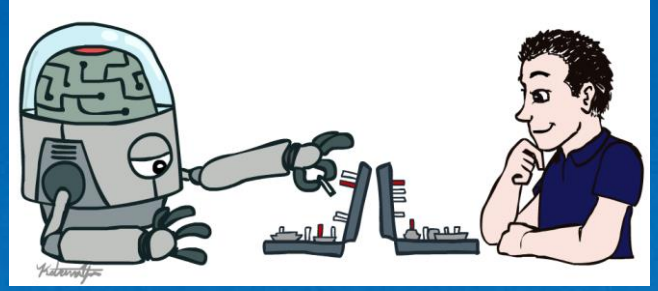


(some slides adapted from http://aima.cs.berkeley.edu/)

innovate achieve lead

BITS Pilani
Pilani Campus

DSE CL 557 - Artificial and Computational Intelligence

#1. Introduction

Saturday, August 29, 2020

Objectives of the course

- To provide solid foundation for designing intelligent agents
- Learn the representation and use of knowledge in inference-based problem solving approaches.
- Learn to apply probability theory to describe and model agents operating in uncertain environments.
- Learn the optimization models of computation and processing in real world application of intelligent agents

BOOKS

Text Book(s)

- T1 Stuart Russell and Peter Norvig, "Artificial Intelligence – A Modern Approach", Third Ed, Pearson Education, 2010

Reference Book(s) & other resources

- R1 Ryszard S. Michalski, Jaime G. Carbonell and Tom M. Mitchell, "Machine Learning: An Artificial Intelligence Approach", Elsevier, 2014
- R2 Dan W Patterson, "Introduction to AI and Expert Systems", Prentice Hall of India, New Delhi, 2010
- R3 Elaine Rich and Kevin Knight, "Artificial Intelligence", Tata McGraw Hill Publishing Company, New Delhi, 2003

Evaluation Components

- Evaluation :
- 25% Assignment
- 5% Quiz
- 30% Mid Semester
- 40% End Semester

Agenda

(1) What is Artificial Intelligence?

i. Acting Humanly

ii. Thinking Humanly,

iii. Thinking Rationally,

iv. Acting Rationally

(2) Foundations of AI

(3)Brief History of AI

(4) Brief Overview of Modern AI & Application Domains.

Definition of Intelligence

- Dictionary.com : capacity for learning, reasoning, understanding and similar forms of mental activity
- Ability to perceive and act
- Reasoning, proving theorems
- Planning: take decisions
- Learning and Adaptation
- Understanding: text, speech and visual scene

Definition of AI

- Artificial Intelligence is concerned with making artificial device intelligent.
- The term was coined by McCarthy in 1956.
- There are two concepts in the definition: Intelligence and Artificial device

Different Types of Artificial Intelligence

- Systems that think like human
- Systems that act like human
- Systems that think rationally
- Systems that act rationally

Last type is adopted by Modern AI

Thinking Humanly

Cognitive Modelling Approach

- Some Definitions of AI

"The exciting new effort to make computers think . . . machines with minds, in the full and literal sense." (Haugeland, 1985)

"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solv-ing, learning . . ." (Bellman, 1978)

Thinking Humanly

Cognitive Modelling Approach

- How do we capture human thinking to implement
  - Introspection
  - Psychological Experiments
  - Brain Imaging
- System : *"General Problem Solver"* (*Newell and Simon, 1961*)
  - Designed to work as a universal problem solver
  - Problems represented by horn clauses
  - First AI Machine which has KB + Inference separation
  - Authors focus on this is on comparing the trace of its reasoning steps to traces of human subjects solving the same problems
- Growth of Cognitive science and AI supports each other

Acting Humanly

Turing Test Approach

Some Definitions of AI:

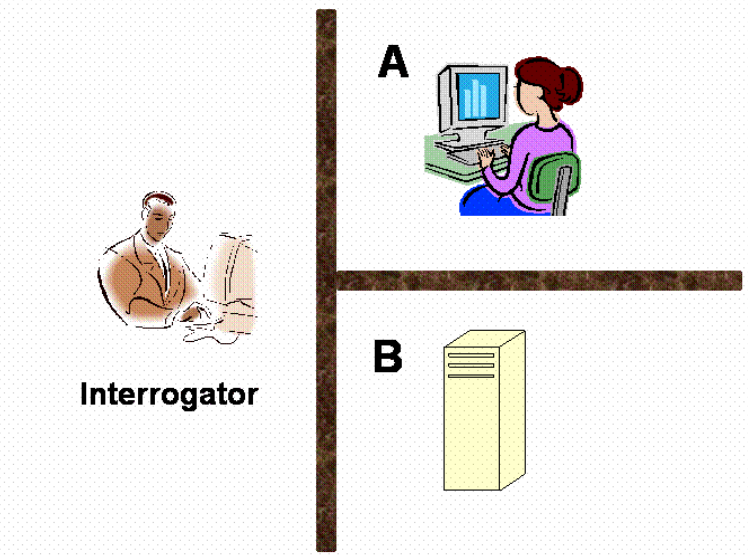
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)

"The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)

Act like Human: Turing Test

There are two rooms, A and B.

