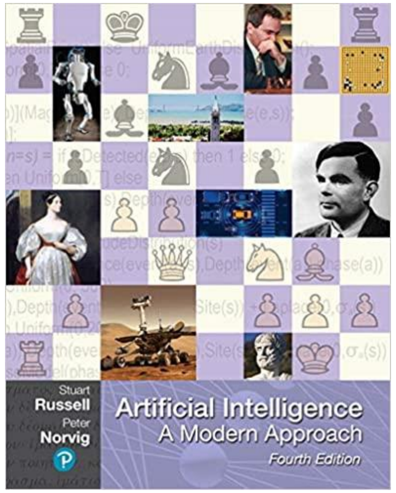
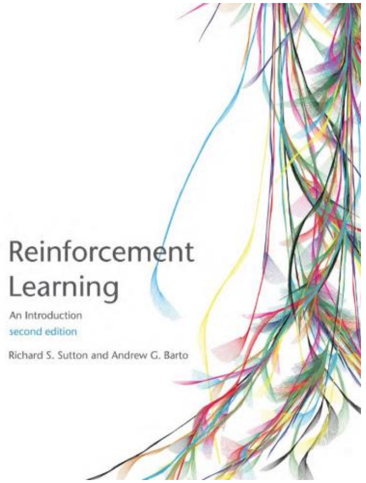
References (will add more during course)

- 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 latest 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%
- Homework (written & programming) 40%
- Project: 25%
- Final exam: 30%

Honor code

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

Course Outline

- Search
- Constraint satisfaction problems
- Game trees
- Markov decision processes (MDPs)
- Reinforcement learning
- Hidden Markov models (HMMs)
- Bayes nets
- Machine learning basics
- Neural networks

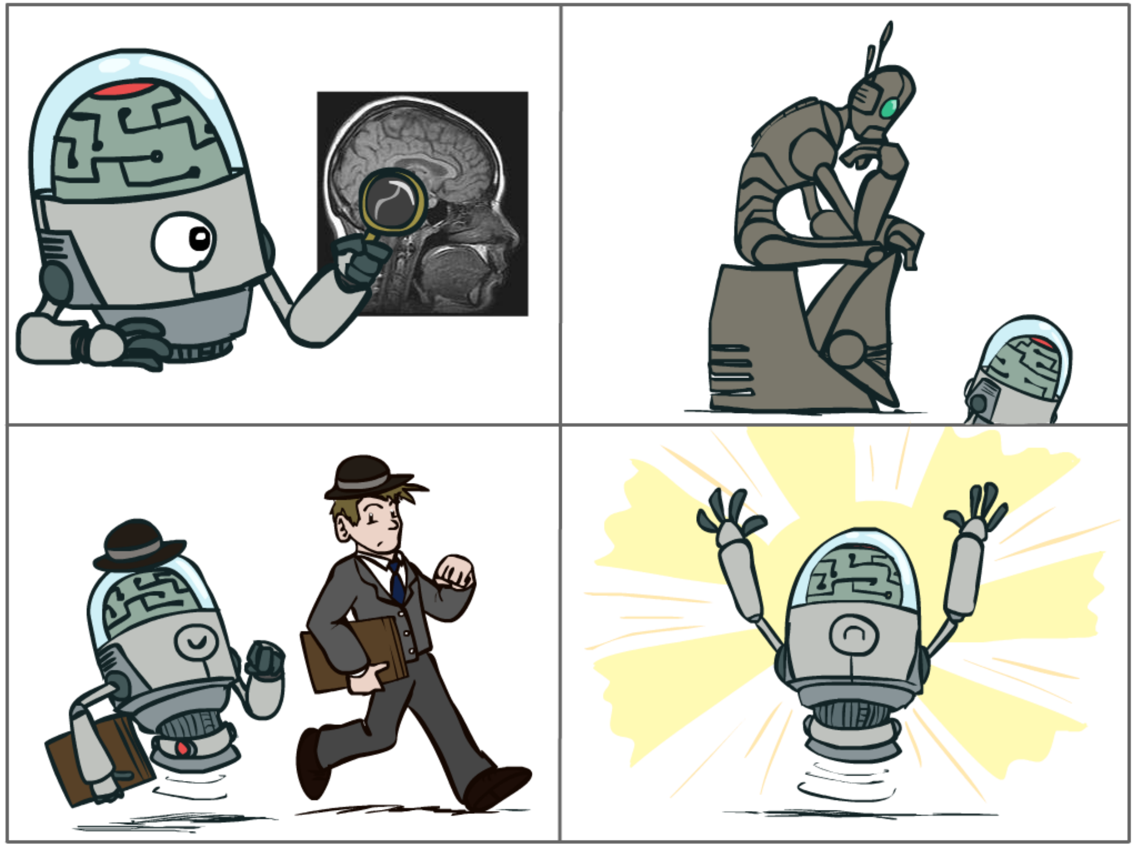
What is AI?

What is AI?

The science of making machines that:

Think like people

Think rationally

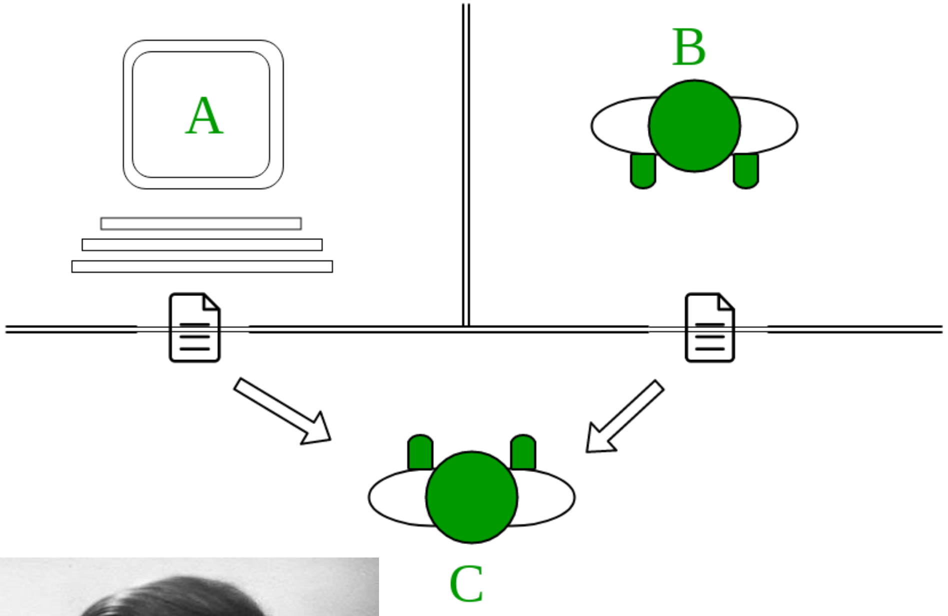


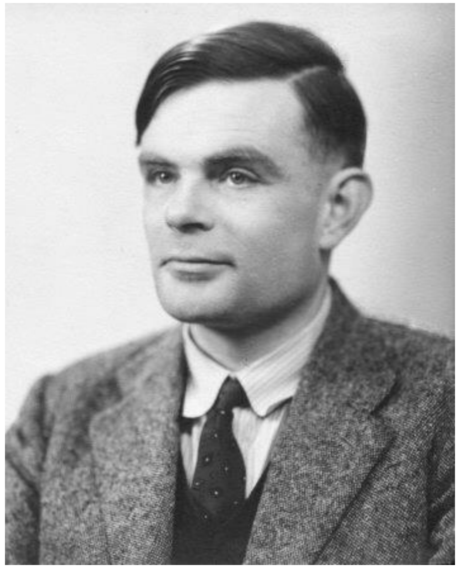
Act like people

Act rationally

Acting humanly: The Turing test approach

- In 1950, Turing defined a test of whether a machine could perform
- Practically though, it is a test of whether a machine can 'act' like a person
- "A human judge engages in a natural language conversation with one human and one machine, each of which tries to appear human. If judge can't tell, machine passes the Turing test"





https://en.wikipedia.org/wiki/Turing_test

Acting humanly: The Turing test approach 2

- The computer would need to possess the following capabilities
  - Natural language processing to enable it to communicate successfully in English/or other languages
  - Knowledge representation to store what it knows or hears
  - Automated reasoning to use the stored information to answer questions and to draw
  - Machine learning to adapt to new circumstances and to detect and extrapolate patterns
- Total Turing test includes a video signal, so the computer will need
  - Computer vision to perceive objects
  - Robotics to manipulate objects and move about

Thinking humanly: The cognitive modeling approach

- The interdisciplinary field of cognitive science brings together computer models from AI and experimental techniques from psychology to construct precise and testable theories of the human mind
- Real cognitive science is necessarily based on experimental investigation of actual humans or animals
- In the early days of AI, people think that an algorithm performs well on a task $\Leftrightarrow$ it is a good model of human performance

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

Thinking rationally: The “laws of thought” approach

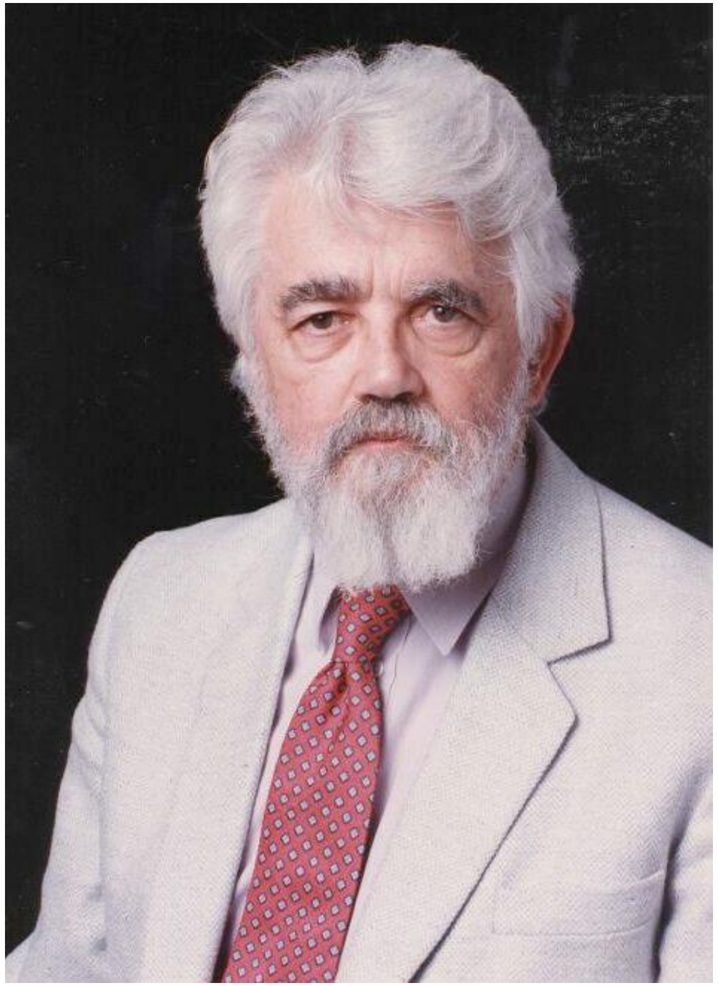
- The Greek philosopher Aristotle, syllogisms (三段论)
- The logicists hope to build on logic systems to create intelligent systems
- The emphasis was on correct inferences

Acting rationally: The rational agent approach

- Making correct inferences is sometimes *part* of being a rational agent, but not *all*
- An agent is just something that acts (agent comes from the Latin agere, to do)
- A rational agent is one that acts so as to achieve the best outcome or, when there is uncertainty, the best expected outcome
- This approach has two advantages:
  - It is more general than the “laws of thought” approach because correct inference is just one of several possible mechanisms for achieving rationality
  - It is more amenable to scientific development than are approaches based on human behavior or human thought

AI Definition by John McCarthy

- What is artificial intelligence
  - It is the science and engineering of making intelligent machines, especially intelligent computer programs
- What is intelligence
  - Intelligence is the computational part of the ability to achieve goals in the world
- John McCarthy (1927-2011)
  - co-authored the document that coined the term "artificial intelligence" (AI), developed the Lisp programming language family



http://www-formal.stanford.edu/jmc/whatisai/whatisai.html

AI and this course

- 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.

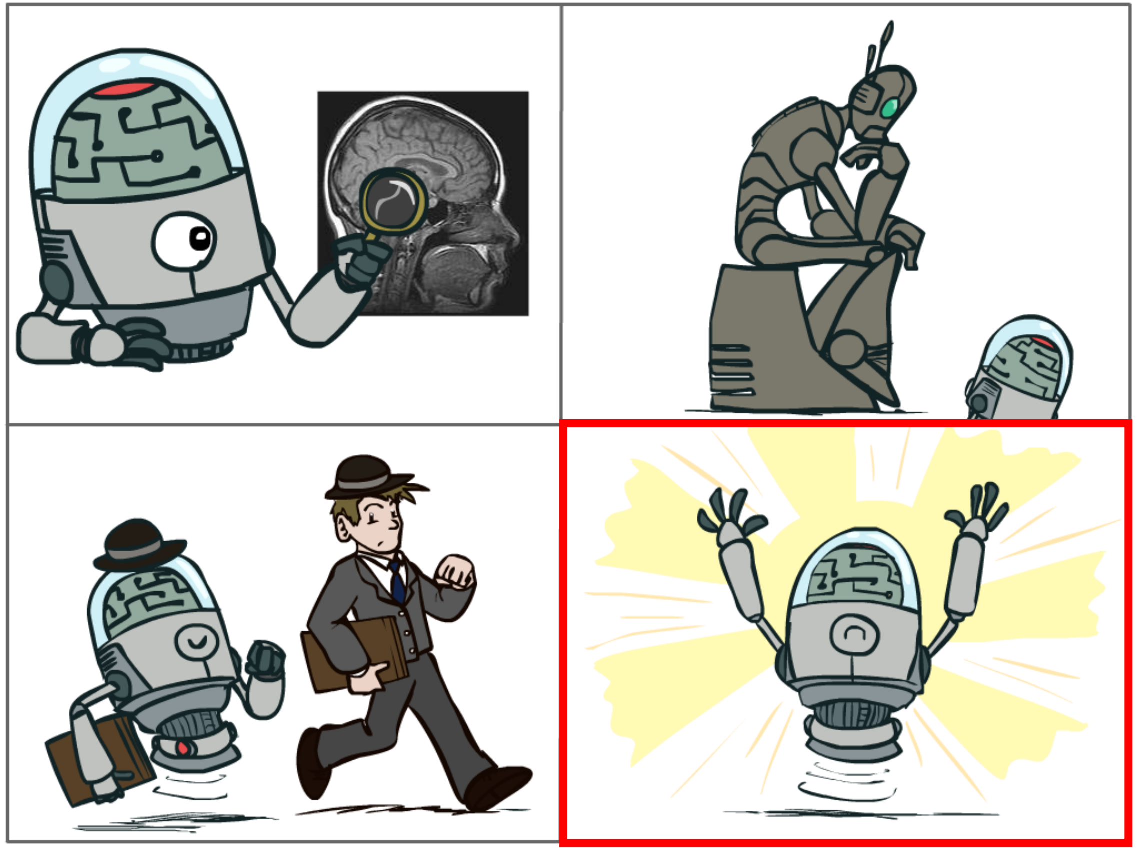
- This course is about:
  - General AI techniques for a variety of problem types
  - Learning to recognize when and how a new problem can be solved with an existing technique
  - Computational Rationality

What is AI?

The science of making machines that:

A: Think like people

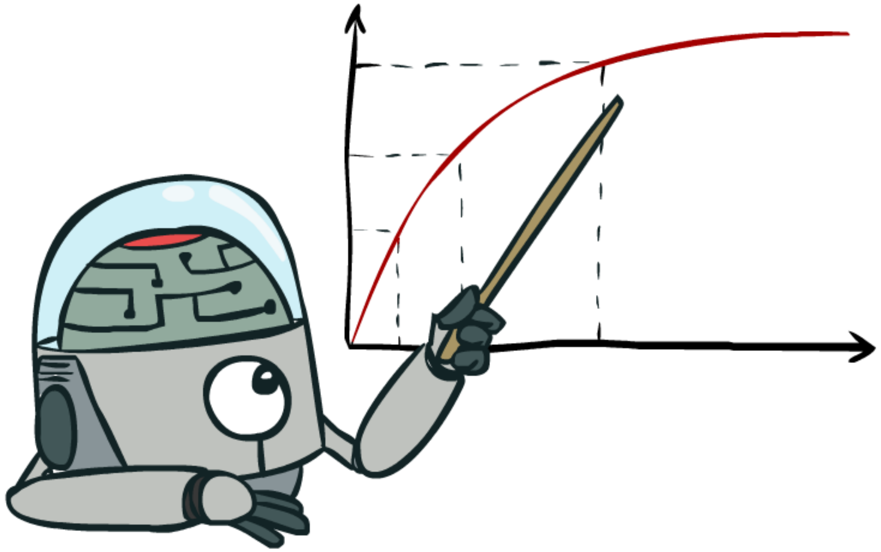
C: Think rationally



B: Act like people

D: Act rationally

Maximize Your Expected Utility



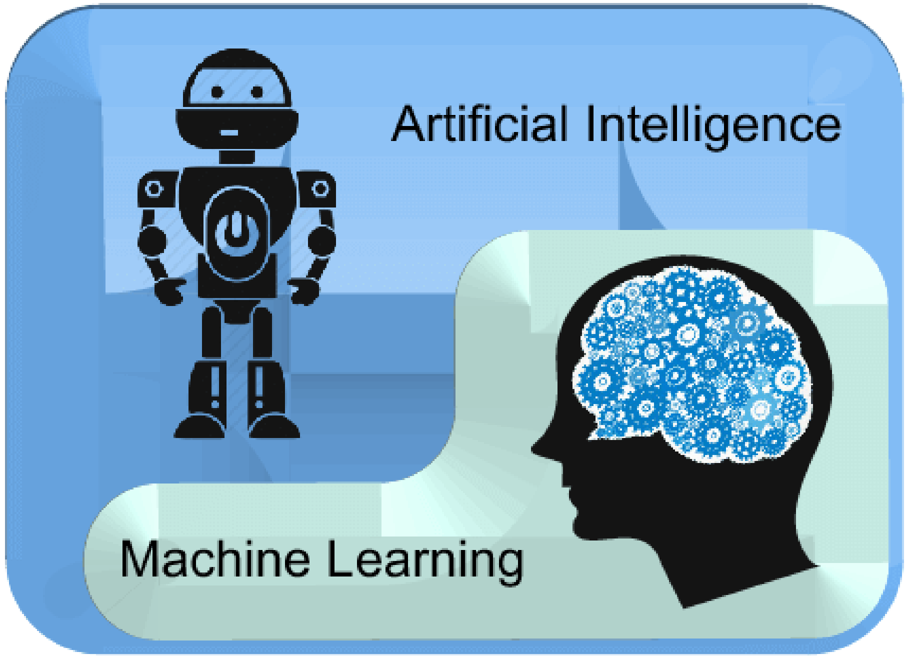
What is Machine Learning?

- 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.



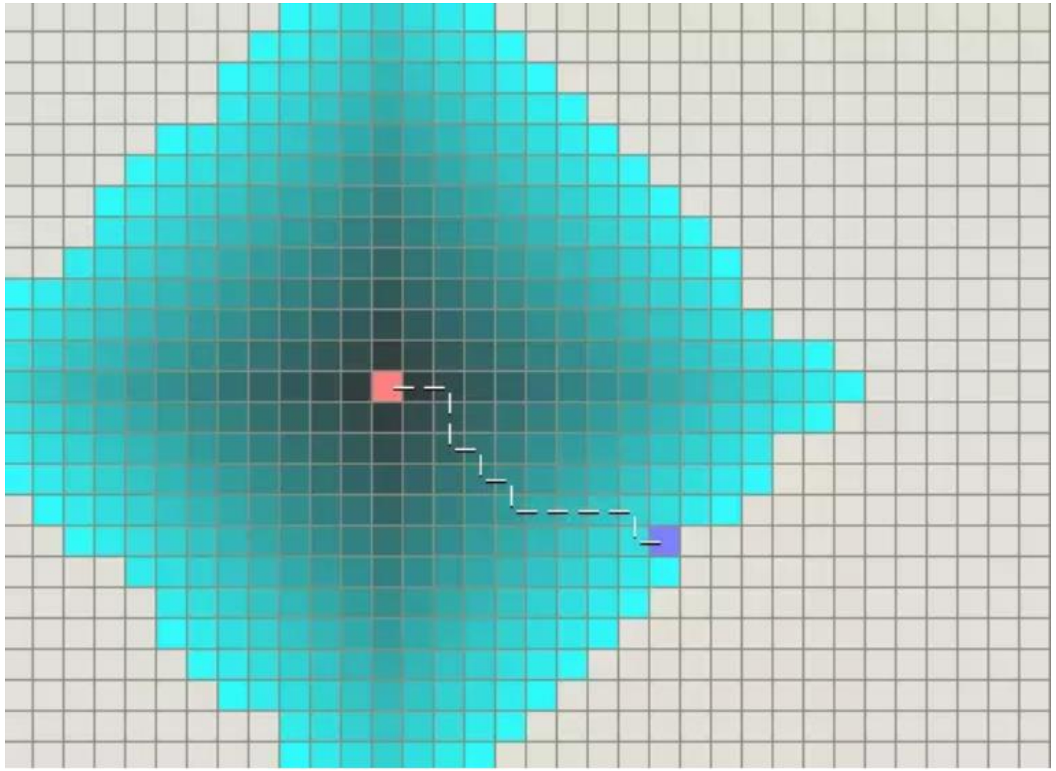
An example of AI but is not machine learning

- 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



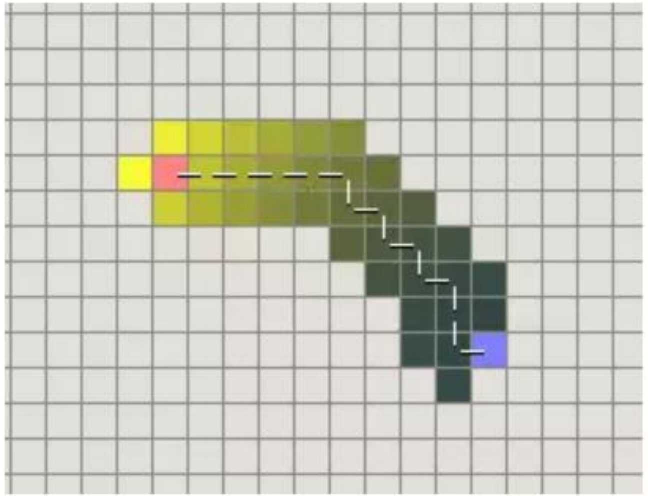
Each time it visits, or expand the point with least $g(n)$ value

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

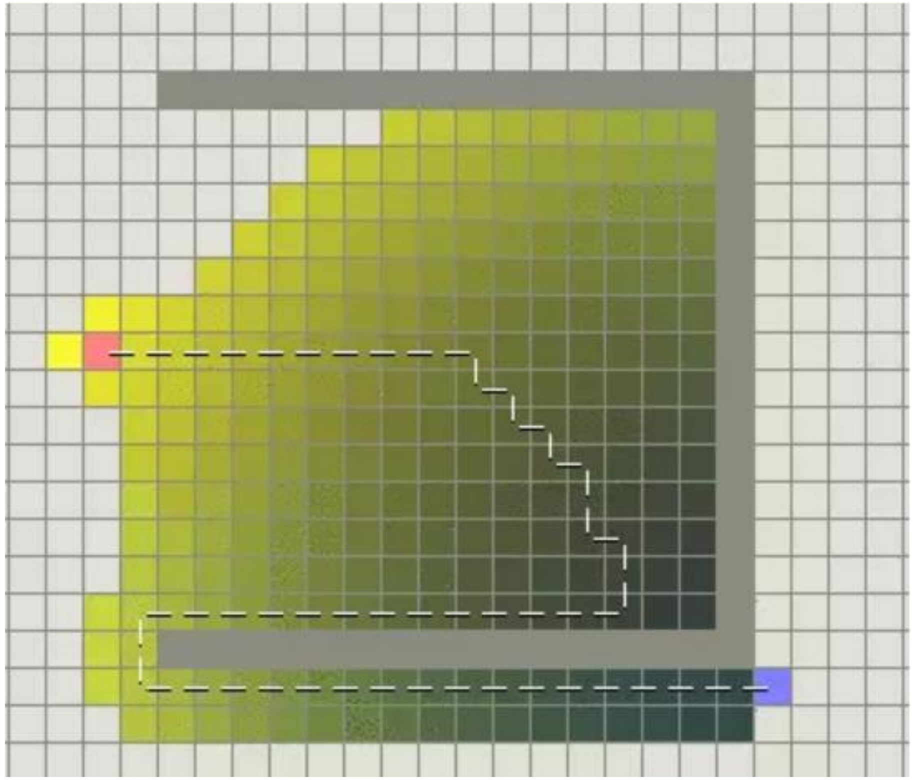
Short comings: computing burden is too high, it visited too many points before getting the end point.