- One of the rooms has a computer and the other contains a human.
- The interrogator is outside and does not know which one is a computer.
- He asks questions through a teletype and receives answers from both A and B rooms.



- The interrogator needs to identify whether A or B are humans.
- To pass the Turing test, the machine has to fool the interrogator into believing that it is human.

Thinking Rationally

"Laws of Thought" Approach

- Invention of Formal Logic, Greek Philosopher Aristotle, Third century BC.
- Introduced syllogisms, providing argument structures

In all boring classes, students sleeps

Thinking Rationally

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It is a boring class
Students sleeps in this class [Are you ?]

Thinking Rationally

"Laws of Thought" Approach

- Invention of Formal Logic, Greek Philosopher Aristotle, Third century BC.
- Introduced syllogisms, providing argument structures

In all boring classes, students sleep
It is a boring class
Students sleep in this class [Are you ?]

- Field of Logics gave rise to codifying rational thinking
  - When elements are '*things*', we reason about things

Hurdles to the idea : (1) Not everything can be logically coded (2) no provably correct action at a moment (3) Exhaustive computational resources

Acting Rationally

The Rational Agent Approach

- An agent is an entity that perceives and acts
- *This course is about designing rational agents*
- Abstractly, an agent is a function from percept histories to actions:

  [f: P* → A]
- For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- Computational limitations make perfect rationality unachievable
- Design best program for given machine resources

Acting Rationally

The Rational Agent Approach

- Rational behavior: doing the *right thing*
- The *right thing:* that which is expected to maximize goal achievement, given the available information
- Rational behaviour is not just about correct inference / thinking, skills needed to pass turing test etc.
- (adv) : More General - Correct inference is just a thing
- (adv) : More amenable for scientific developments, as the rational behaviour is better defined than human thinking and behavior

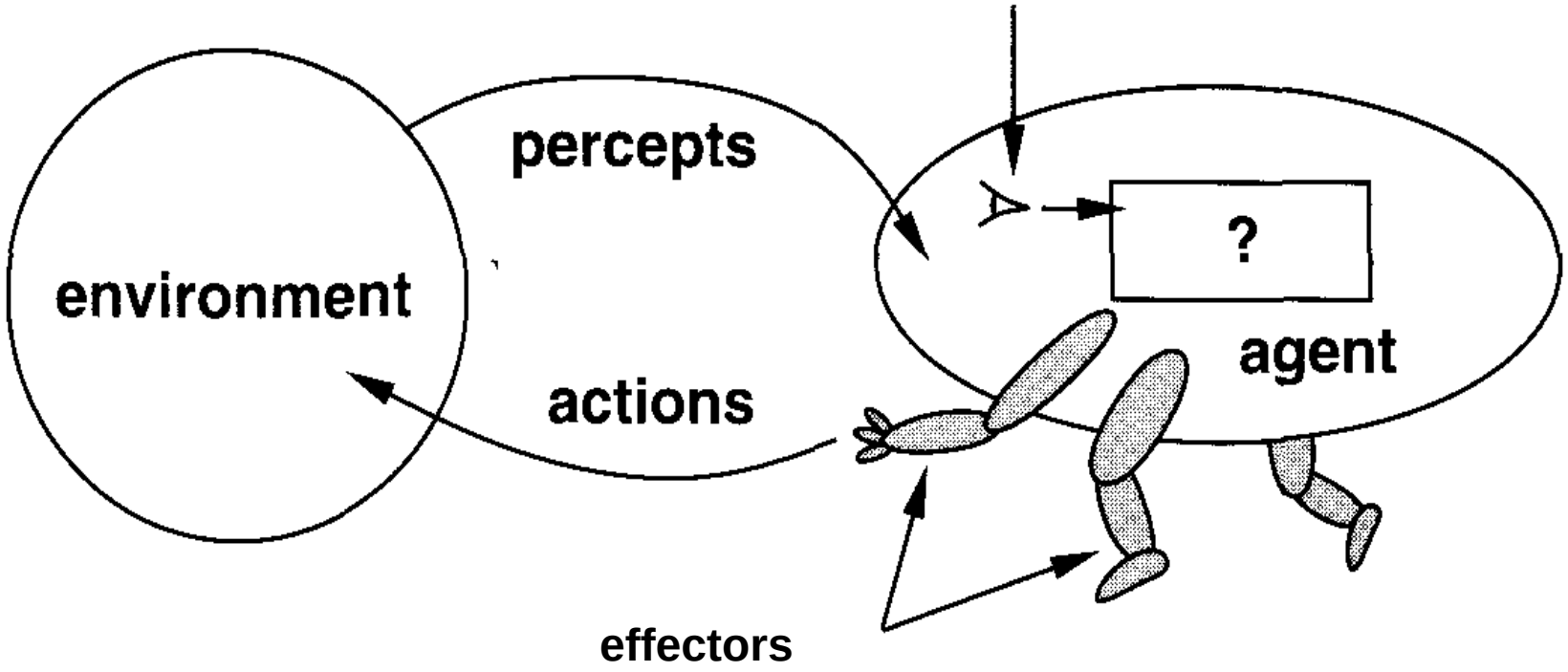
Definitions

Thinking Humanly	Thinking Rationally
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998) "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

About the course

- Course focuses on
  - principles of artificial intelligence
  - concepts, algorithms involved in building rational agents
  - topics covered like
    - (informed and uninformed) search & applications
    - (logical & probabilistic) knowledge representation
    - (logical & probabilistic) Reasoning & applications
    - a bit of learning (reinforcement learning)
  - topics not-covered like
    - Formal introduction to machine learning algorithms, neural networks etc are covered as a ML course is running in parallelly, Deep neural networks (deep learning course) , which are part of AI as well.

Intelligent Agents

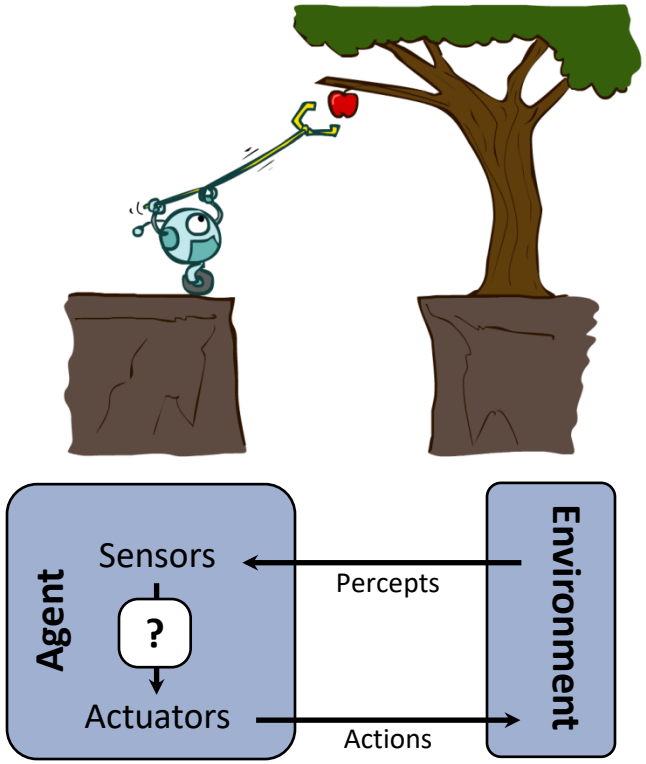


Rational Agents

- An agent should strive to do the right thing based on what it can perceive and the actions it can perform. The right action is the one that will cause the agent to be most successful.
- Performance measure: An objective criterion for success of an agent's behavior
- Eg. Performance measure of a vacuum-leaner agent could be the amount of dirt cleaned up, amount of time taken, amount of electricity consumed, amount of noise generated

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



TYPICAL AI PROBLEMS

- Intelligent entities should be able to do both mundane and expert tasks.
- Mundane tasks:
  - Planning route, activity
  - Recognizing people, objects
  - Communicating through natural language
  - Navigating round obstacles on the streets.
- Expert tasks:
  - Medical diagnosis
  - Mathematical problem solving

What's easy and what's hard

The following requires skill development and/or intelligence and only some specialists can perform them well.

- Symbolic integration
- Proving theorems
- Playing chess
- Medical diagnosis

Computer systems have made an achievement in accomplishing these tasks.

What's easier and what's hard

Its very hard to make computer systems perform many routine tasks that all humans and a lot of animals can do

- Walking around without running into things
- Catching prey and avoiding predators
- Interpreting complex sensory information
- Modeling the internal states of animals from their behavior

Intelligent behavior

- Perception
- Reasoning
- Learning
- Understanding language
- Solving problems

Applications

- Computer Vision
- Image recognition
- Robotics
- Natural Language Processing
- Speech Processing

Practical Impact of AI

- AI components are embedded in numerous devices. E.g. copy machine
- AI systems are in everyday use
  - Detecting credit card fraud
  - Configuring products
  - Aiding complex planning task
  - Advising physician
- Intelligent tutoring systems provide the students with personalized attention

Limits of AI Today

➢ Today's successful AI systems

- operate in well-defined domains
- employ narrow and specialized knowledge.

➢ Common sense knowledge

- Needed in complex and open-ended worlds.
- understand unconstrained natural language.

What can AI systems do

- Computer vision : face recognition
- Robotics: autonomous vehicles.
- Natural language processing: simple machine translation.
- Expert systems: medical diagnosis
- Speech understanding systems ~ 1000 words continuous speech
- Learning: text categorization into ~ 1000 topics
- In Games, AI systems can play at the Grand Master level in chess (world champion), checkers, etc.

What can AI systems NOT do yet?