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.

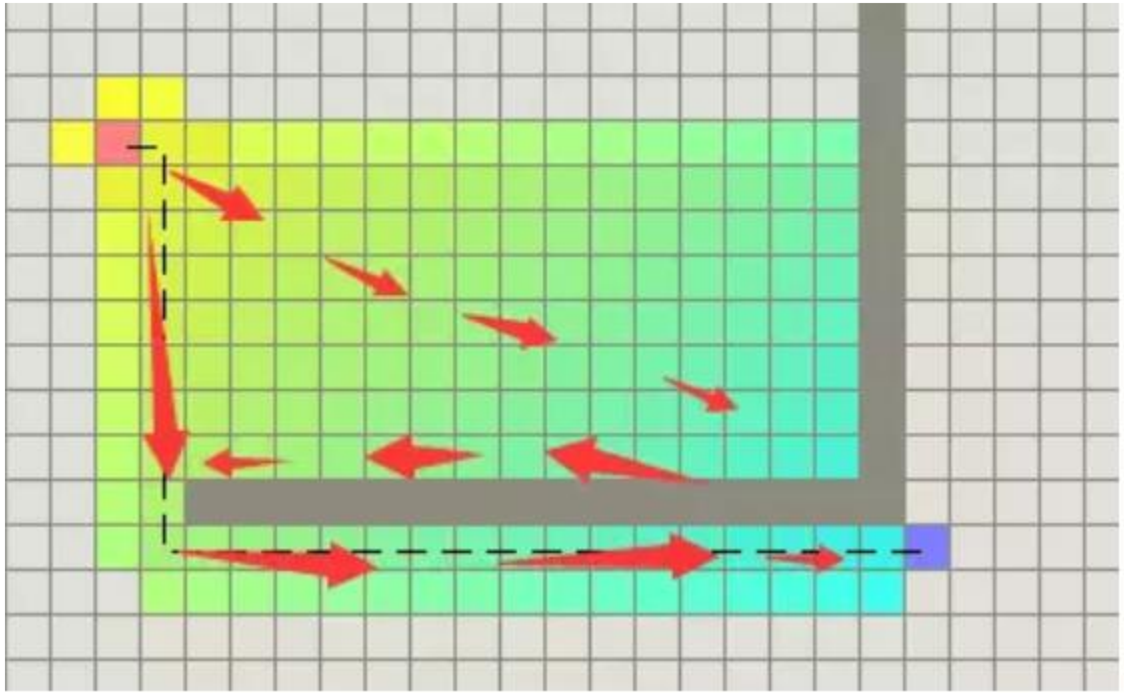


- The cost doubles when there is obstacles



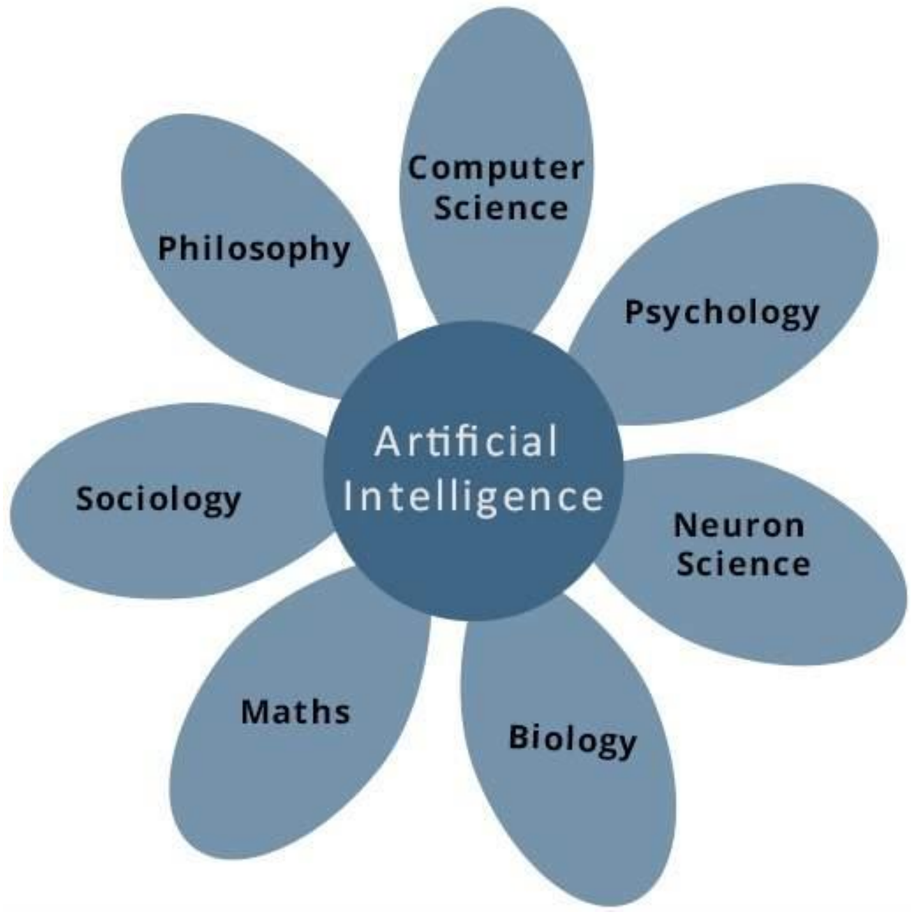
A* algorithm

- 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.



The Foundations of AI

The disciplines that contributed ideas, viewpoints, and techniques to AI



Philosophy

- Can formal rules be used to draw valid conclusions?
- How does the mind arise from a physical brain?
- Where does knowledge come from?
- How does knowledge lead to action?

- Rationalism (理性主义)/materialism (唯物主义)/empiricism (经验主义)

Mathematics

- What are the formal rules to draw valid conclusions?
- What can be computed?
- How do we reason with uncertain information?

- The first nontrivial algorithm is thought to be Euclid's algorithm for computing greatest common divisors
- The word algorithm (and the idea of studying them) comes from al-Khowarazmi, a Persian mathematician of the 9th century
- NP-completeness/probability/entropy

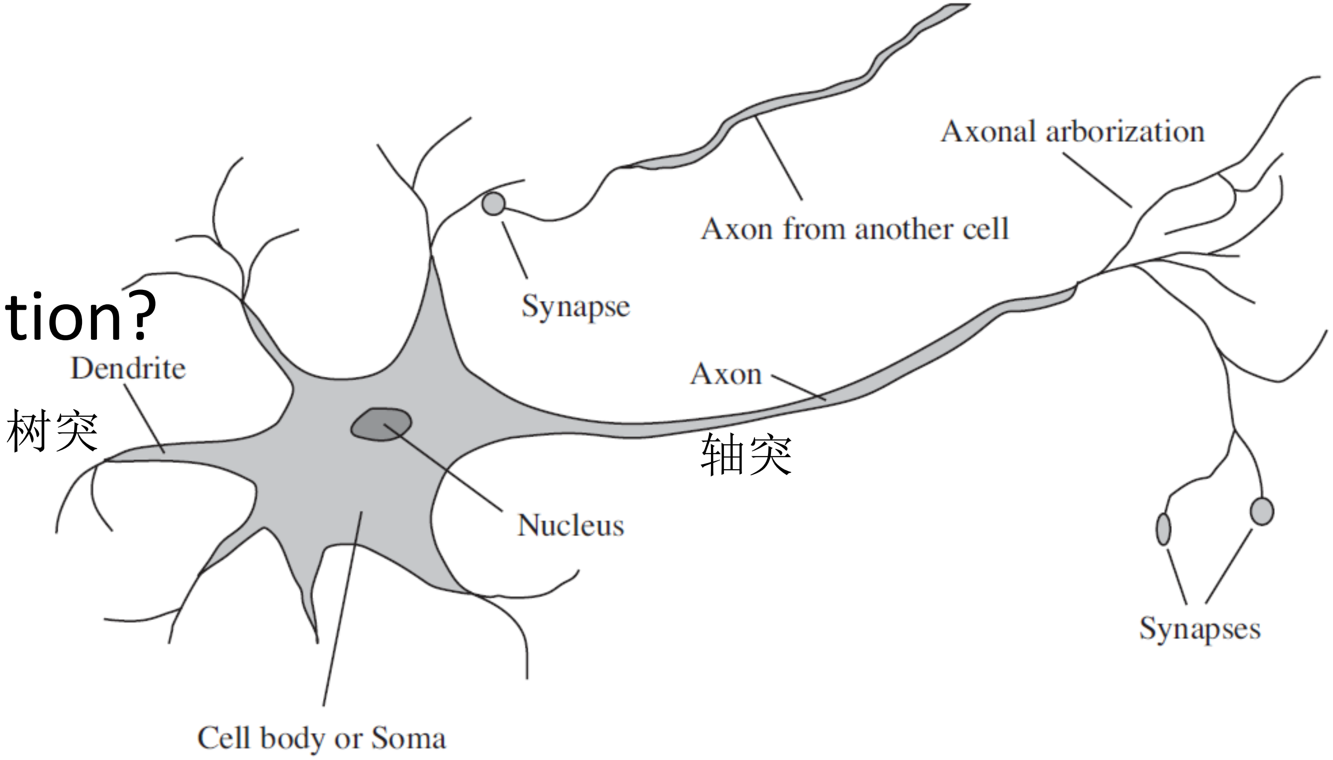
Economics

- How should we make decisions so as to maximize payoff?
- How should we do this when others may not go along?
- How should we do this when the payoff may be far in the future?

- The pioneering AI researcher Herbert Simon (1916–2001) won the Nobel Prize in economics in 1978 for his early work showing that models based on satisficing—making decisions that are “good enough,” rather than laboriously calculating an optimal decision—gave a better description of actual human behavior (Simon, 1947).

Neuroscience

- How do brains process information?



	Supercomputer	Personal Computer	Human Brain
Computational units	10^4 CPUs, 10^{12} transistors	4 CPUs, 10^9 transistors	10^{11} neurons
Storage units	10^{14} bits RAM	10^{11} bits RAM	10^{11} neurons
	10^{15} bits disk	10^{13} bits disk	10^{14} synapses
Cycle time	10^{-9} sec	10^{-9} sec	10^{-3} sec
Operations/sec	10^{15}	10^{10}	10^{17}
Memory updates/sec	10^{14}	10^{10}	10^{14}

Psychology

- How do humans and animals think and act?

- Cognitive psychology views the brain as an information-processing device
- Developmental psychology is the scientific study of how and why human beings change over the course of their life, especially concerned with infants and children

Computer engineering

- How can we build an efficient computer?

- Designing algorithms is not enough
- Hardware
  - modern digital electronic computer
- Software
  - operating systems, programming languages, and tools needed to write modern programs (and papers about them)
- Work in AI has also pioneered many ideas that have made their way back to mainstream computer science
  - time sharing, interactive interpreters, personal computers with windows and mice

Control theory and cybernetics

- How can artifacts operate under their own control?

- Goal of modern control theory, especially the branch known as stochastic optimal control, is to
  - Design systems that maximize an objective function over time
  - Roughly match our view of AI: designing systems that behave optimally
- Differences of control theory and AI:
  - Control theory more care about continuous variables with calculus and matrix algebra as tools
  - AI uses logical inference and computation to escape these limitations and consider problems such as language, vision, and planning that fell completely outside the control theorist's purview

Linguistics

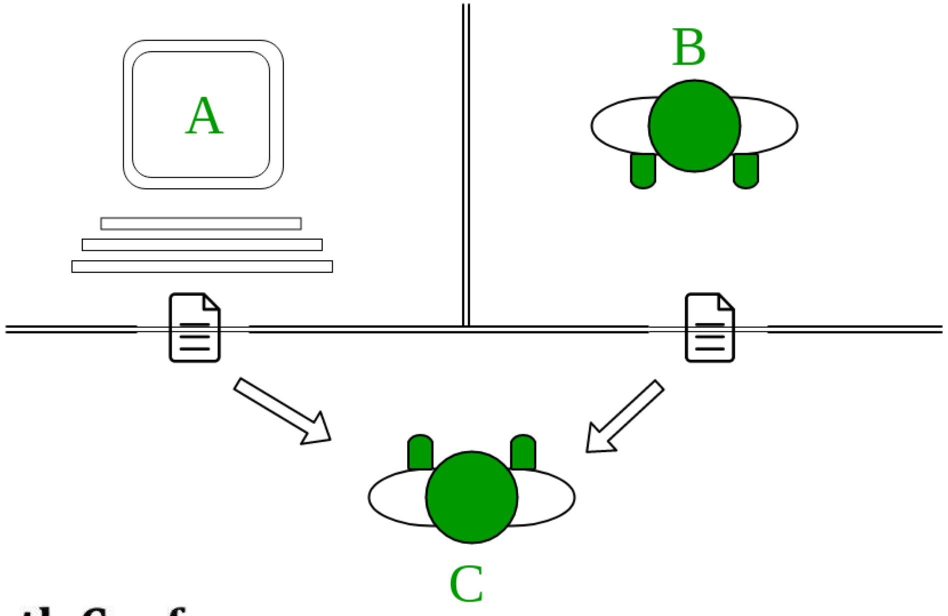
- How does language relate to thought?

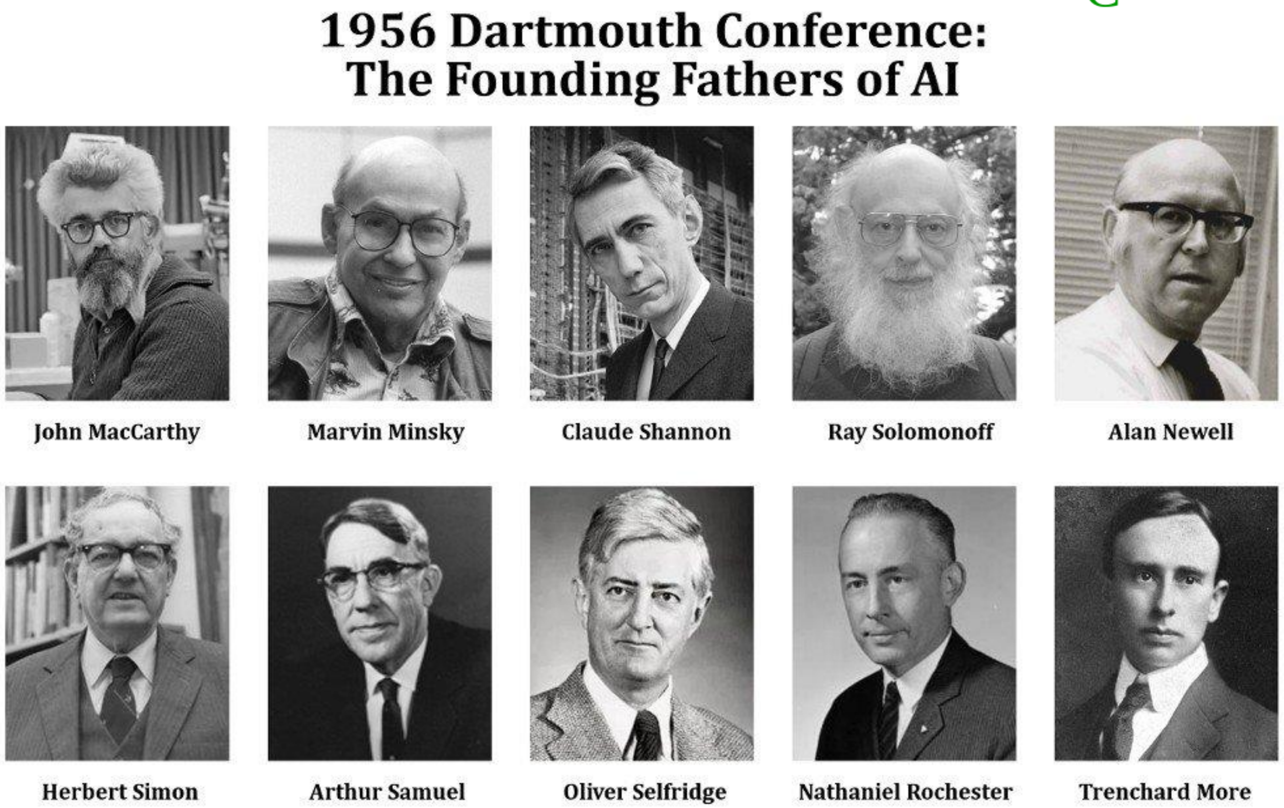
- Understanding language requires an understanding of the subject matter and context, not just an understanding of the structure of sentences
- Knowledge representation (the study of how to put knowledge into a form that a computer can reason with)
  - decades of work on the philosophical analysis of language

The History of AI

1950s

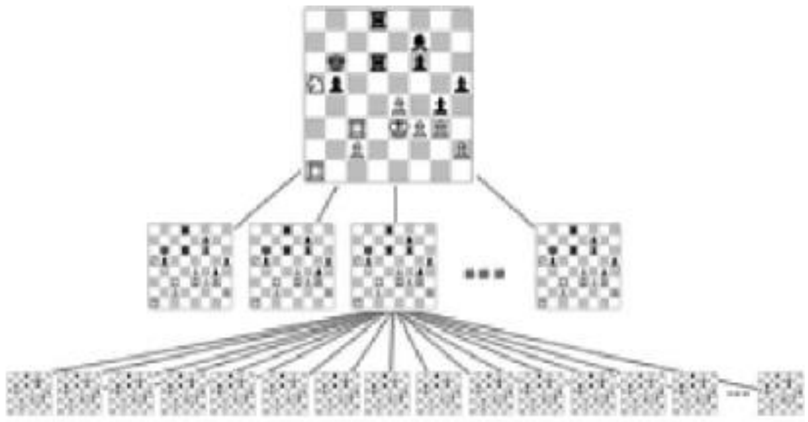
- Turing's test
- Dartmouth Conference 1956: the birth of AI

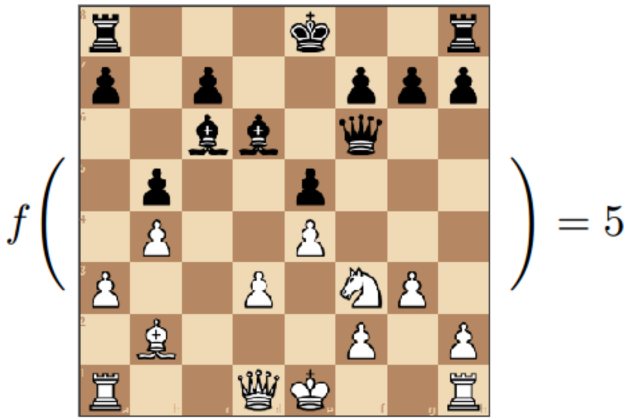




Chess as the First Killer App for AI

- Claude Shannon proposed the first chess playing program in 1950
  - It included adversarial search and minimax (later lecture)
  - It also included many heuristics for faster searching





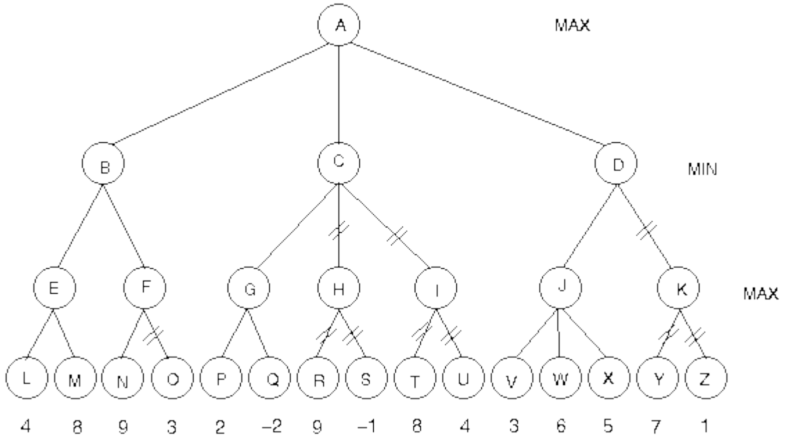


TABLE 1 Comparison of Current Chess Programs

	Turing	Kister, Stein, Ulam, Walden, Wells (Los Alamos)	Bernstein, Roberts, Arbuckle, Belsky (Bernstein)	Newell, Shaw, Simon (NSS)
Vital statistics				
Date	1951	1956	1957	1958
Board	8 × 8	6 × 6	8 × 8	8 × 8
Computer	Hand simulation	MANIAC-I 11,000 ops./sec	IBM 704 42,000 ops./sec	RAND JOHNNIAC 20,000 ops./sec
Chess program				
Alternatives	All moves	All moves	7 plausible moves Sequence of move generators	Variable Sequence of move generators
Depth of analysis	Until dead (exchanges only)	All moves 2 moves deep	7 plausible moves 2 moves deep	Until dead Each goal generates moves
Static evaluation	Numerical Many factors	Numerical Material, mobility	Numerical Material, mobility Area control King defense	Nonnumerical Vector of values Acceptance by goals
Integration of values	Minimax	Minimax (modified)	Minimax	Minimax
Final choice	Material dominates Otherwise, best value	Best value	Best value	1. First acceptable 2. Double function
Programming				
Language		Machine code	Machine code	IPL-IV, interpretive
Data scheme		Single board No records	Single board Centralized tables Recompute	Single board Decentralized List structure Recompute
Time	Minutes	12 min/move	8 min/move	1–10 hr/move (est.)
Space		600 words	7000 words	Now 6000 words, est. 16,000
Results				
Experience	1 game	3 games (no longer exists)	2 games	0 games Some hand simulation
Description	Loses to weak player Aimless Subtleties of evaluation lost	Beats weak player Equivalent to human with 20 games experience	Passable amateur Blind spots Positional	Good in spots (opening) No aggressive goals yet

45

Allen Newell
J. C. Shaw
H. A. Simon

Chess-Playing Programs and the Problem of Complexity

The Promise of AI

- In 1965, Herbert Simon predicted that “machines will be capable, within 20 years, of doing any work a man can do”

- In 1967, AI pioneer Marvin Minsky predicted “in from three to eight years we will have a machine with the general intelligence of an average human being.”