- Understand natural language robustly (e.g., read and understand articles in a newspaper)
- Surf the web
- Interpret an arbitrary visual scene
- Learn a natural language
- Construct plans in dynamic real-time domains
- Exhibit true autonomy and intelligence

AI History

- The dream of making computer imitate us began many centuries ago.
- Aristotle (384-322 BC) developed an informal system of syllogistic logic, which is the basis of the first formal deductive reasoning system.
- Early in the 17th century, Descartes proposed that bodies of animals are nothing more than complex machines.
- Pascal in 1642 made the first mechanical digital calculating machine.
- In the 19th century, George Boole developed a binary algebra representing (some) "laws of thought."
- Charles Babbage & Ada Byron worked on programmable mechanical calculating machines.
- In the late 19th century and early 20th century, mathematical philosophers like Gottlob Frege, Bertram Russell, Alfred North Whitehead, and Kurt Gödel built on Boole's initial logic concepts to develop mathematical representations of logic problems.

AI History

- The advent of electronic computers provided a revolutionary advance in the ability to study intelligence.
- In 1950 Turing wrote an article on "Computing Machinery and Intelligence" which articulated a complete vision of AI.
- Turing's paper talked of many things, of solving problems by searching through the space of possible solutions, guided by heuristics. He illustrated his ideas on machine intelligence by reference to chess. He even propounded the possibility of letting the machine alter its own instructions so that machines can learn from experience.

AI History

- In 1956 a famous conference took place in Dartmouth. The conference brought together the founding fathers of artificial intelligence for the first time. In this meeting the term “Artificial Intelligence” was adopted.

AI History

The 1990's saw major advances in all areas of AI including the following:

- machine learning, data mining
- intelligent tutoring,
- case-based reasoning,
- multi-agent planning, scheduling,
- uncertain reasoning,
- natural language understanding and translation,
- vision, virtual reality, games, and other topics.

Modern AI

Deep Learning Breakthroughs (2012 – Present)

- In 2012, deep learning beats previous benchmark on the ImageNet competition.
- In 2013, deep learning is used to understand "conceptual meaning" of words.
- In 2014, similar breakthroughs appeared in language translation.
- These have led to advancements in Web Search, Document Search, Document Summarization, and Machine Translation.

Google Translate

Deep Learning Breakthroughs (2012 – Present)

- In 2014, computer vision algorithm can describe photos.
- In 2015, Deep learning platform TensorFlow* is developed.

Modern AI (2012 – Present): Deep Learning Impact

Computer vision

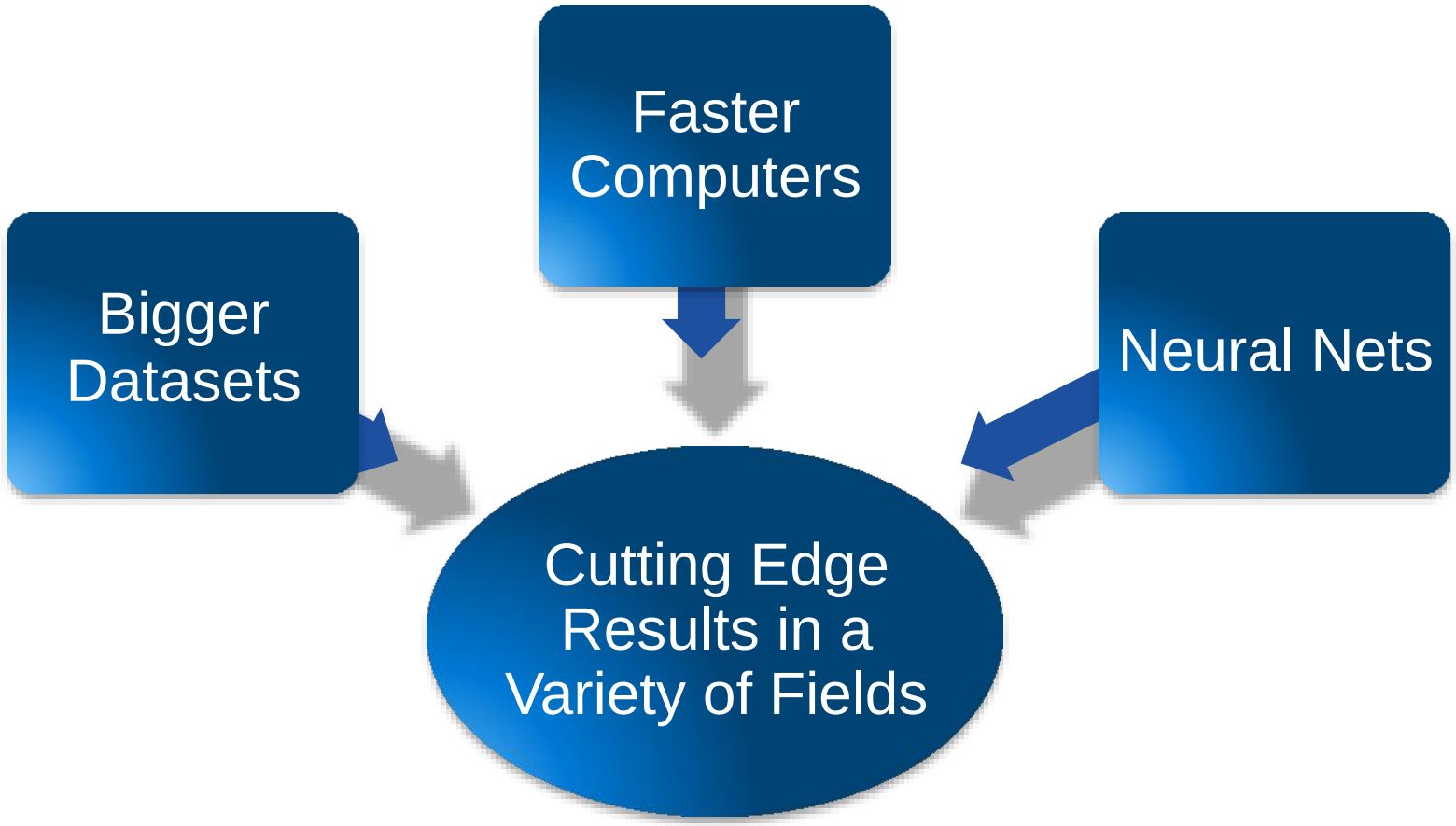
Self-driving cars:
object detection

Healthcare:
improved diagnosis

Natural language

Communication:
language translation

How Is This Era of AI Different?



Other Modern AI Factors

- Continued expansion of open source AI, especially in Python*, aiding machine learning and big data ecosystems.
- Leading deep learning libraries *open sourced*, allowing further adoption by industry.
- Open sourcing of large datasets of millions of labeled images, text datasets such as Wikipedia has also driven breakthroughs.

AI In Transportation

Navigation

Google & Waze find the fastest route, by processing traffic data.

Ride sharing

Uber & Lyft predict real-time demand using AI techniques, machine learning, deep learning.

AI In Social Media

Audience

Facebook & Twitter use AI to decide what content to present in their feeds to different audiences.

Content

Image recognition and sentiment analysis to ensure that content of the appropriate “mood” is being served.

Autonomous cars

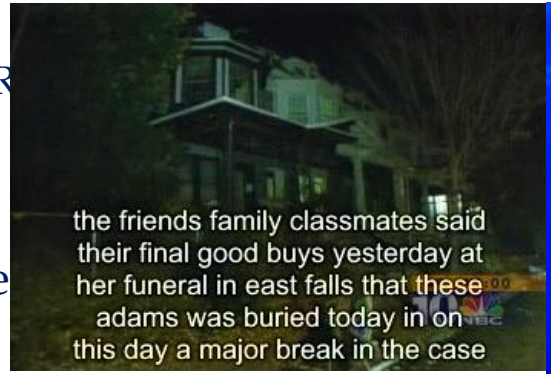
Robots help nurses in hospitals deliver stuff to different rooms

Drones that record cool videos

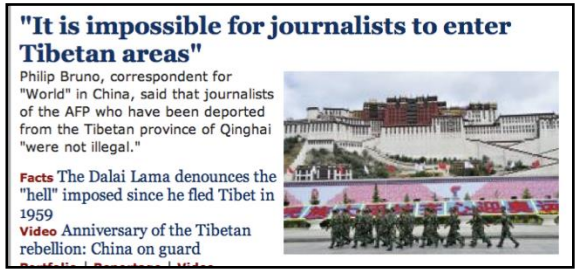
A Robot Learning on it's own

Natural Language

- Speech technologies (e.g. Siri)
  - Automatic speech recognition (ASR
  - Text-to-speech synthesis (TTS)
  - Dialog systems