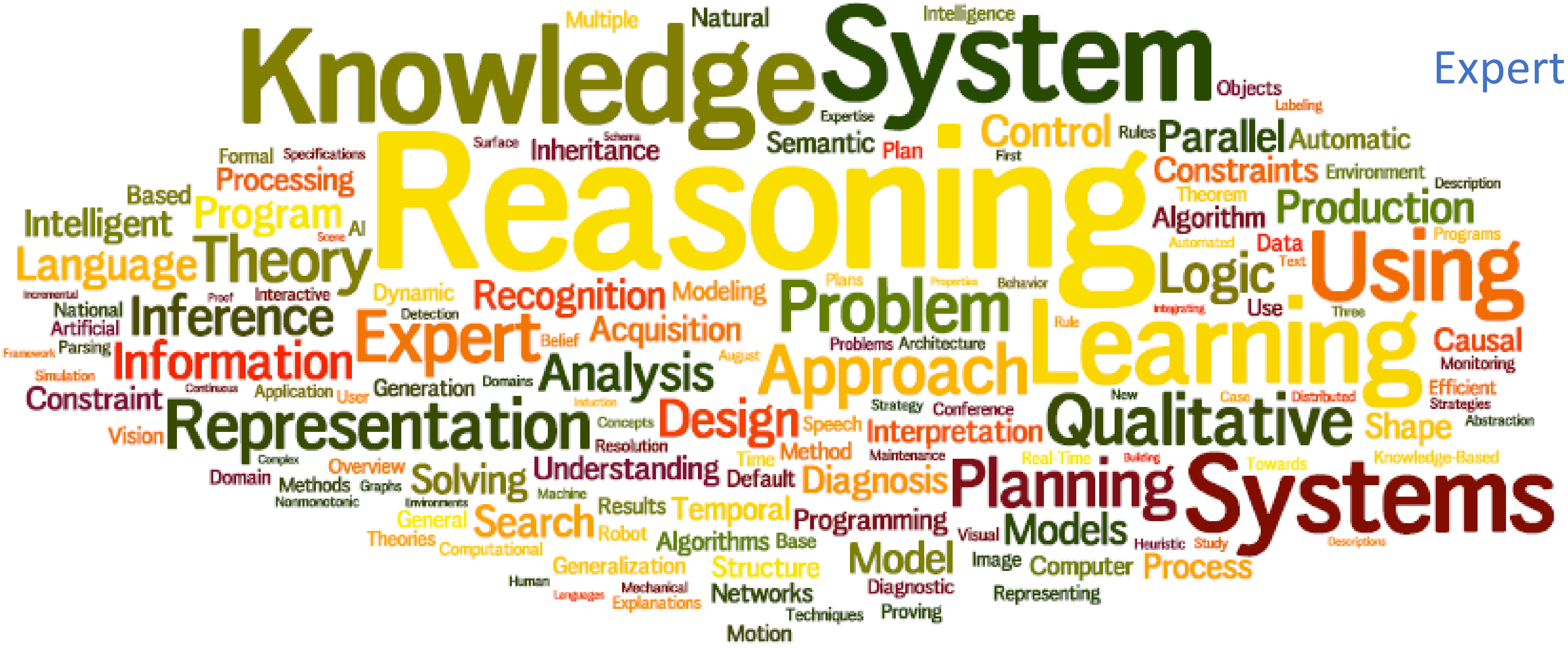
- In 1967, John McCarthy told the U.S. government that it would be possible to build “a fully intelligent machine” in the space of a decade

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

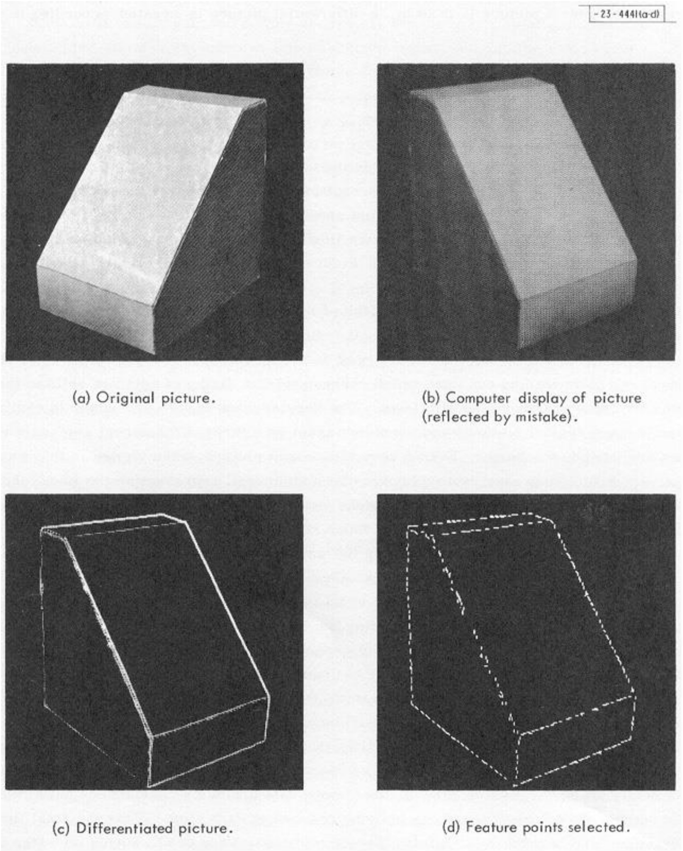
Evolution of AI Research: 1970s and 1980s

- Focus on:
  - Searching for a solution using general search algorithms
  - Encoding knowledge that humans have and using logic to solve

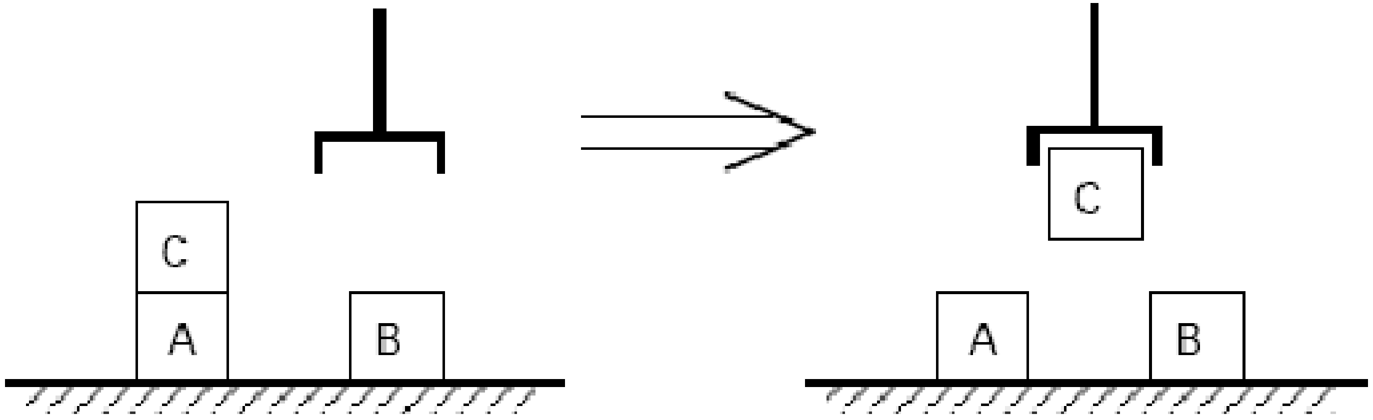


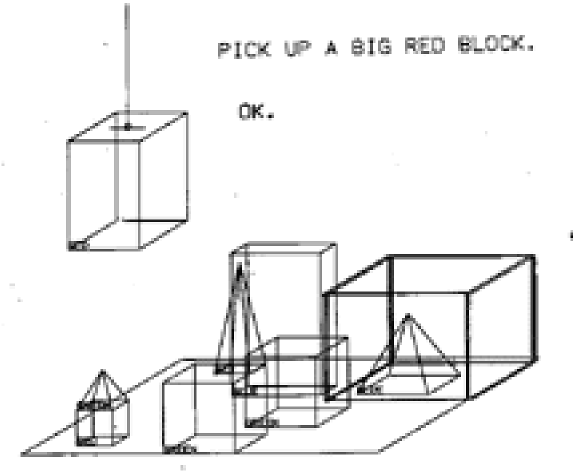
Expert System

Computer Vision, Blocks World, Natural Language



Larry Roberts 1963 Thesis





Terry Winograd's 1971 Thesis on SHRDLU for natural language understanding

Early Robots

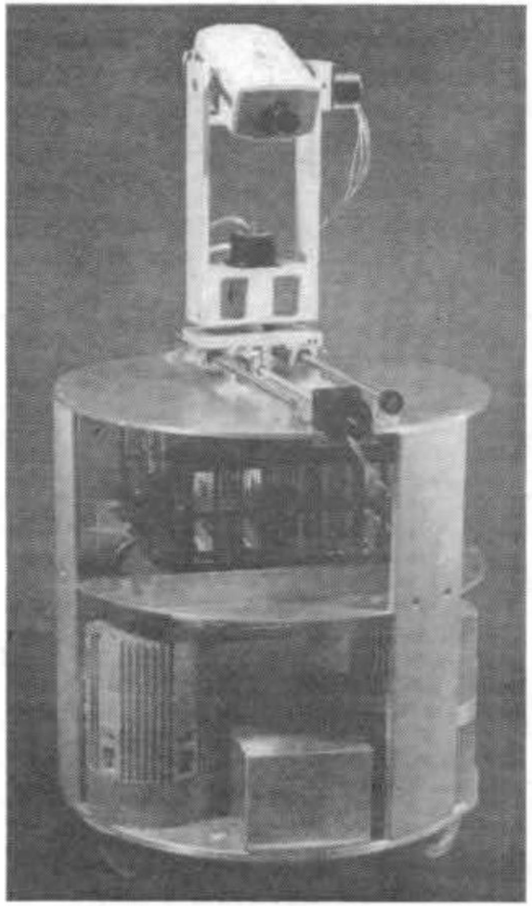


Fig. 8. The CMU Rover.

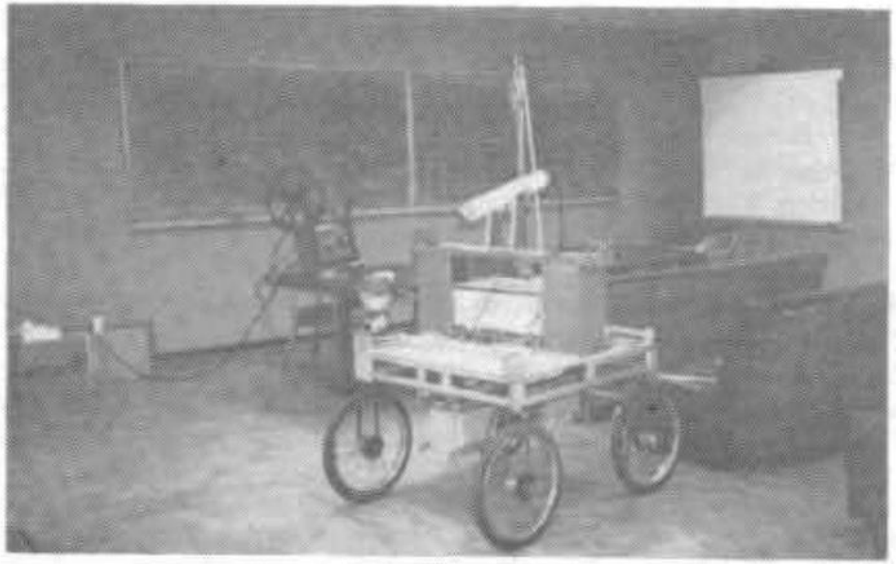


Fig. 1. The Stanford Cart.

1983 – mobile robots by Hans Moravec

Dean Pomerleau (CMU) 1986
NAVLAB controlled by NNs

https://www.nytimes.com/video/science/1247468063802/stanford-cart.html
https://www.youtube.com/watch?v=ntIczNQKfjQ

Deep Blue

- Started in the mid-1980s at CMU, didn’t win until 1997
- Project moved to IBM
- “Good Old-Fashioned” Brute Force Search using custom hardware

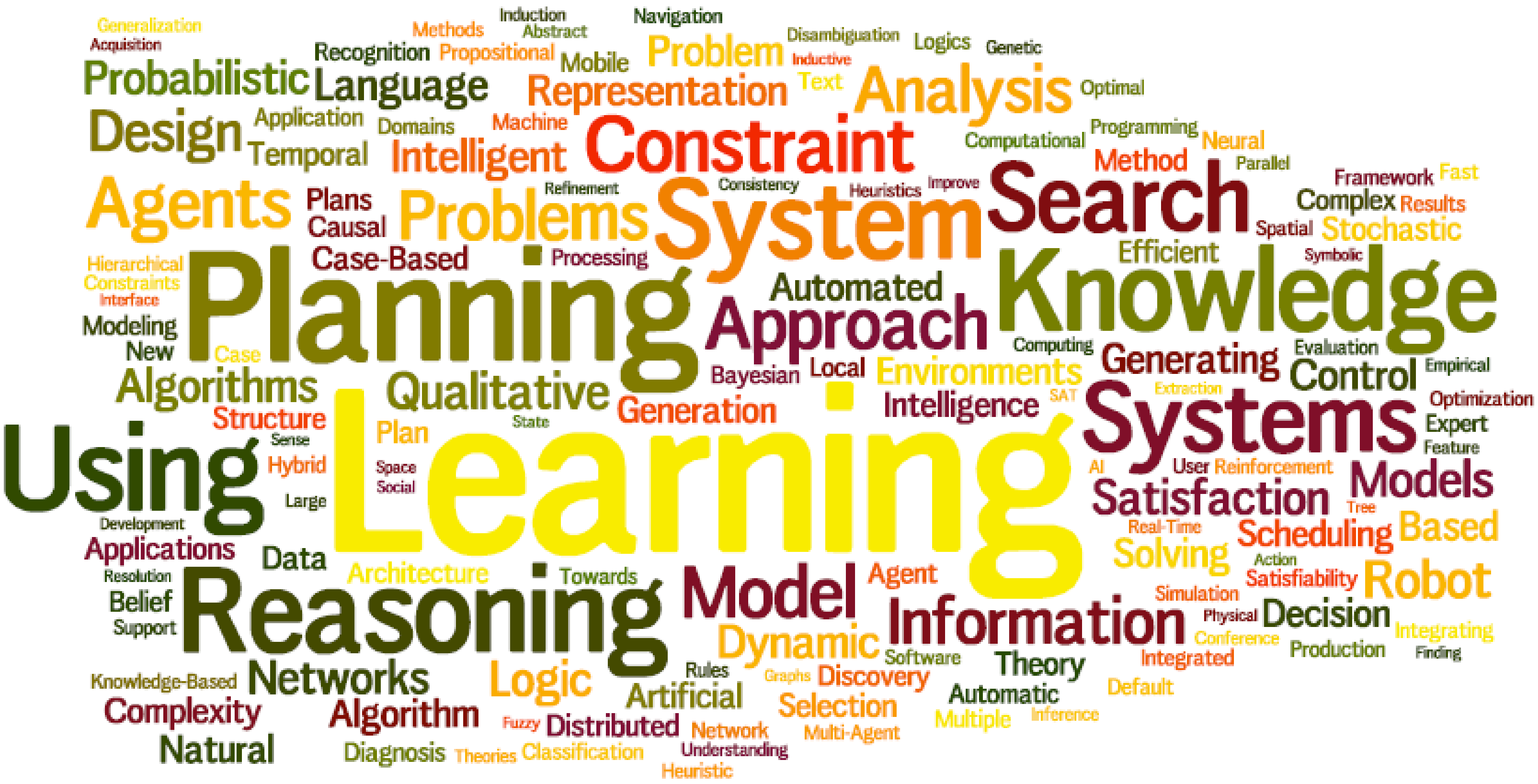
- Win Garry Kasparov by 3.5:2.5 on Chess
- Search over 12 following steps

- https://www.youtube.com/watch?v=KF6sLCeBj0s

Rise of Statistical Approaches: 1990s – 2000s

- Knowledge-based:
  - Search for a solution using general search algorithms
  - Encode knowledge that humans have and use logic to solve
- Statistical:
  - Learning patterns and choosing solutions based on observed likelihood

Evolution of AI Research:1990s



Evolution of AI Research: 2000s

Evolution of AI Research: 2010s

2010s-now

- Deep learning
  - The return of neural networks
- Big data
  - Large datasets, like ImageNet
- Computational power
- Artificial general intelligence (AGI)