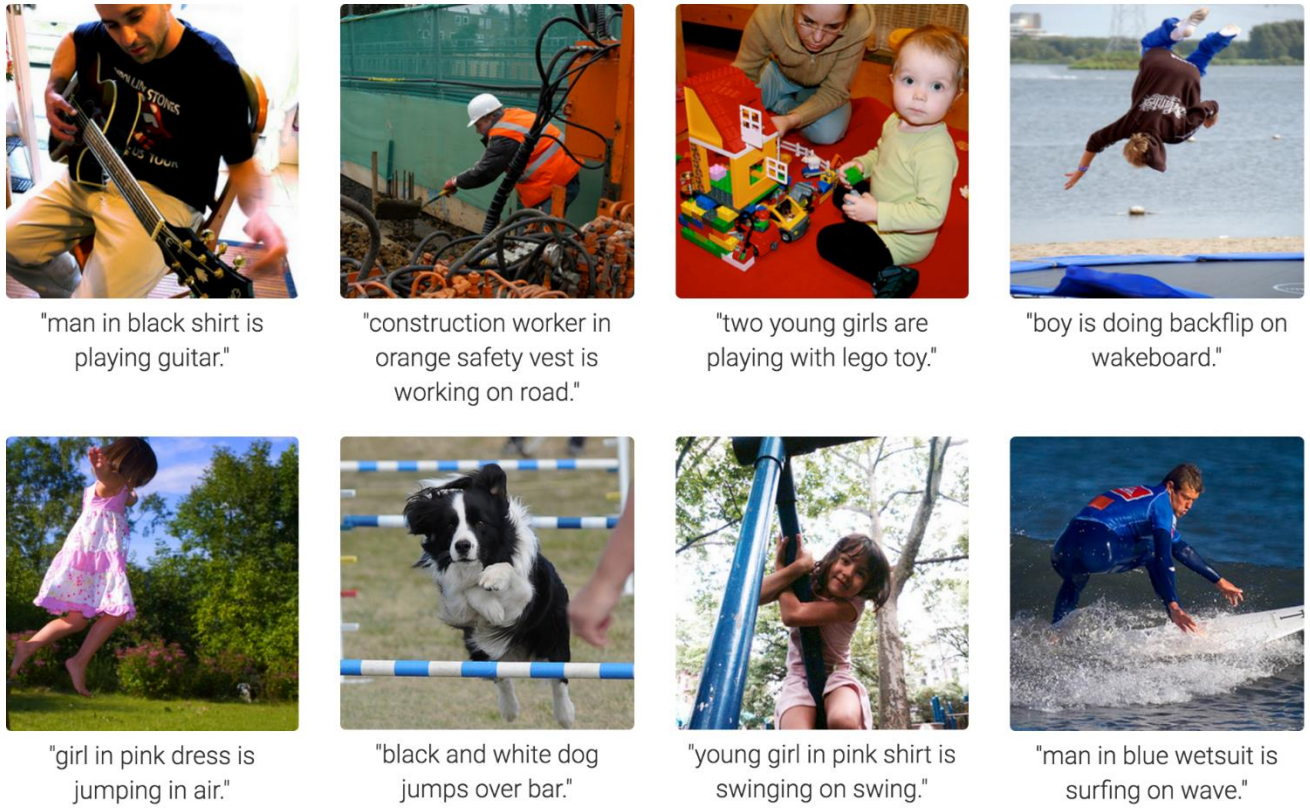
- Language processing technologie
  - Question answering
  - Machine translation



  - Web search
  - Text classification, spam filtering, etc…

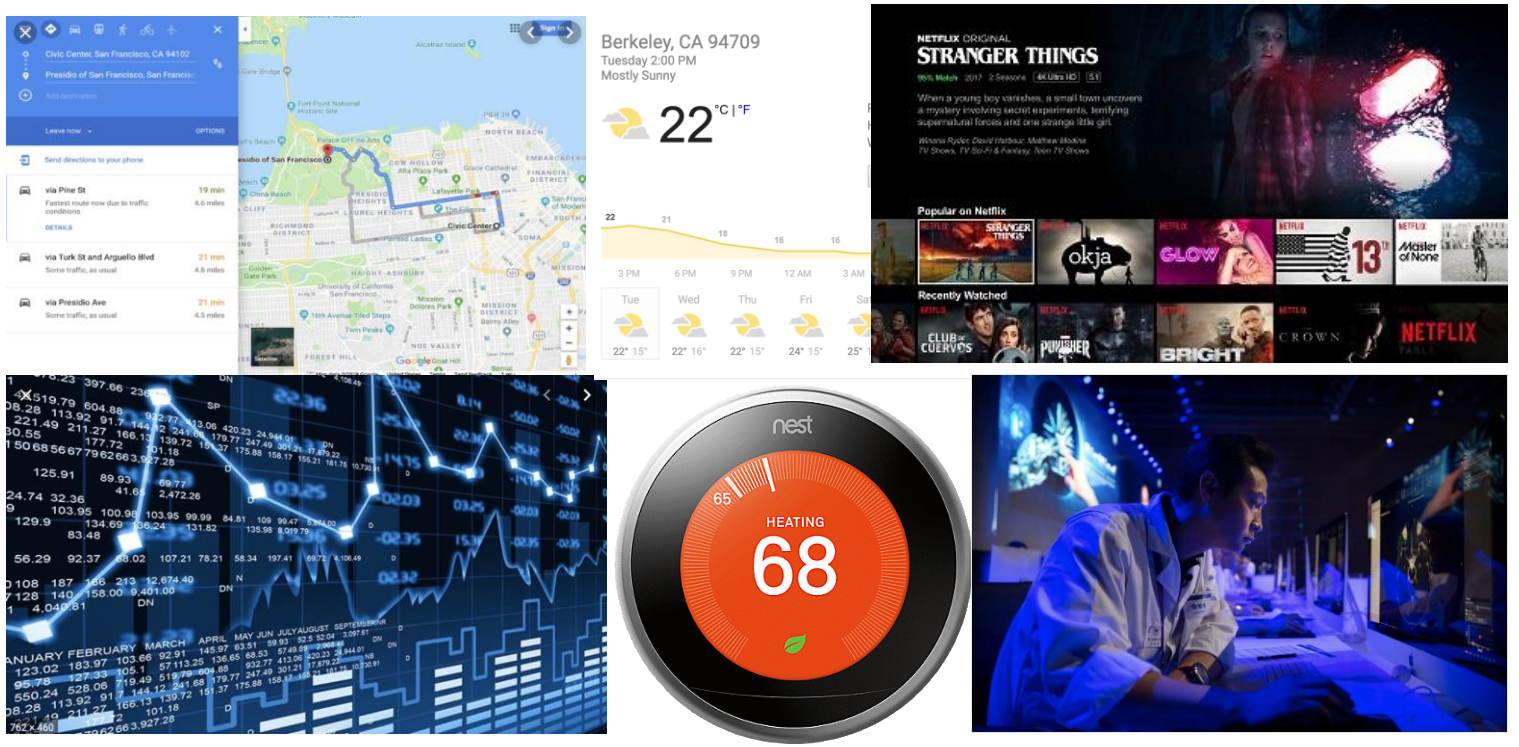
https://play.aidungeon.io/

Computer Vision



Karpathy & Fei-Fei, 2015; Donahue et al., 2015; Xu et al, 2015; many more

Tools for Predictions & Decisions

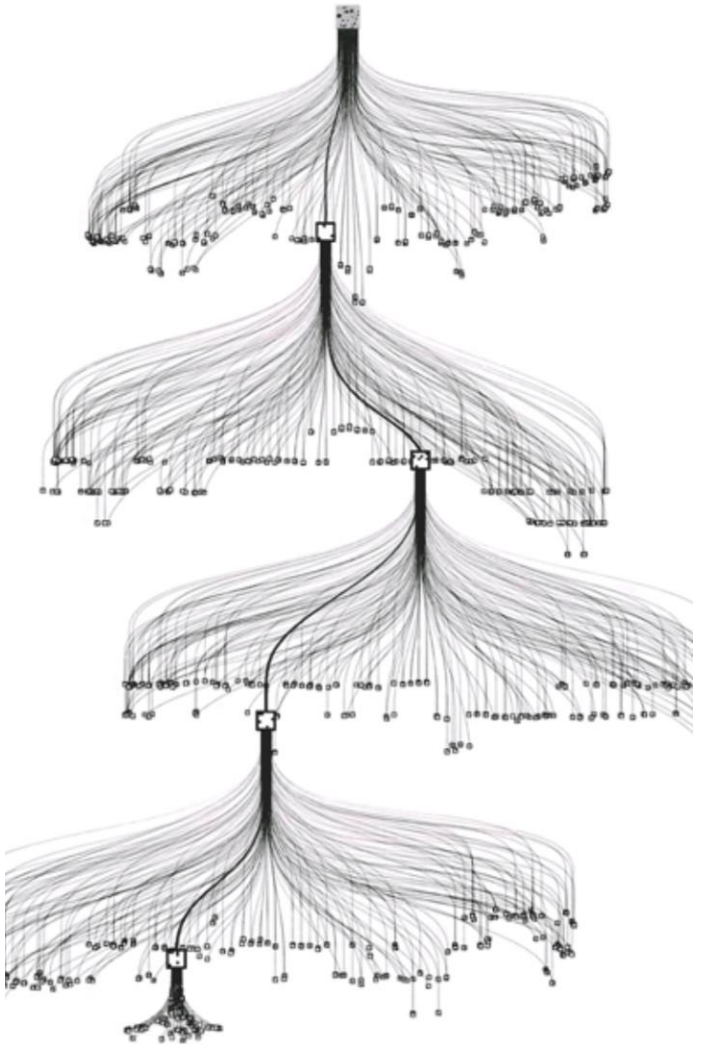


AlphaGo

- AlphaGo is the first computer program to defeat a professional human Go player
- Go originated in China over 3,000 years ago. Winning this board game requires multiple layers of strategic thinking.
- At the opening move in Chess there are 20 possible moves. In Go the first player has 361 possible moves
- Policy network -selects the next move to play.
- Value network predicts the game winner

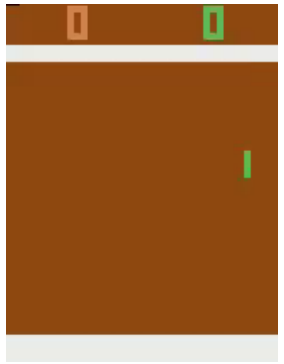
AlphaGo

- AlphaGo must restrict Breath and Depth of search among all board configurations with heuristics information supplied by training and winning policy for max reward.