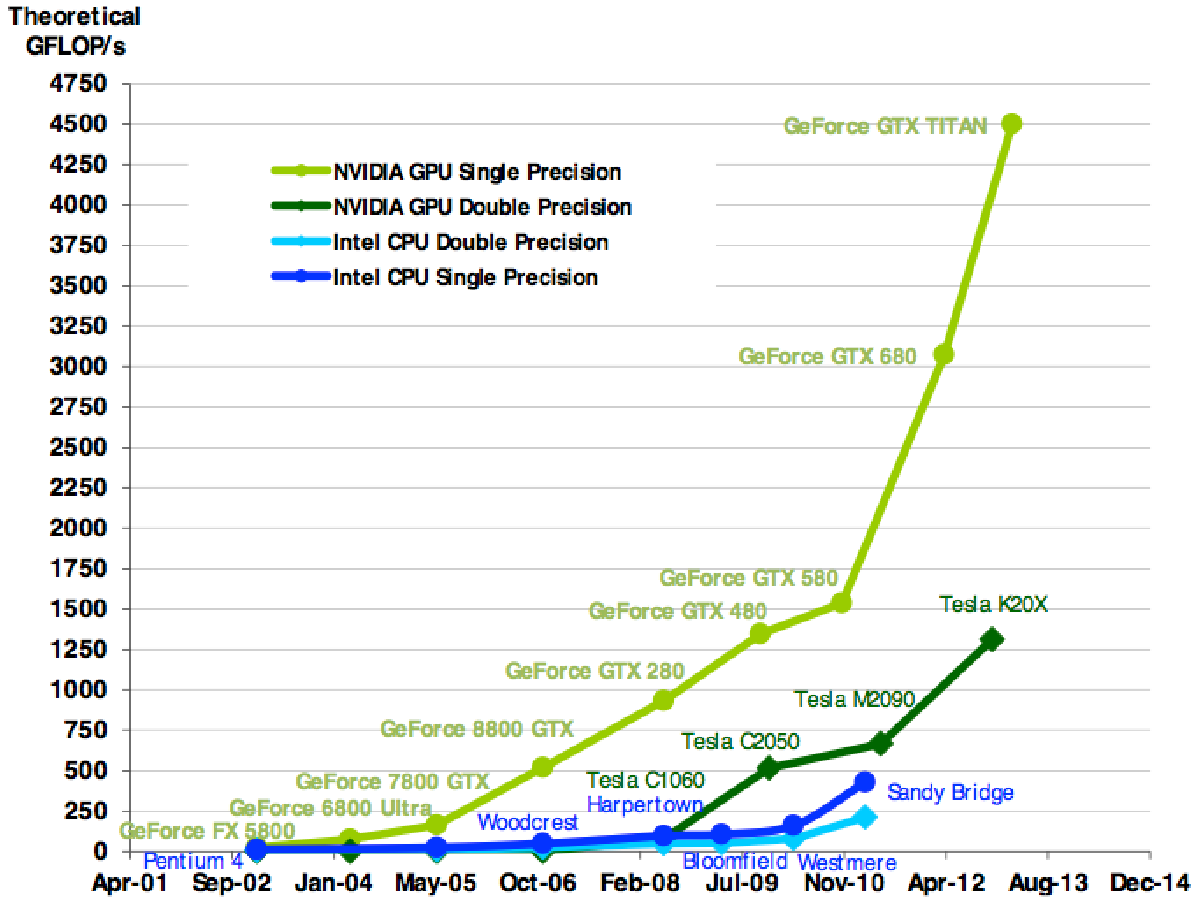
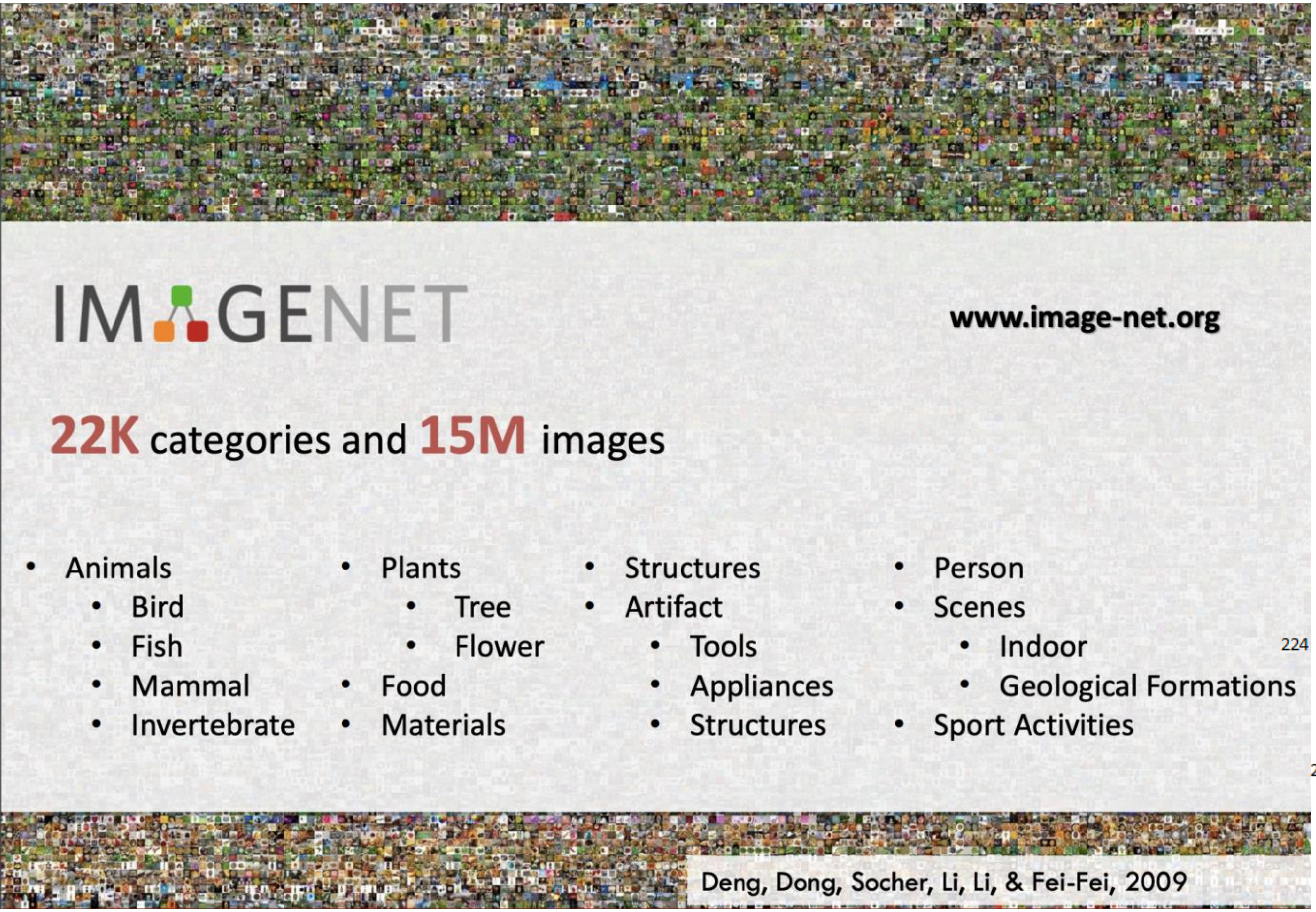


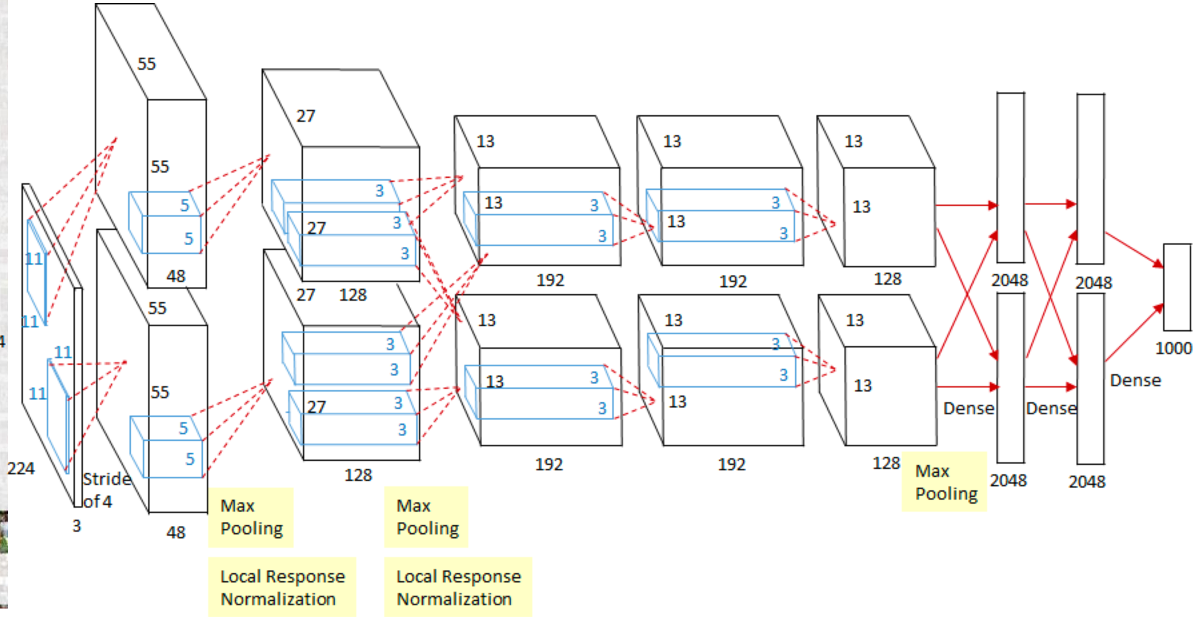
Figure 1 Floating-Point Operations per Second for the CPU and GPU

Computer Vision (CV) -- ImageNet, AlexNet



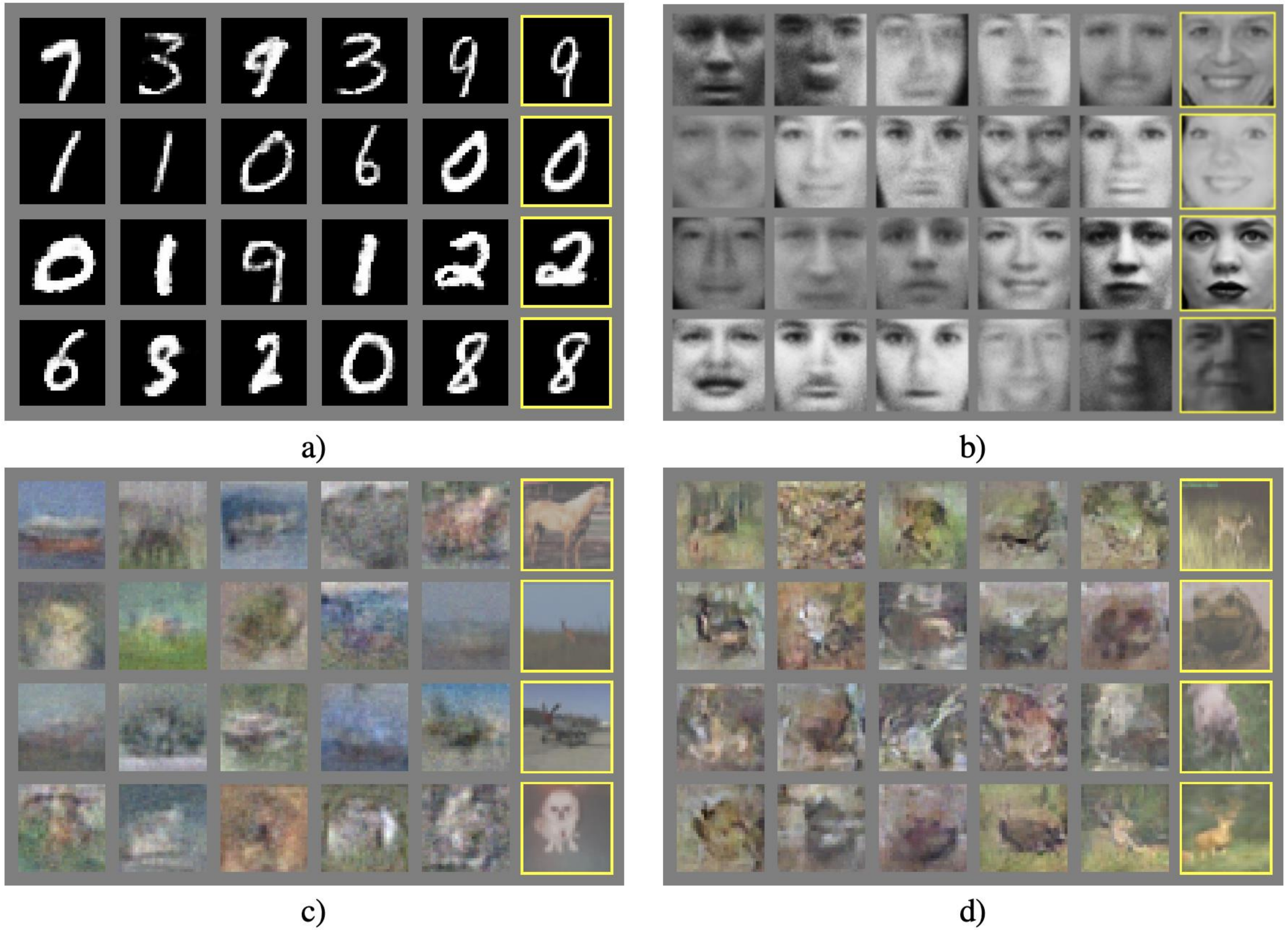
Deng, J., Dong, W., Socher, R., Li, L. J., Li, K., & Fei-Fei, L. (2009, June). Imagenet: A large-scale hierarchical image database. In *2009 IEEE conference on computer vision and pattern recognition* (pp. 248-255). IEEE.

AlexNet, CNN



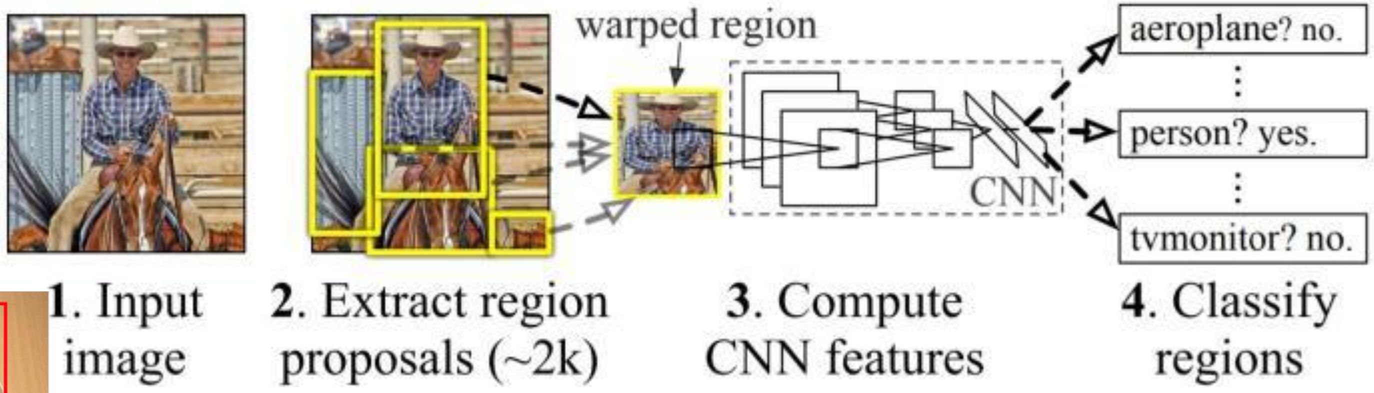
Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. In *Advances in neural information processing systems* (pp. 1097-1105).

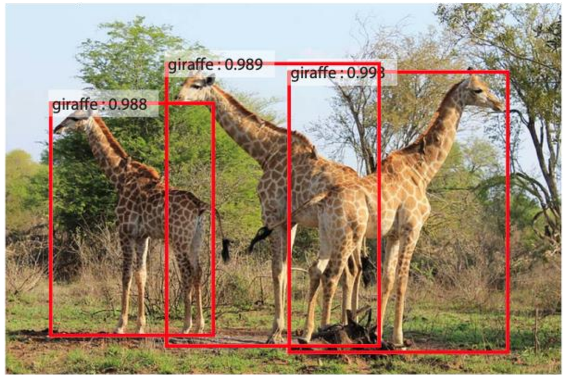
CV -- GAN

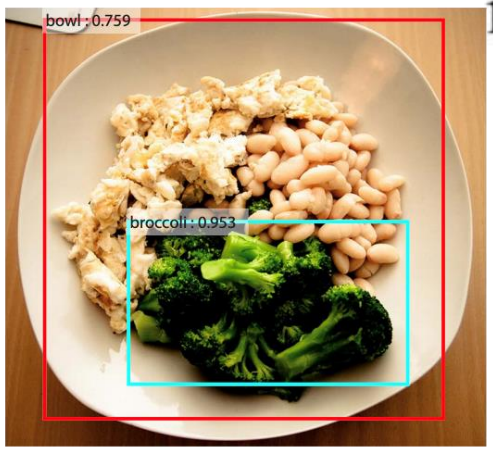


Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., ... & Bengio, Y. (2014). Generative adversarial nets. In *Advances in neural information processing systems* (pp. 2672-2680).

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

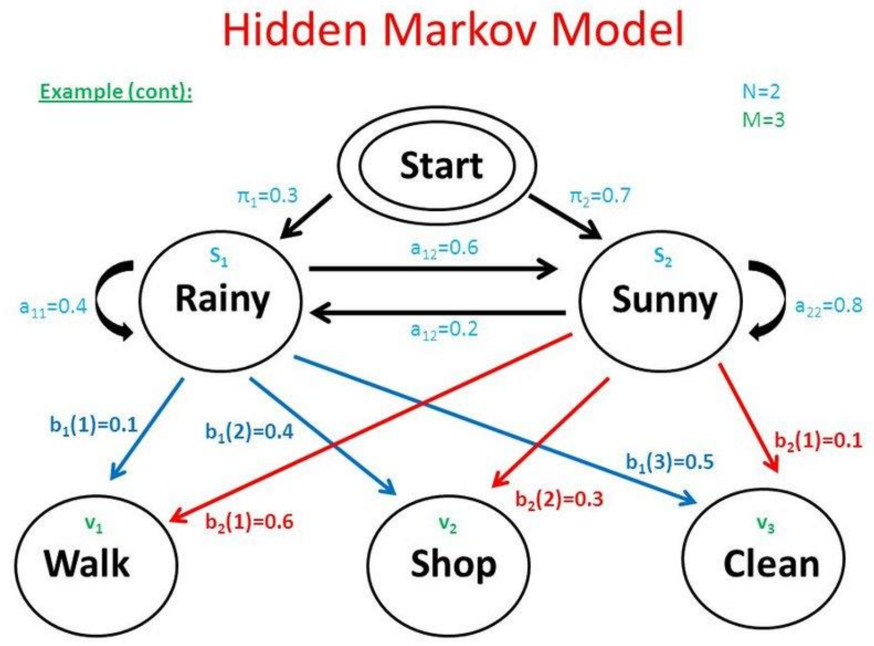
Separated

Speech recognition (Unsupervised, ICA, cont.)

Mixed

Separated

Speech recognition

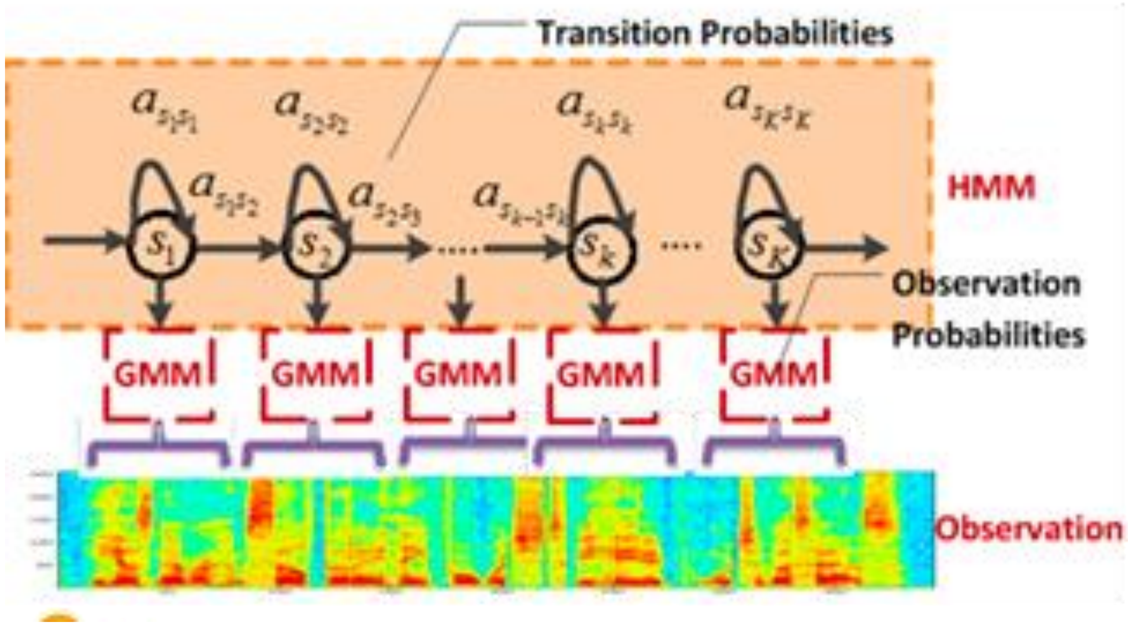


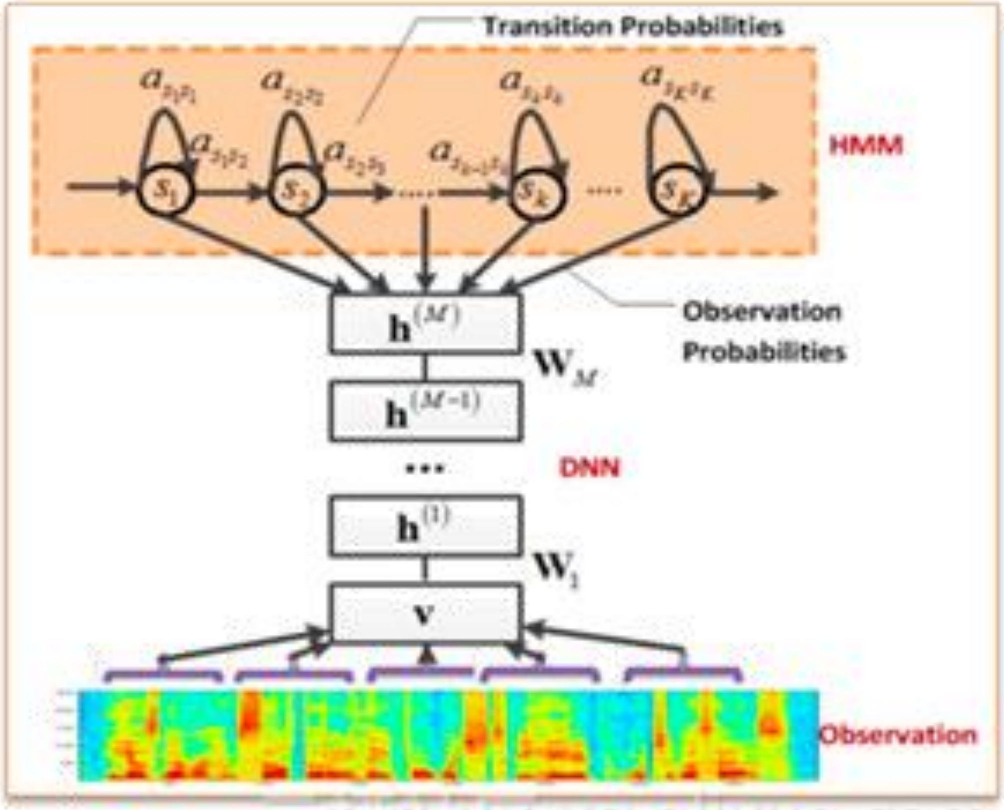
- Previous works use
  - Hidden Markov models (HMMs)
    - Deal with the temporal variability of speech
  - Gaussian mixture models (GMMs)
    - Determine how well each state of each HMM fits a frame or a short window of frames of coefficients that represents the acoustic input
- New
  - Feed-forward 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*.

Speech recognition

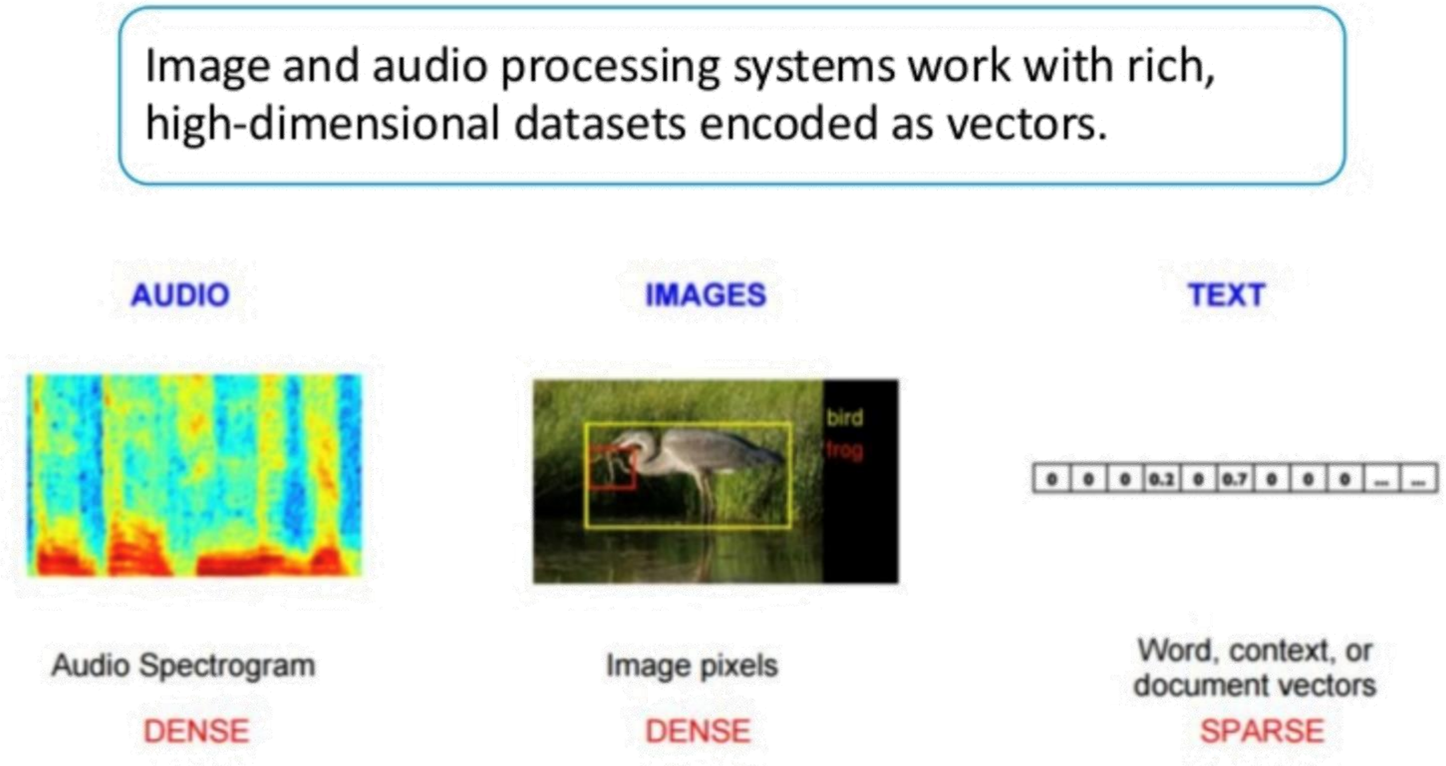
- **Deep Learning: From GMM-HMM to DNN-HMM**





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



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

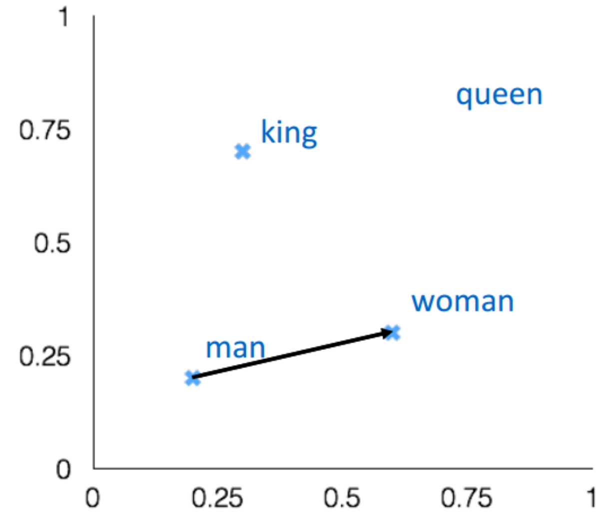
Test for linear relationships, examined by Mikolov et al. (2014)

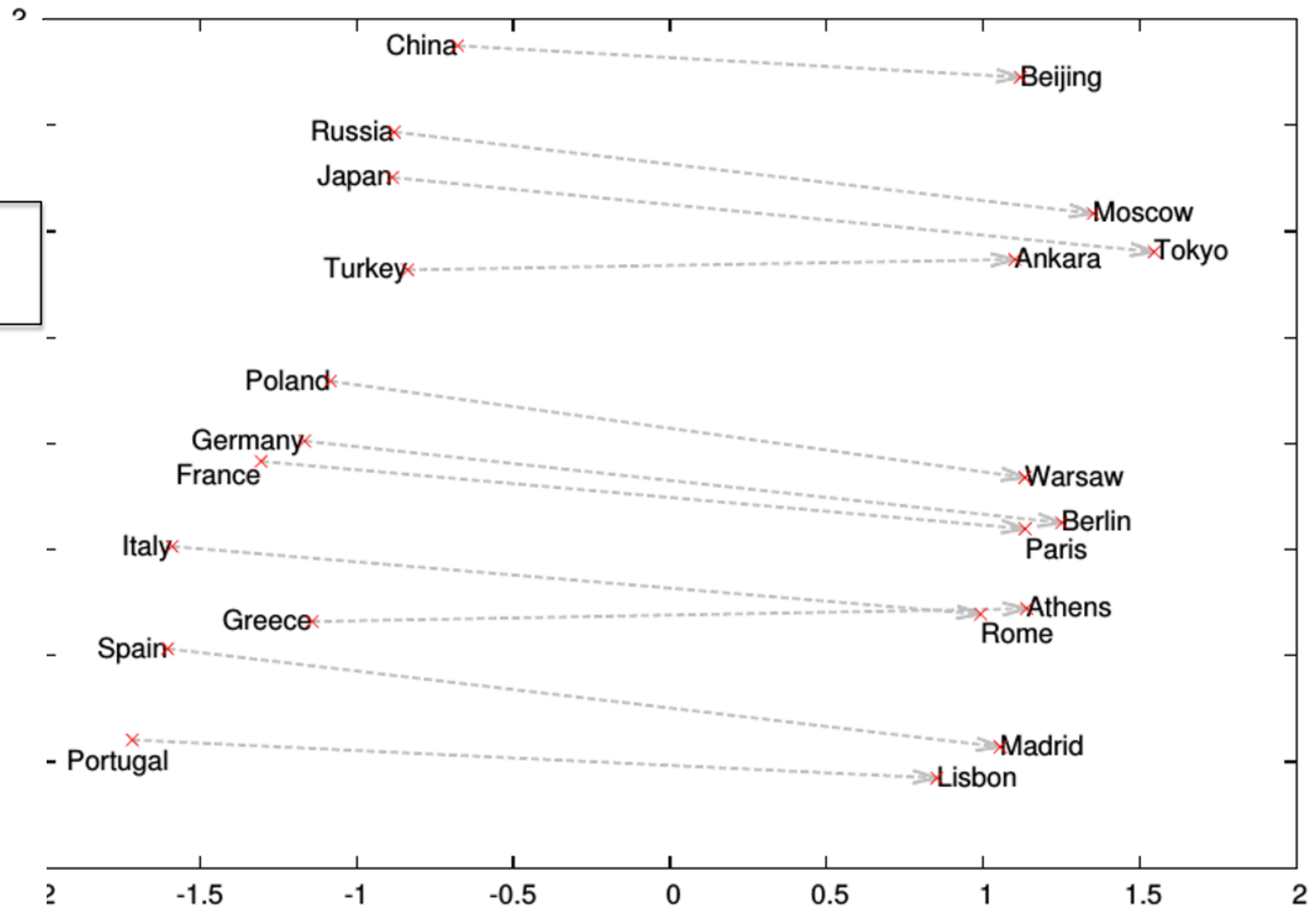
a:b :: c:?

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

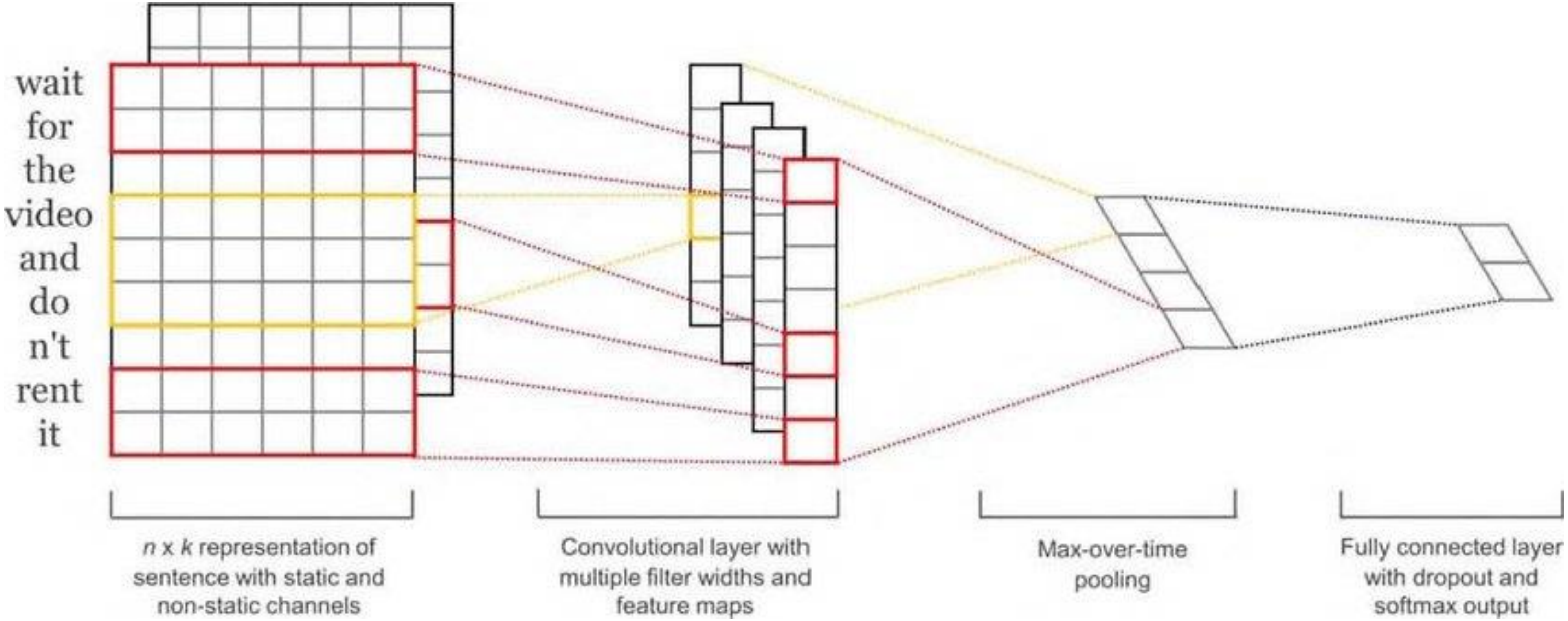
man:woman :: king:?

+	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

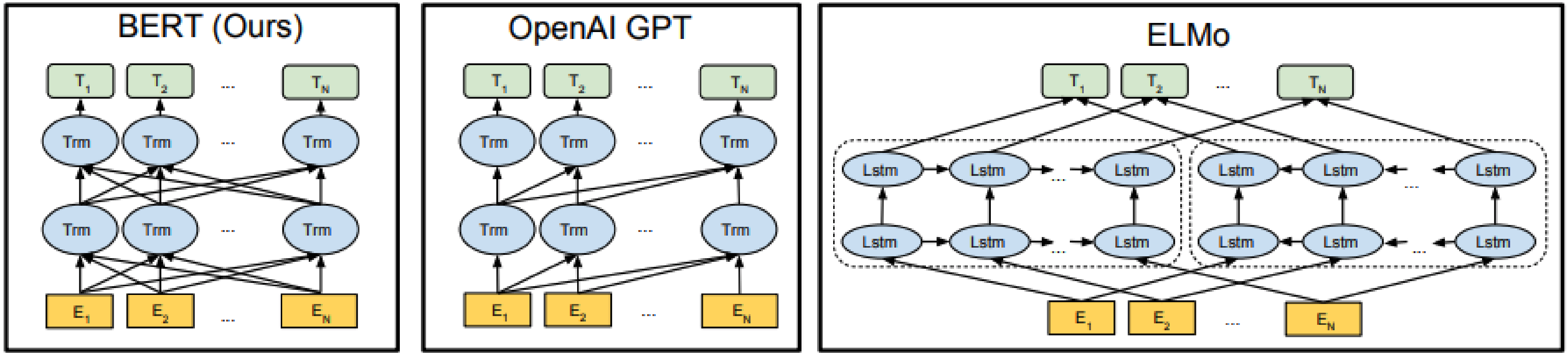
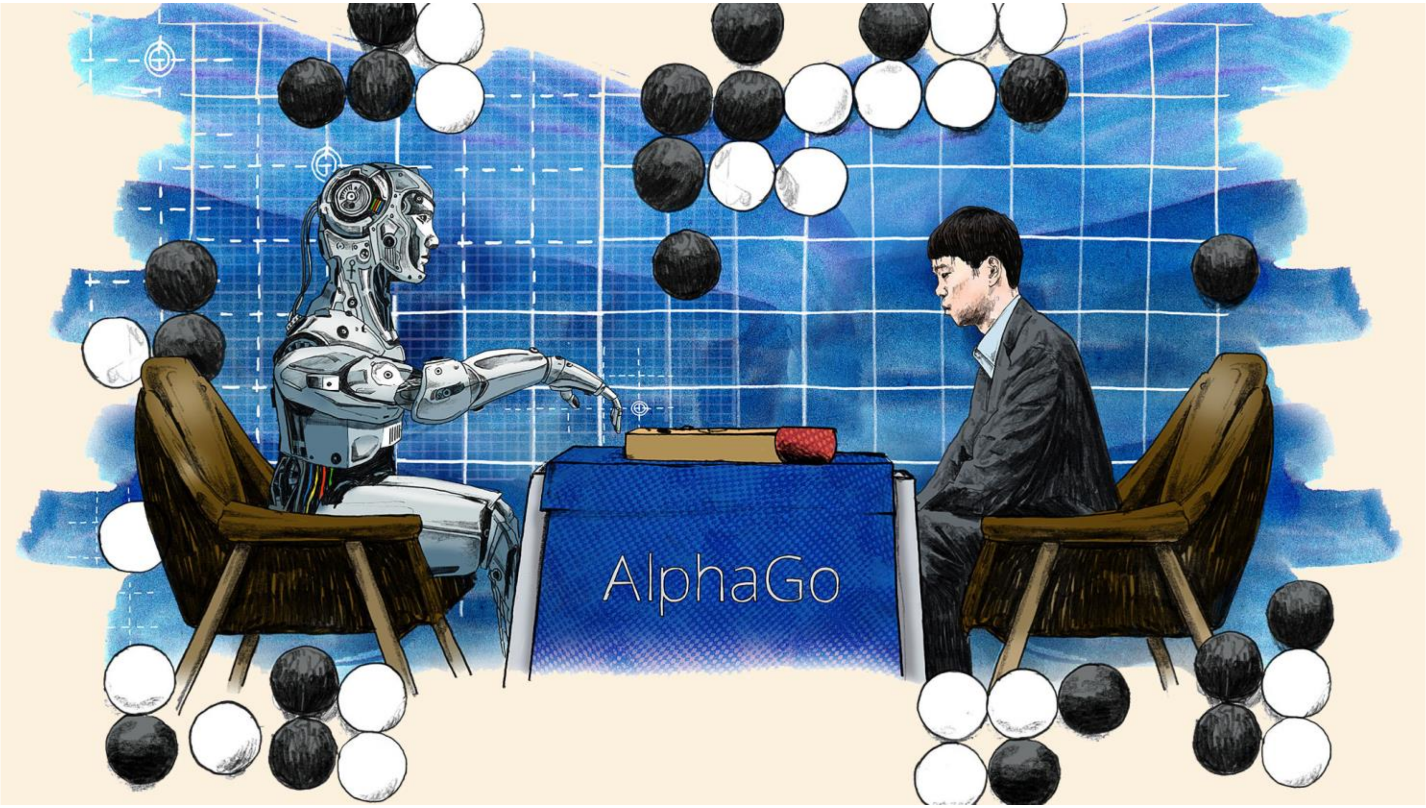


Figure 1: Differences in pre-training model architectures. BERT uses a bidirectional Transformer. OpenAI GPT uses a left-to-right Transformer. ELMo uses the concatenation of independently trained left-to-right and right-to-left LSTM to generate features for downstream tasks. Among three, only BERT representations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

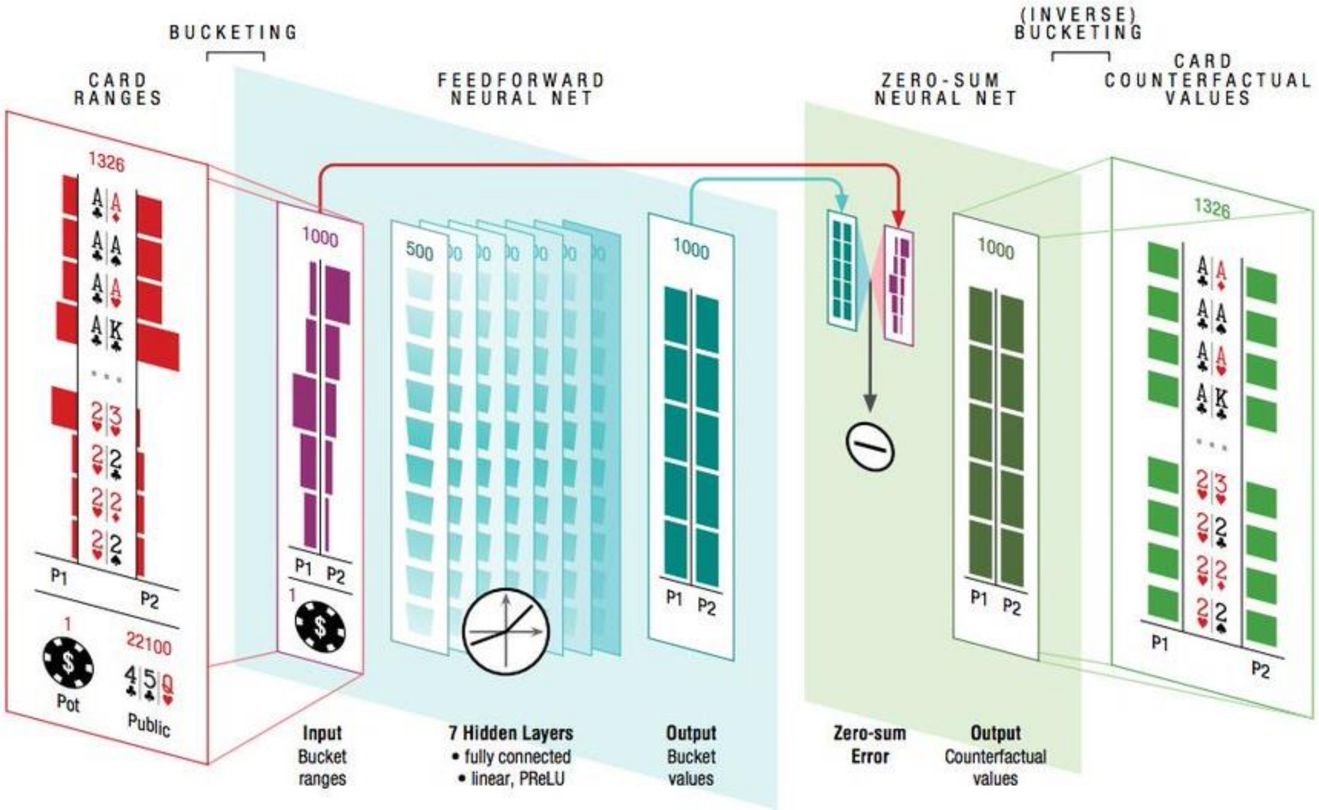
AlphaGo 2016



- 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.

Texas hold’em 2017



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

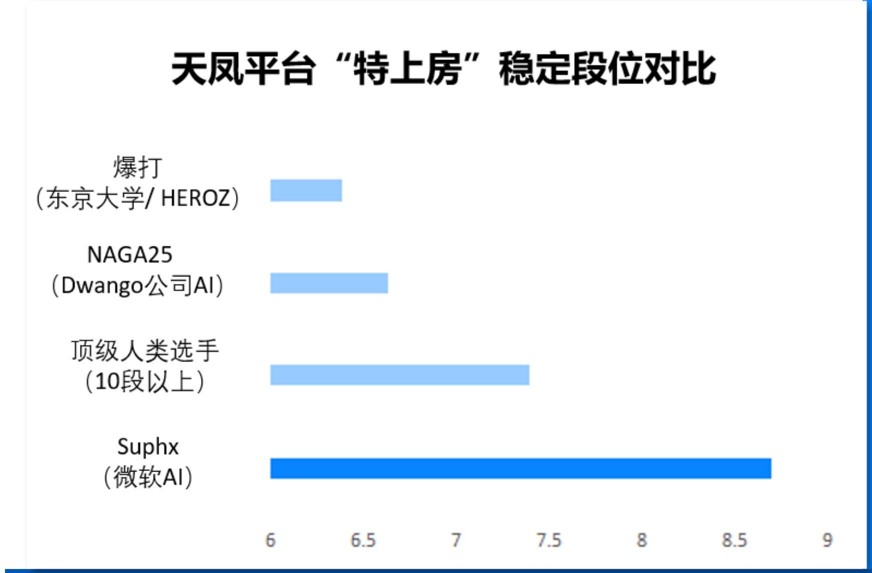
1994 checkers

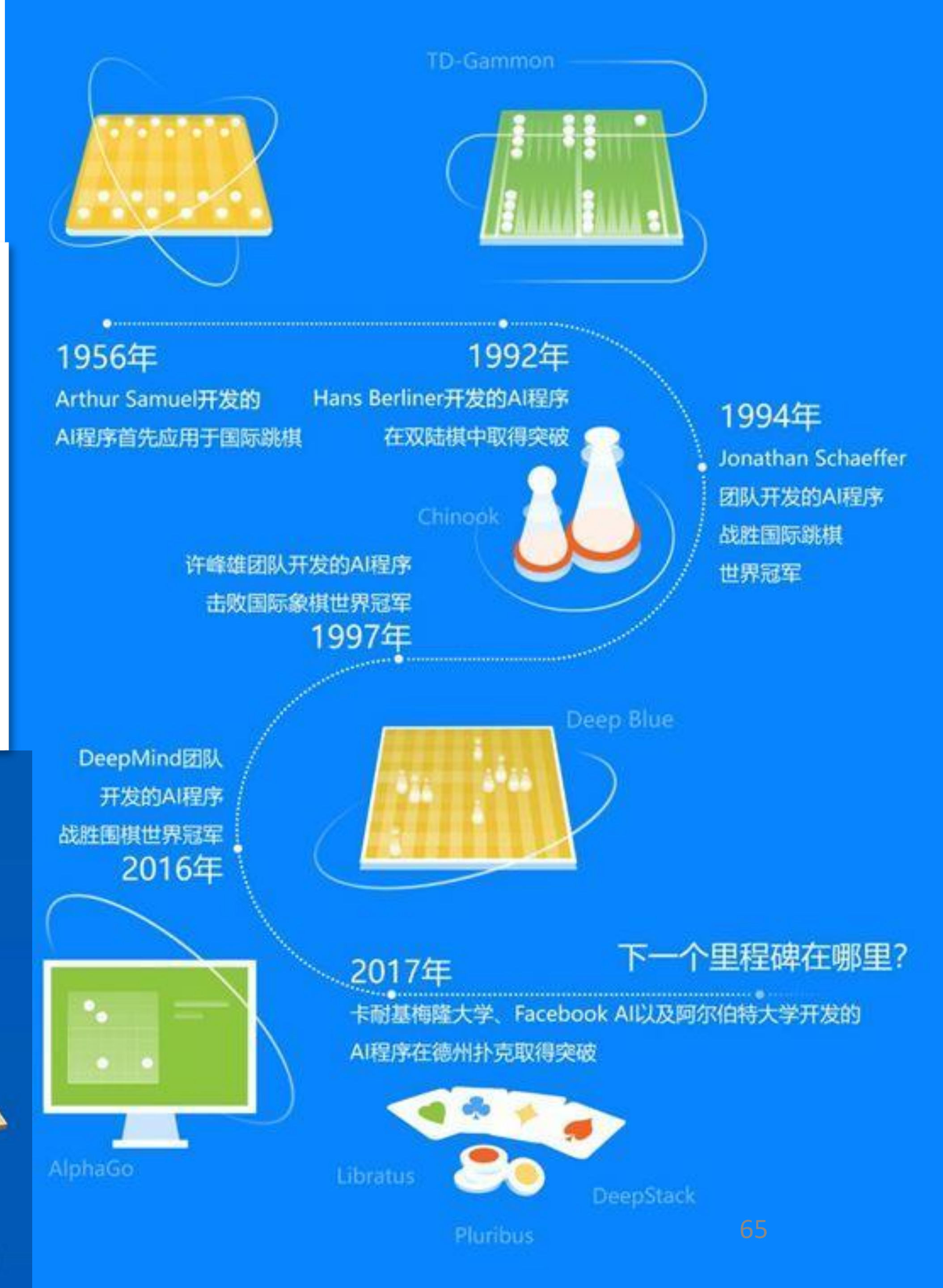
1997 chess

2016 Go

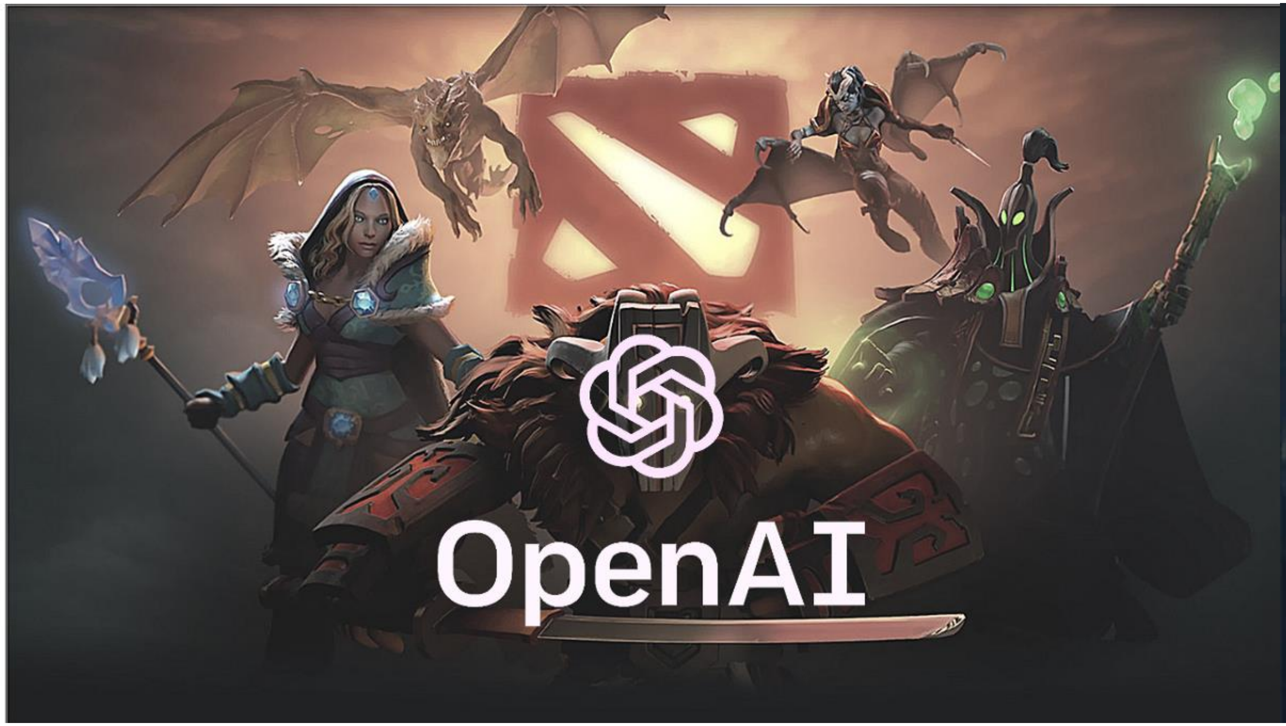
2017 Texas hold'em

2019 Majiang

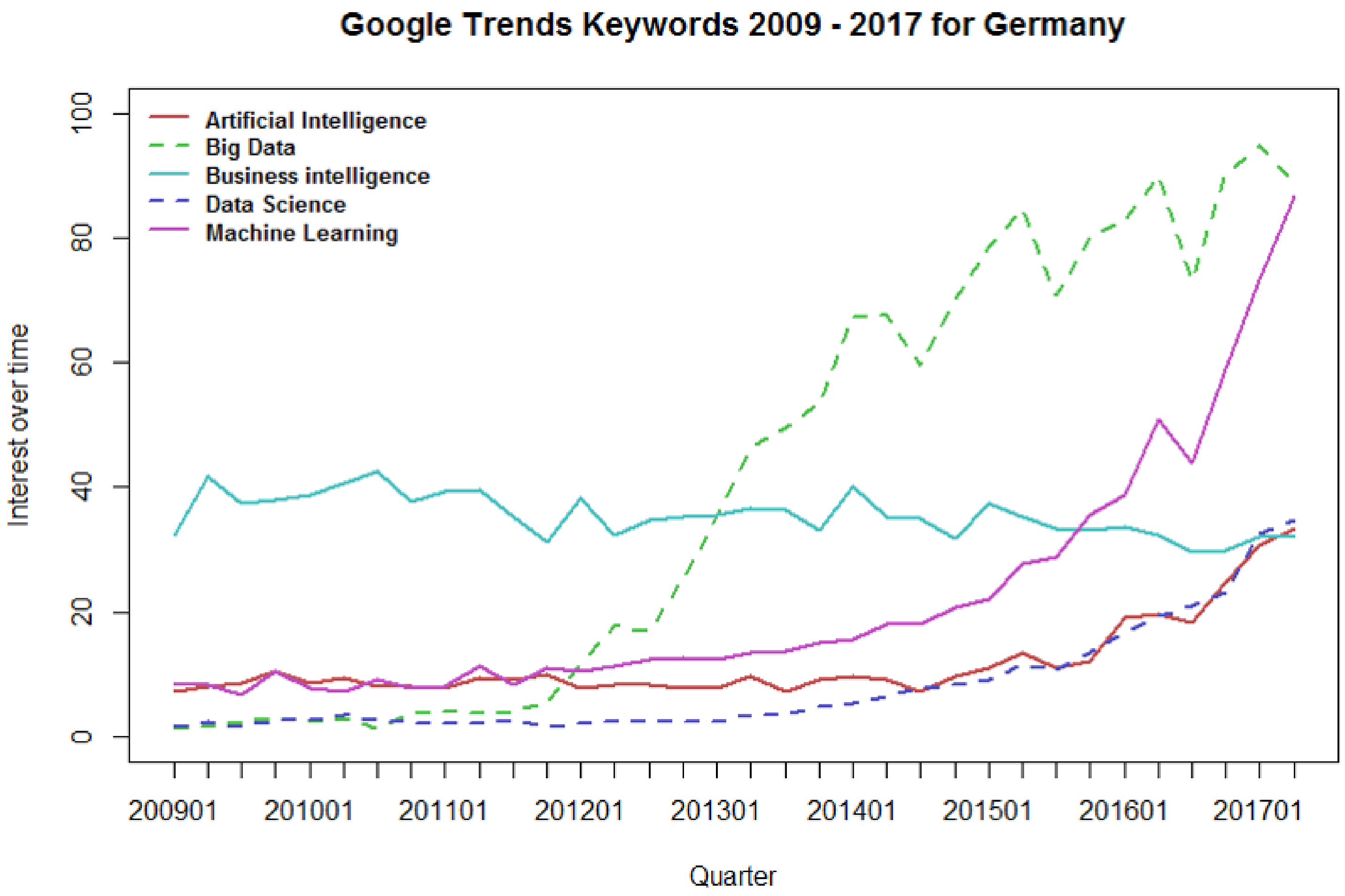




Game playing – state of the art



Recent popularity of AI and ML



AI and Machine Learning Together: 2010s and 2020s

WIRED BUSINESS CULTURE GEAR IDEAS SCIENCE SECURITY TRANSPORTATION SIGN IN | SUBSCRIBE

We've spent years feeding neural nets vast amounts of data, teaching them to think like human brains. They're crazy-smart, but they have absolutely no common sense. What if we've been doing it all wrong? BETH HOLZER

CLIVE THOMPSON BUSINESS 11.13.2018 06:00 AM

How to Teach Artificial Intelligence Some Common Sense

We've spent years feeding neural nets vast amounts of data, teaching them to think like human brains. They're crazy-smart, but they have absolutely no common sense. What if we've been doing it all wrong?

2,456 views | Oct 16, 2018, 08:30am

AI Requires More Than Machine Learning

Jans Aasman Forbes Councils Member
Forbes Technology Council
COUNCIL POST | Paid Program
Innovation

BBC NEWS

Home | UK | World | Business | Politics | Tech | Science | More

Researchers: Are we on the cusp of an 'AI winter'?

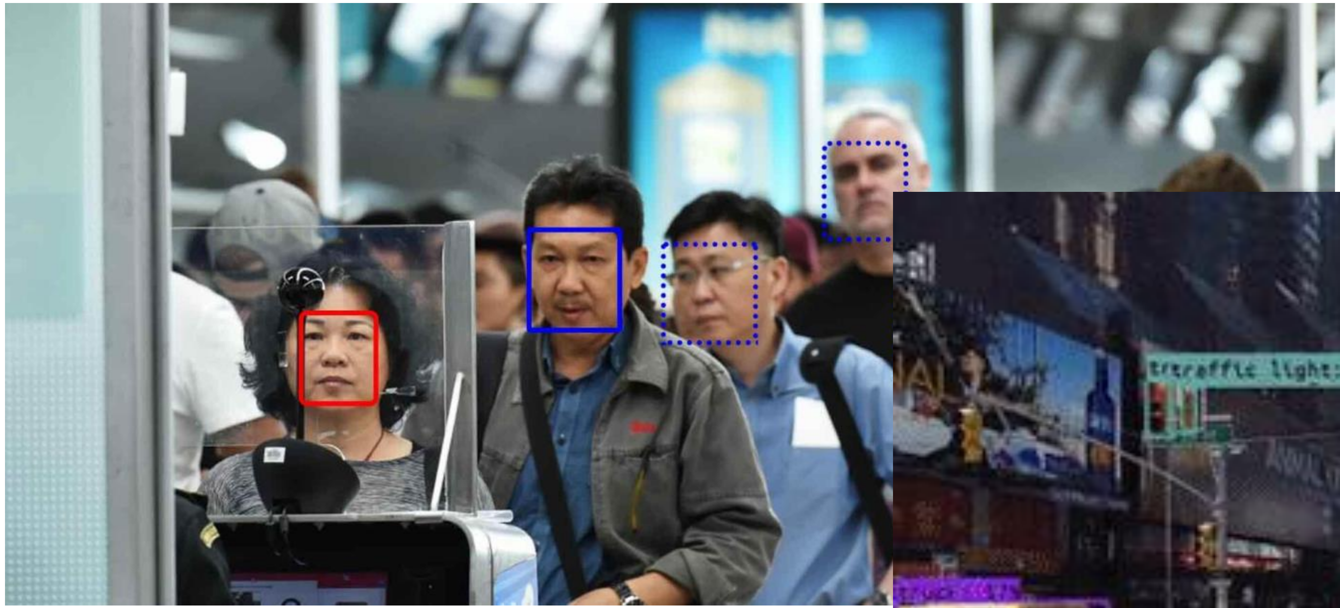
By Sam Shead
Technology reporter

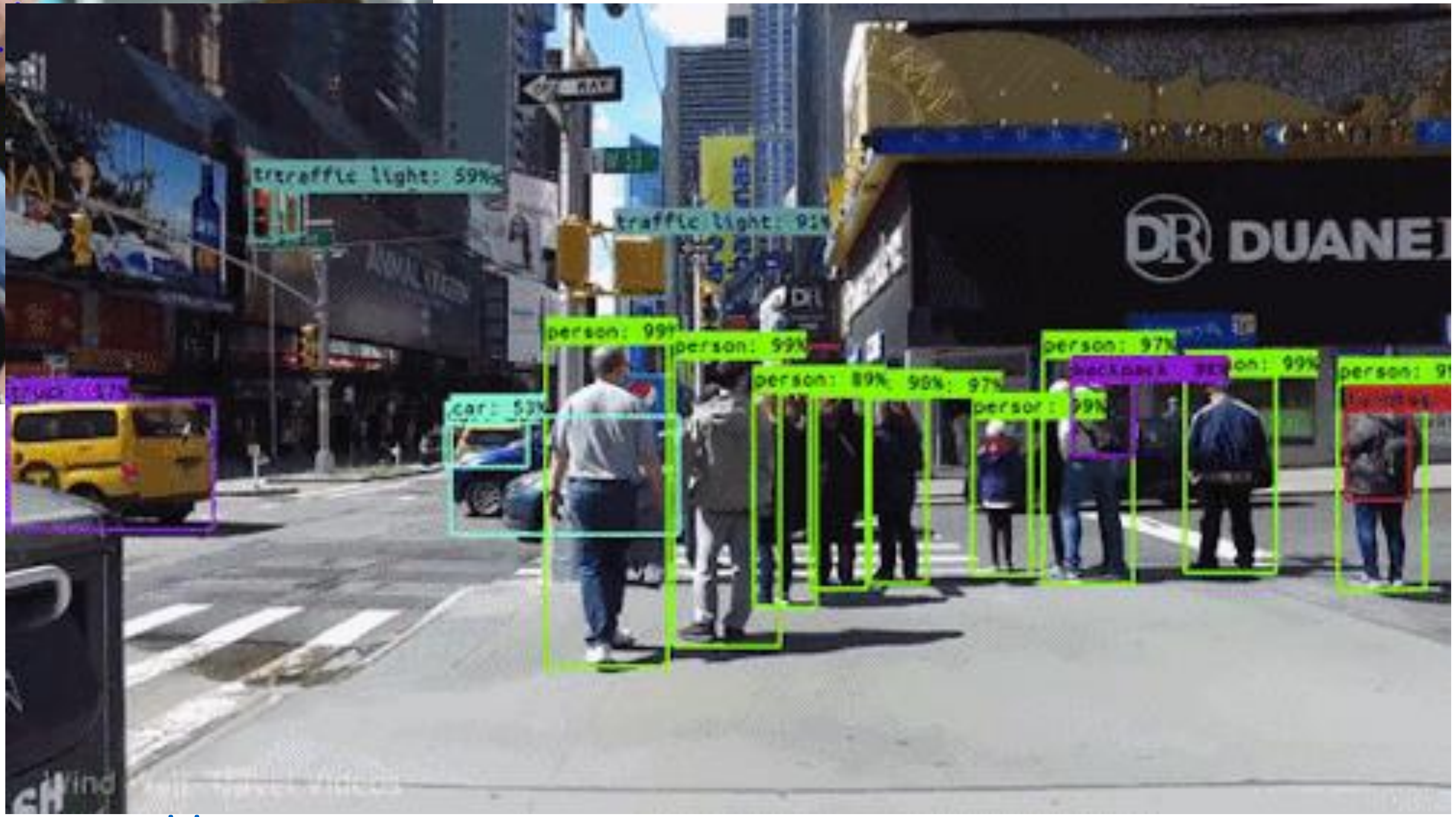
12 January 2020 | Technology

What Can AI Do?

Sci-Fi AI

Face recognition, real-time detection





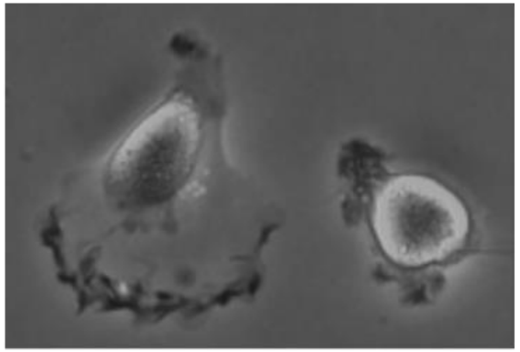
https://bitrefine.group/home/transportation/face-recognition-support-system

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

Medical image analysis

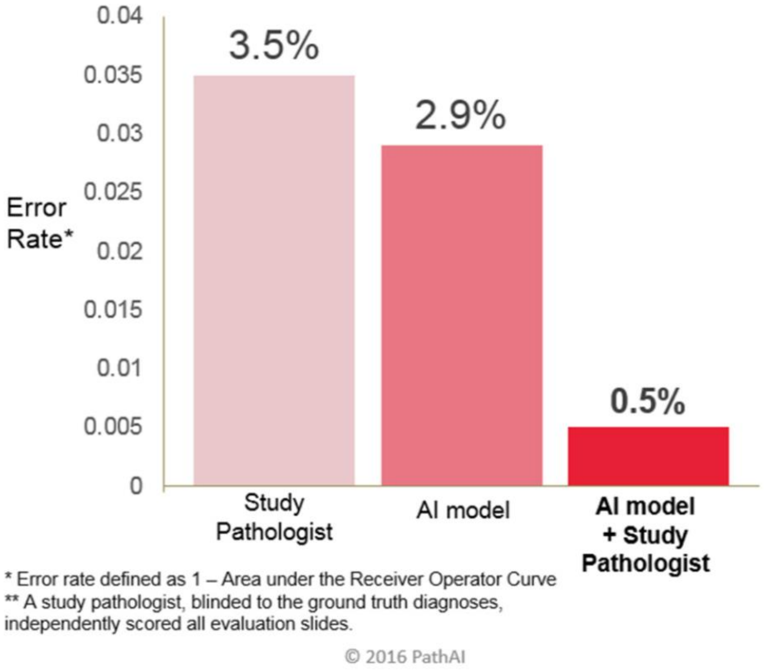
- Segmentation re:

a



- Breast Cancer Diagnoses

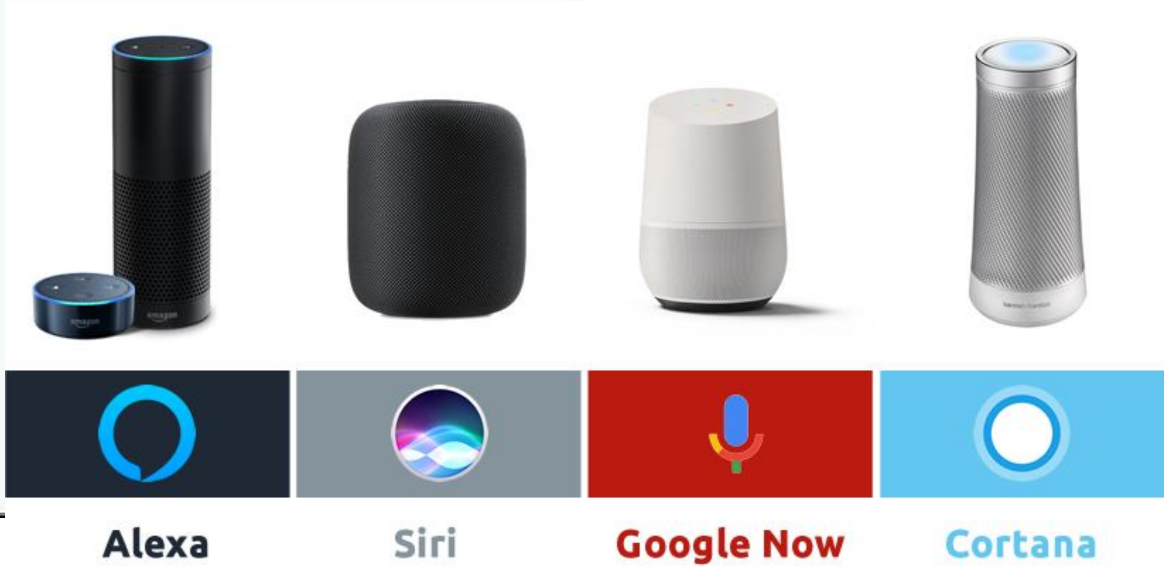
(AI + Pathologist) > Pathologist



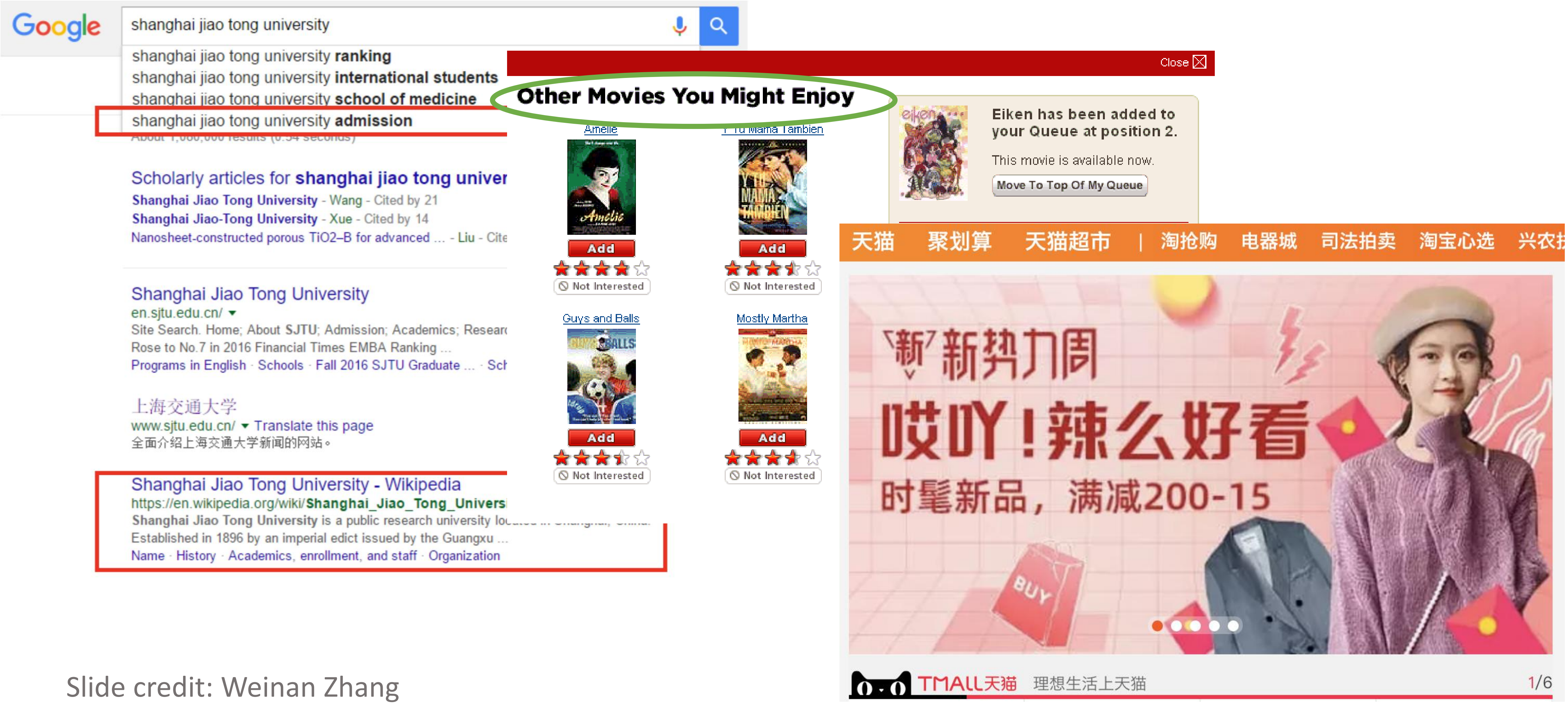
Ronneberger, O., Fisch
segmentation. In *Inter*
234-241). Springer, Cham.

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/

Voice assistants: Google AI 2018



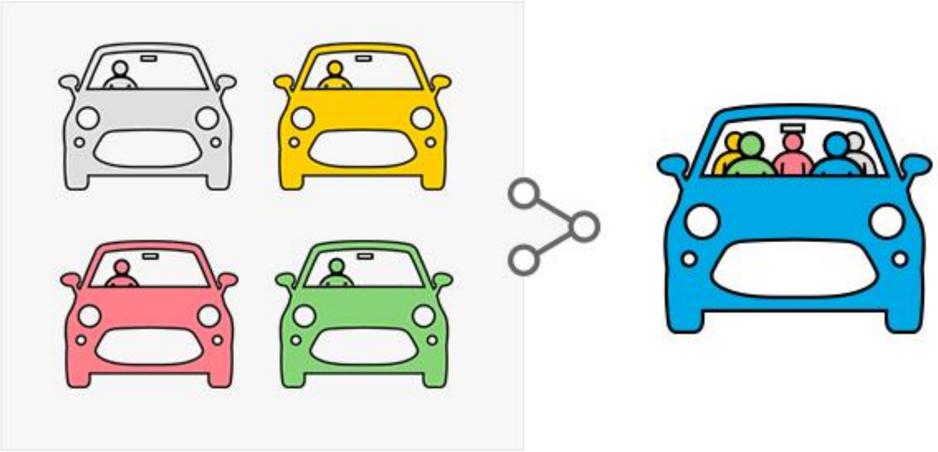
Web app: search, recommendation, ad

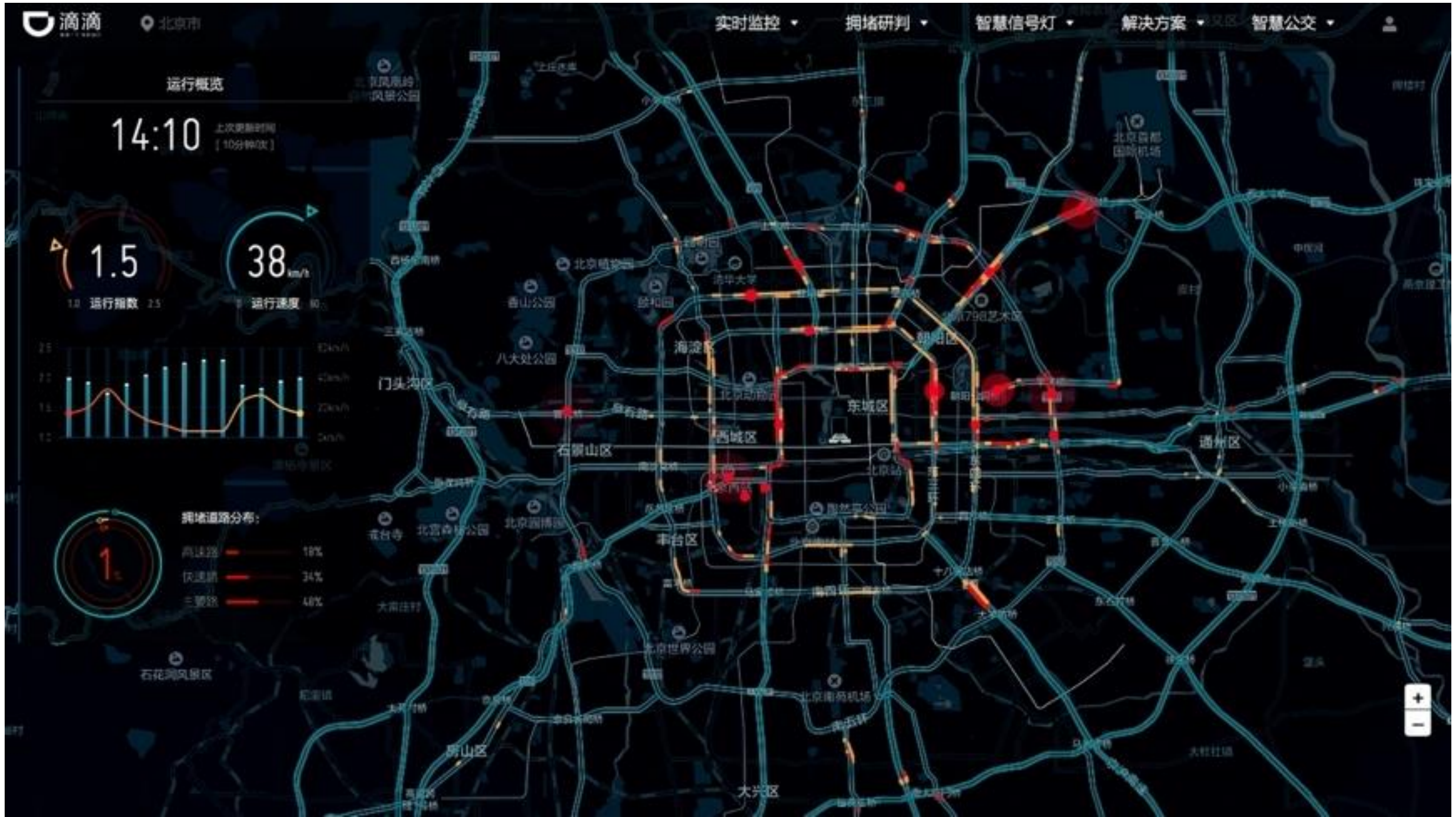


Slide credit: Weinan Zhang

Alleviate traffic congestion

- Ride sharing
- Disperse traffic





Exoskeletons

Agriculture: Crop-dusting

- DJI drones (unmanned aerial vehicles)

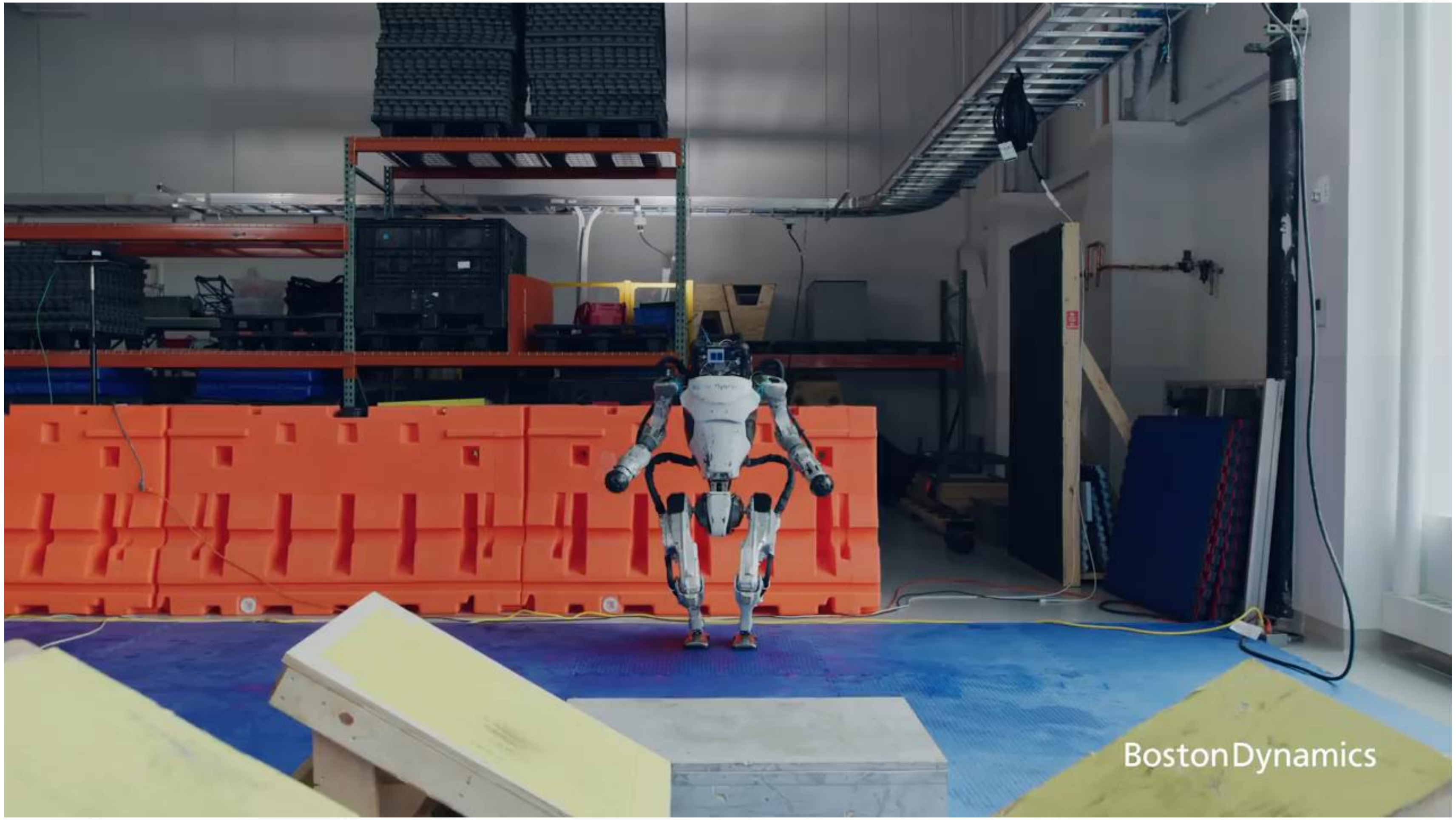
Transportation: Sorting parcels

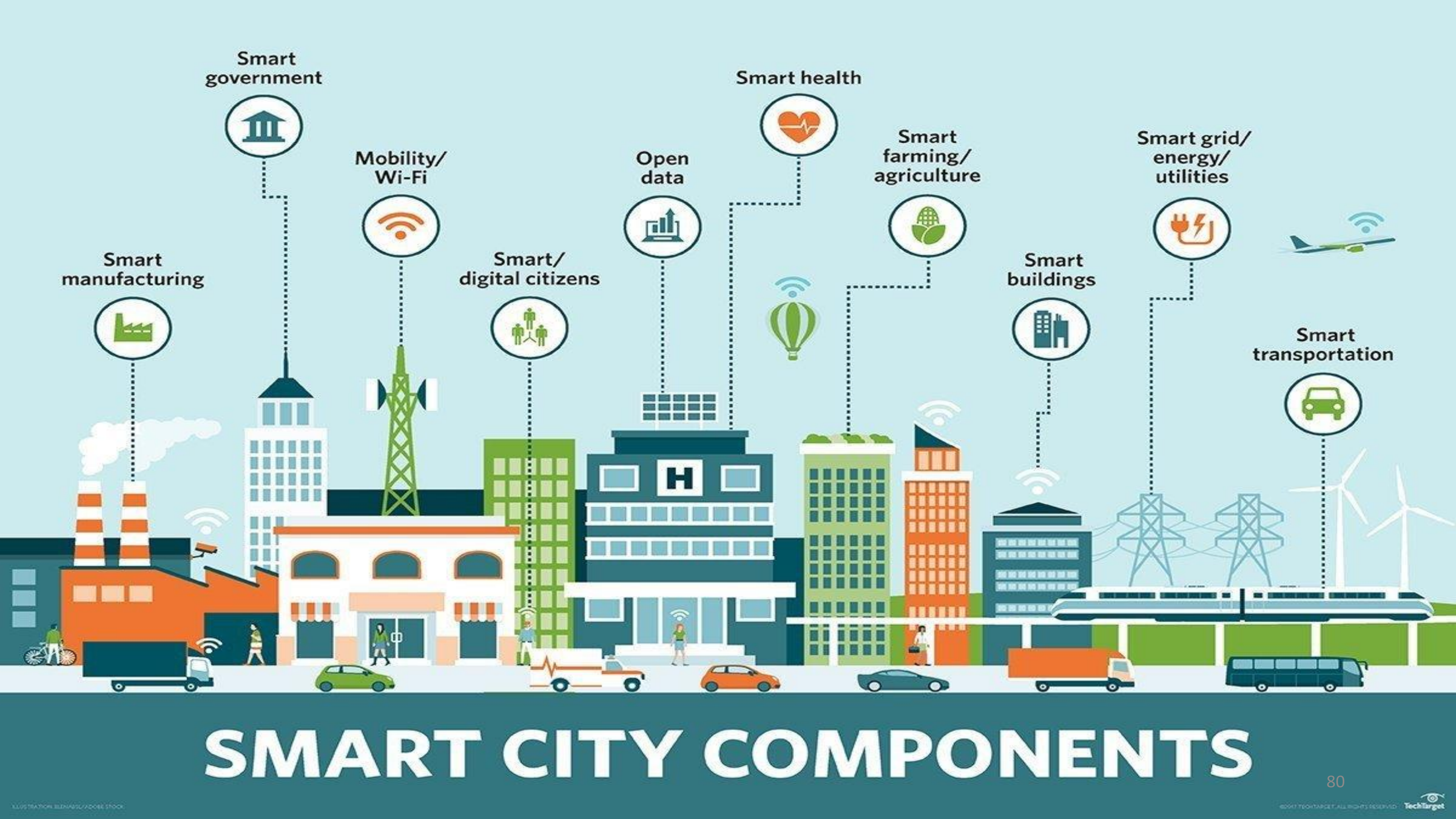
Boston Dynamics: Atlas | Partners in Parkour

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.

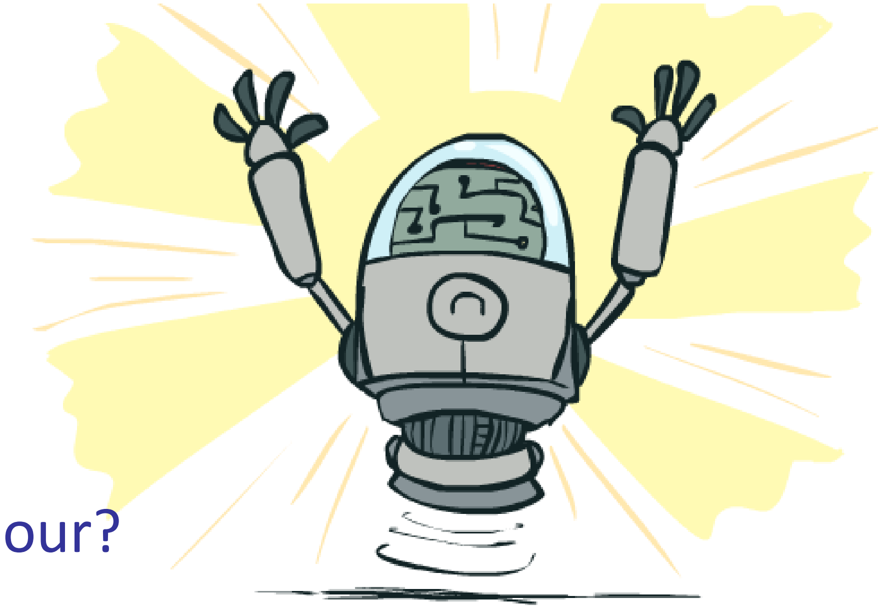



Smart government
Smart health
Mobility/ Wi-Fi
Open data
Smart farming/ agriculture
Smart grid/ energy/ utilities
Smart manufacturing
Smart/ digital citizens
Smart buildings
Smart transportation
H
SMART CITY COMPONENTS

What Can AI Do?

Quiz: Which of the following can be done at present?

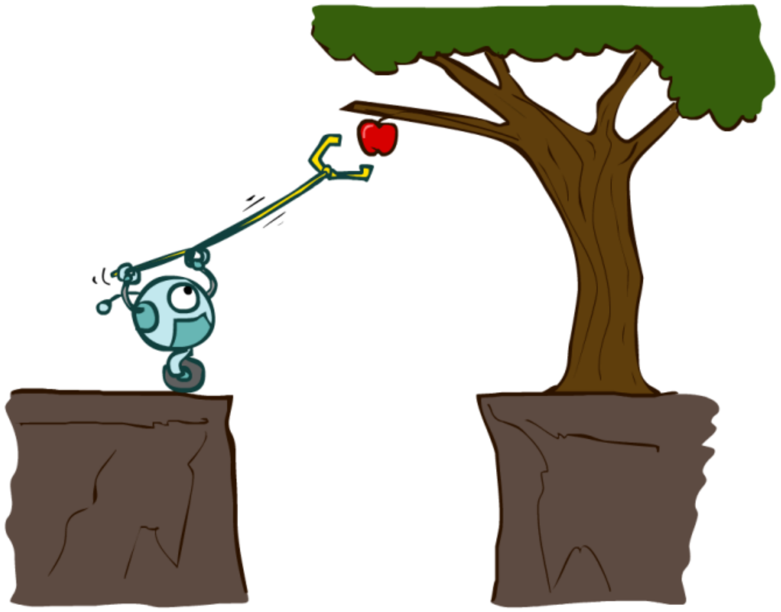
- Play a decent game of table tennis?
- Play a decent game of Jeopardy?
- Drive safely along a curving mountain road?
- Drive safely across Pittsburgh?
- Buy a week's worth of groceries on the web?
- Buy a week's worth of groceries at a local market?
- Discover and prove a new mathematical theorem?
- Converse successfully with another person for an hour?
- Perform a surgical operation?
- Put away the dishes and fold the laundry?
- Translate spoken Chinese into spoken English in real time?
- Write an intentionally funny story?

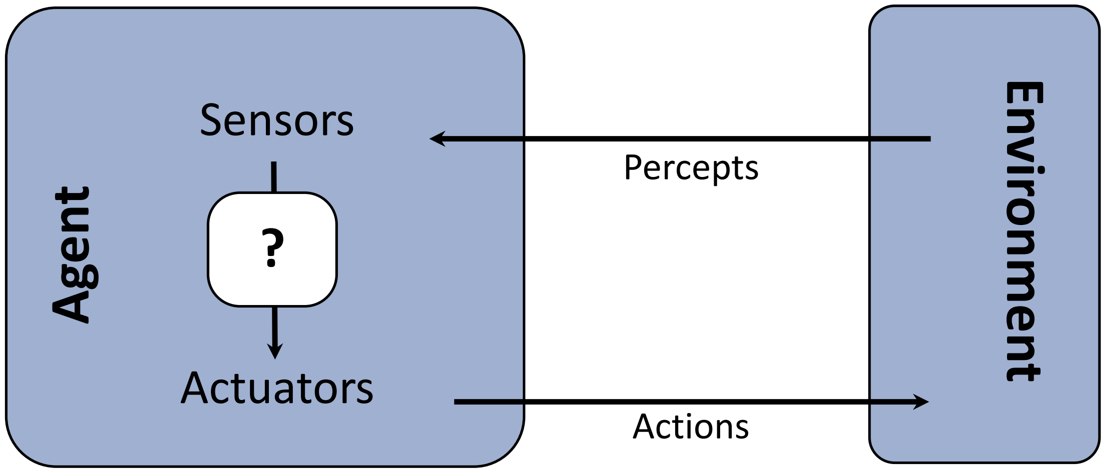


Intelligent Agents

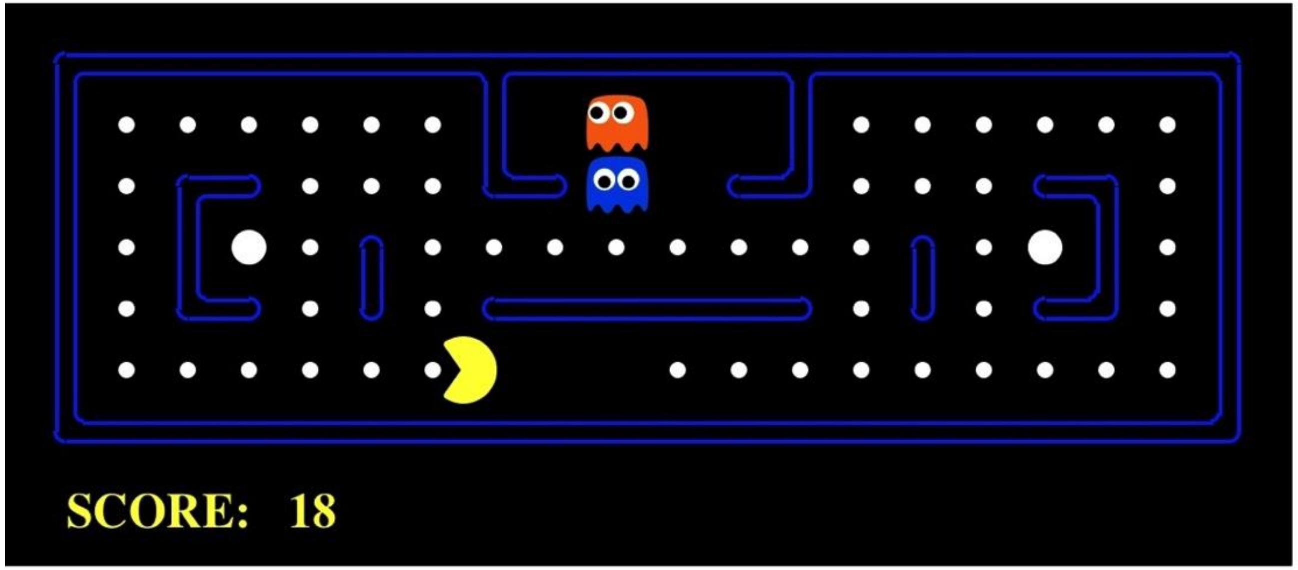
Agents and environments

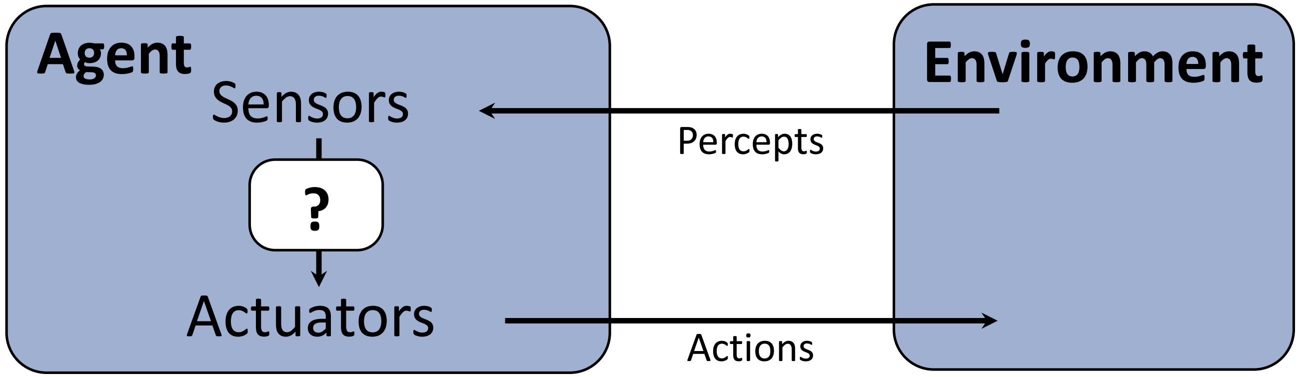
- Agents interact with environments through sensors and actuators
- An agent is an entity that perceives and acts
- A rational agent selects actions that maximize its (expected) utility
- Characteristics of the percepts, environment, and action space dictate techniques for selecting rational actions





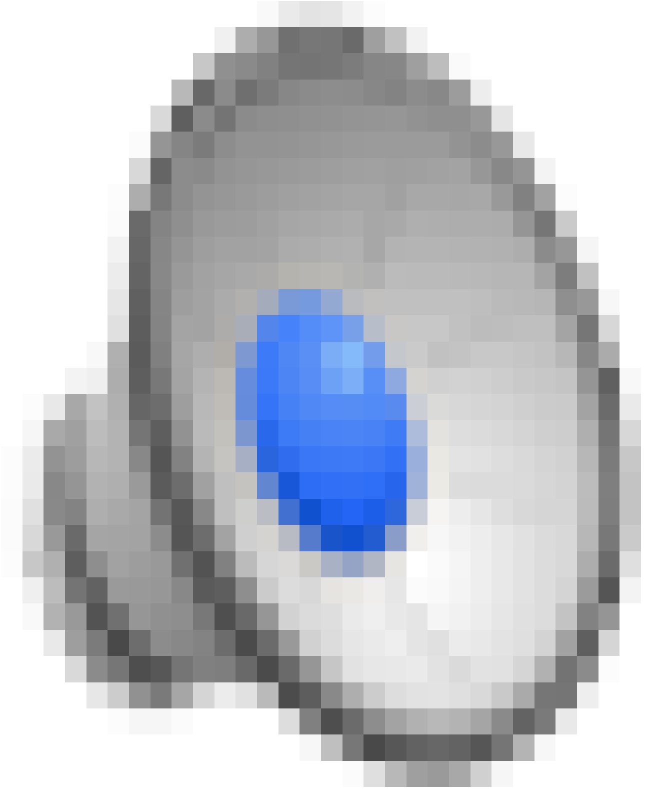
Pac-Man as an Agent





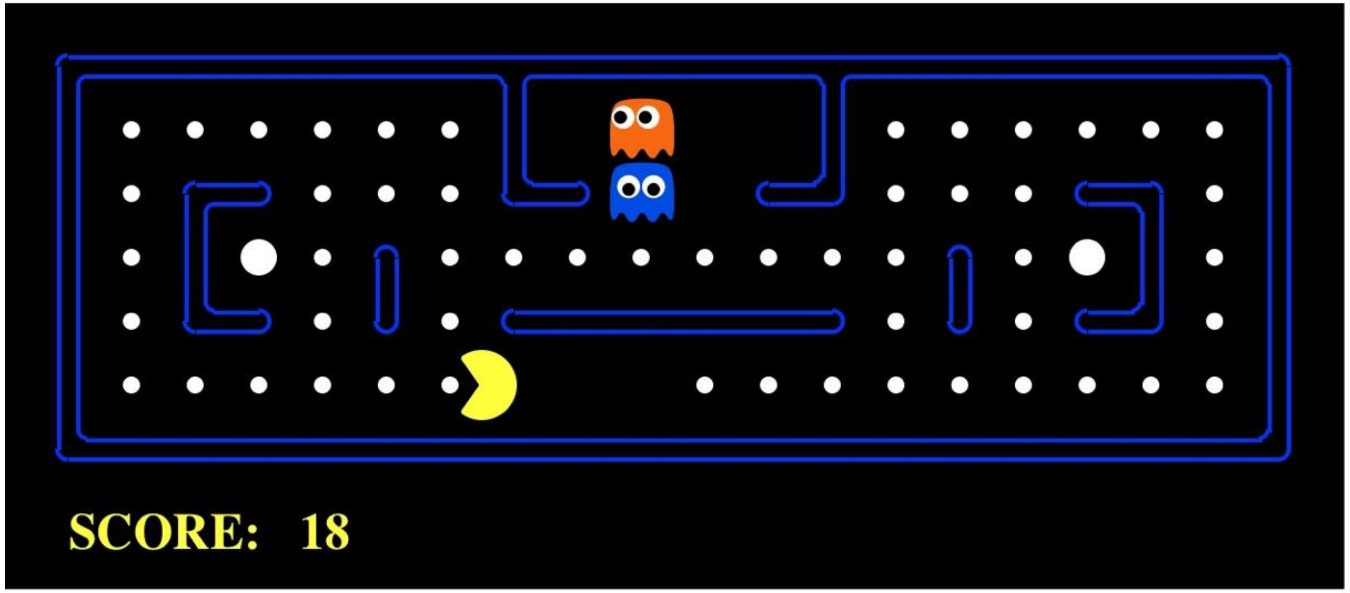
Pac-Man is a registered trademark of Namco-Bandai Games, used here for educational purposes

Demo1: pacman-l1.mp4



Environment 1: Pac-Man

- Performance measure
  - -1 per step; +10 food; +500 win; -500 die; +200 hit scared ghost
- Environment
  - Pacman dynamics (incl ghost behavior)
- Actuators
  - North, South, East, West, (Stop)
- Sensors
  - Entire state is visible



Environment 2: Automated taxi

- Performance measure
  - Income, happy customer, vehicle costs, fines, insurance premiums
- Environment
  - streets, other drivers, customers
- Actuators
  - Steering, brake, gas, display/speaker
- Sensors
  - Camera, radar, accelerometer, engine sensors, microphone

Image: http://nypost.com/2014/06/21/how-google-might-put-taxi-drivers-out-of-business/

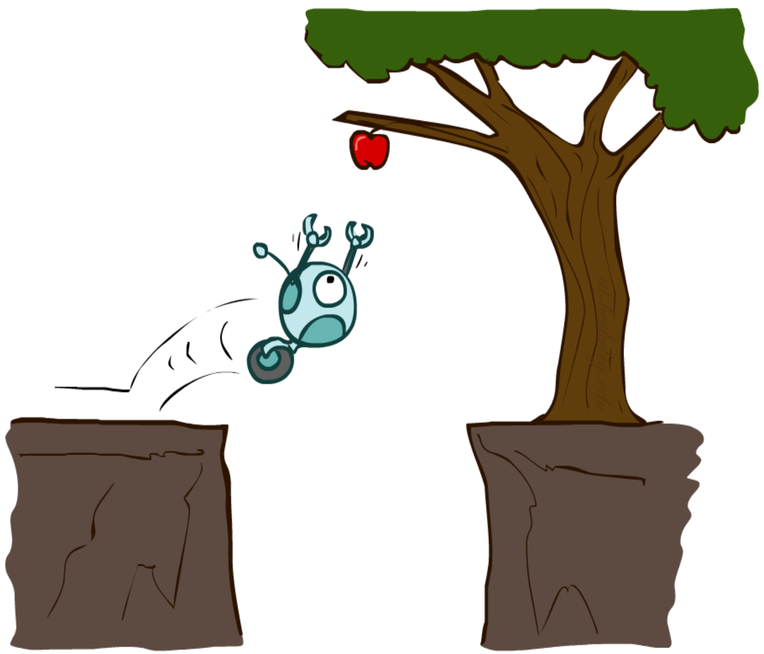
Environment Types

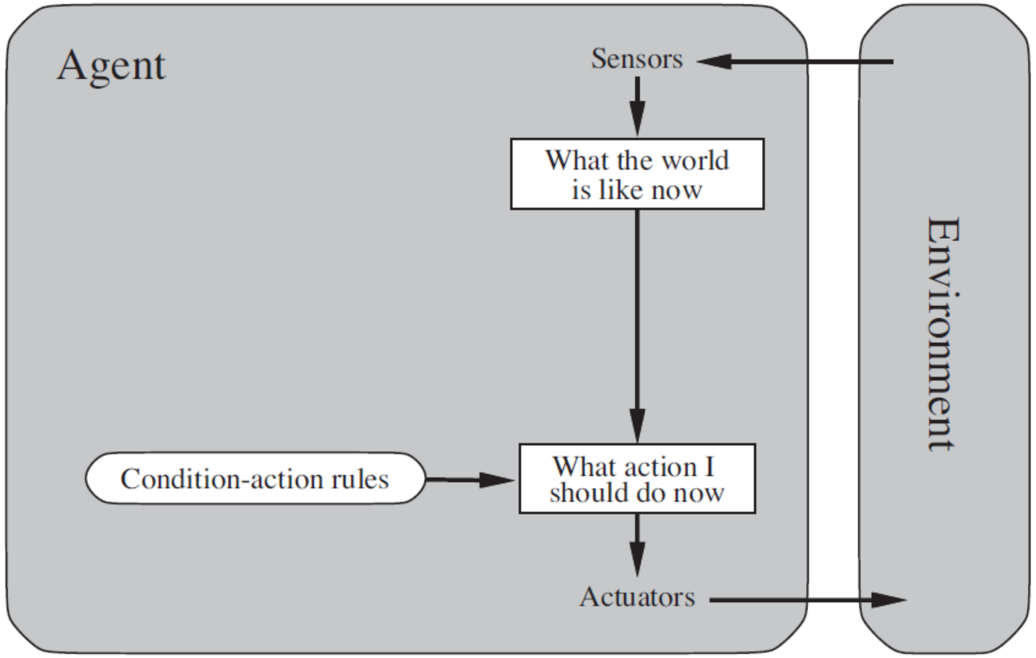
	Pacman	Taxi
Fully or partially observable		
Single agent or multi-agent		
Deterministic or stochastic		
Static or dynamic		
Discrete or continuous		

Simple reflex agents

- Reflex agents:
  - Choose action based on current percept (and maybe memory)
  - May have memory or a model of the world's current state
  - Do not consider the future consequences of their actions
  - Consider how the world IS

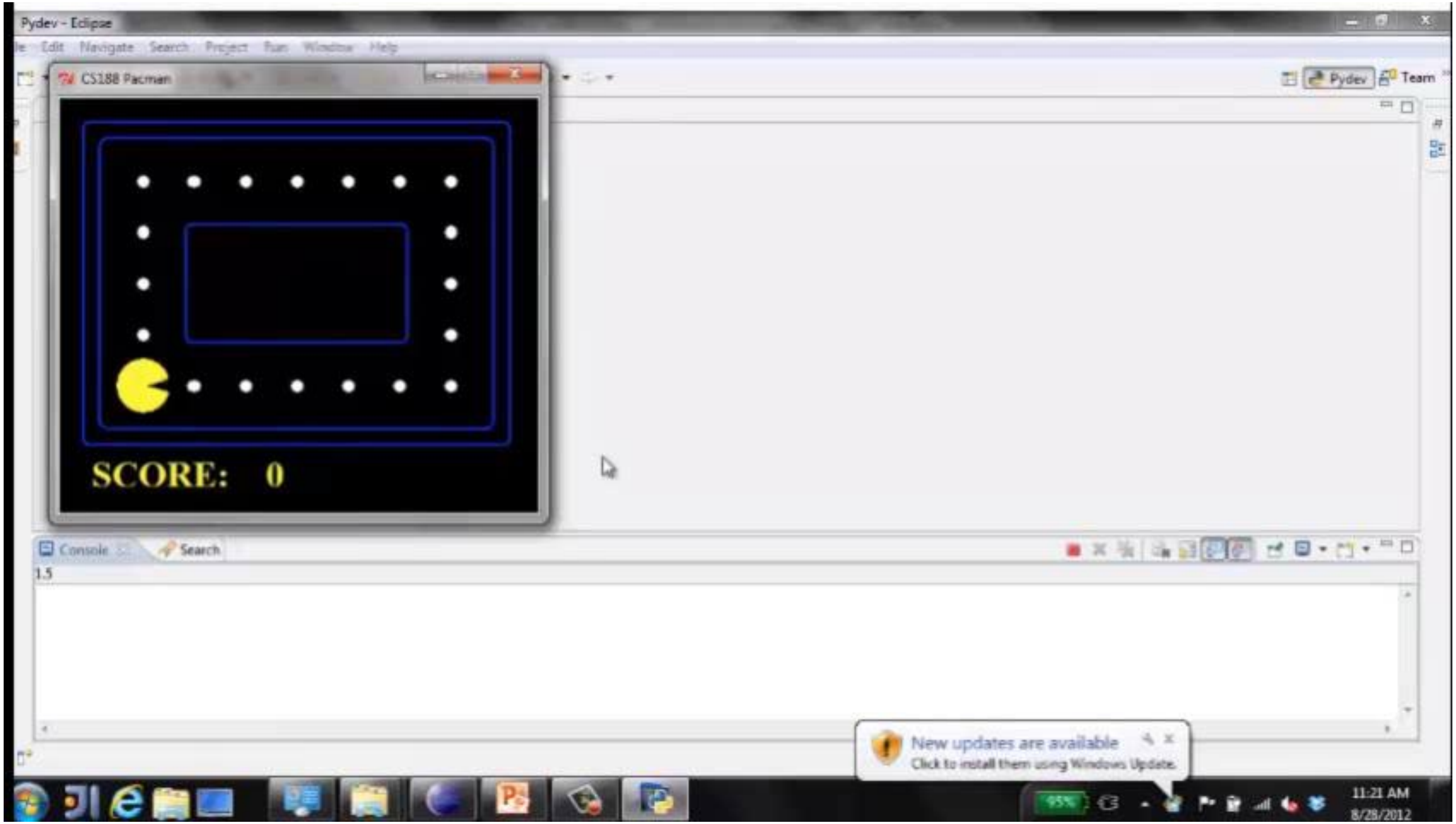
- Can a reflex agent be rational?



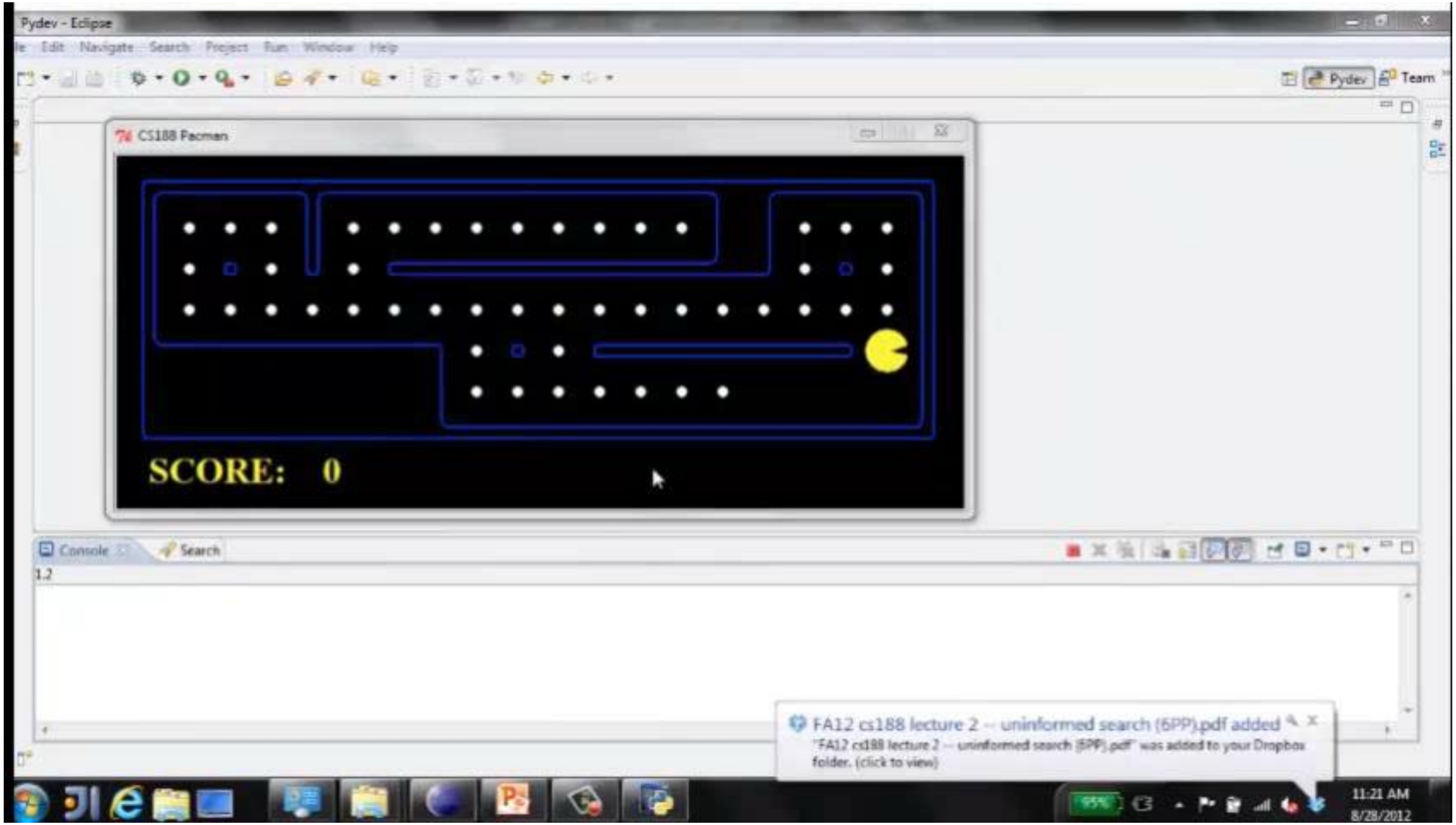


[Demo: reflex optimal (L2D1)]
[Demo: reflex optimal (L2D2)]

Video of Demo Reflex Optimal



Video of Demo Reflex Odd



Summary

Shuai Li

https://shuaili8.github.io

- What is AI and ML
- An example of AI but not ML
    - A* algorithm
- Foundation of AI
- History of AI
- What can AI do
    - Many applications in different industries/many aspects of life
- Intelligent agents
    - reflex agents

Questions?