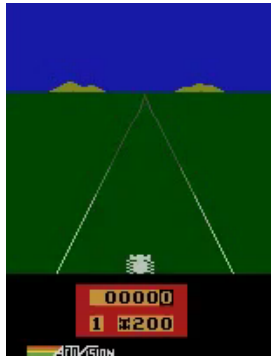


Game Agents

- Reinforcement learning

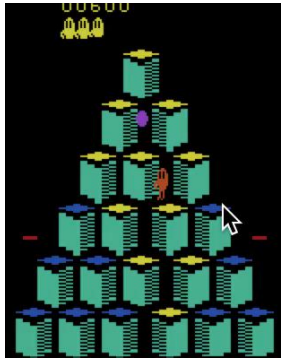


Pong



Enduro

Beamrider



Q*bert

Human-AI Interaction

Areas Contributing to AI

Philosophy
Mathematics
Economics
Neuroscience
Psychology
Computer Engineering
Control theory, Cybernetics
Linguistics

- How should we make decisions so as to maximize payoff?

Utility / preferred outcomes

Decision theory -Probability & utility theory

Game theory

- How to make decisions when payoffs are not immediate?
  - MDP

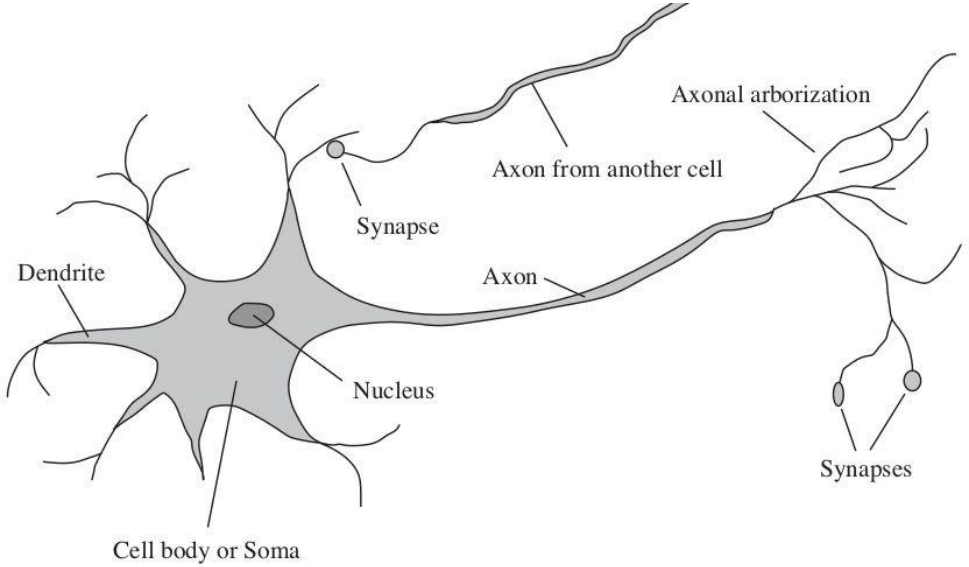
Areas Contributing to AI

Philosophy
Mathematics
Economics
Neuroscience
Psychology
Computer Engineering
Control theory, Cybernetics
Linguistics

How do brains process information?

- Study of the nervous system / brain
- How does brain enables thoughts - Mystery Still

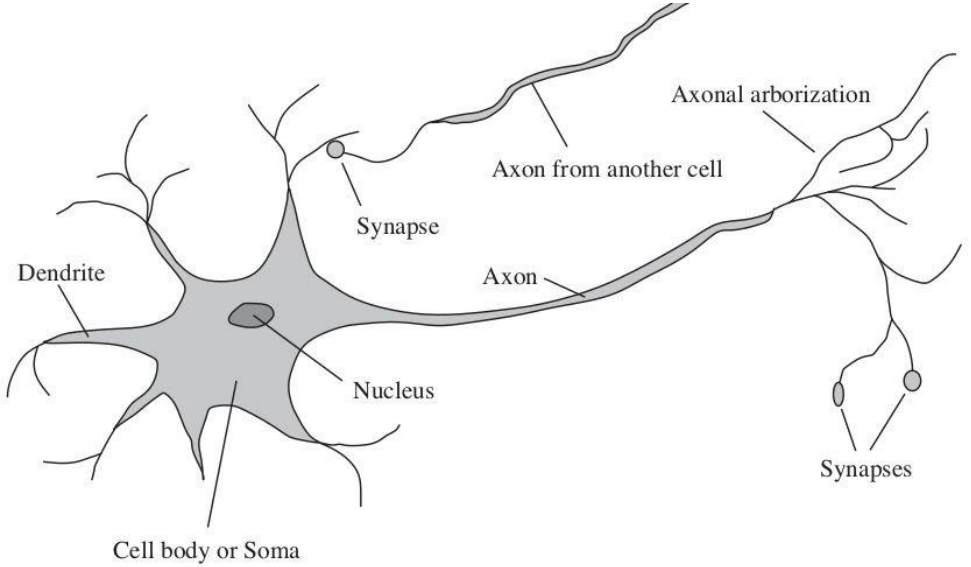
Aristotle , "*Of all the animals, man has the largest brain in proportion to his size*"



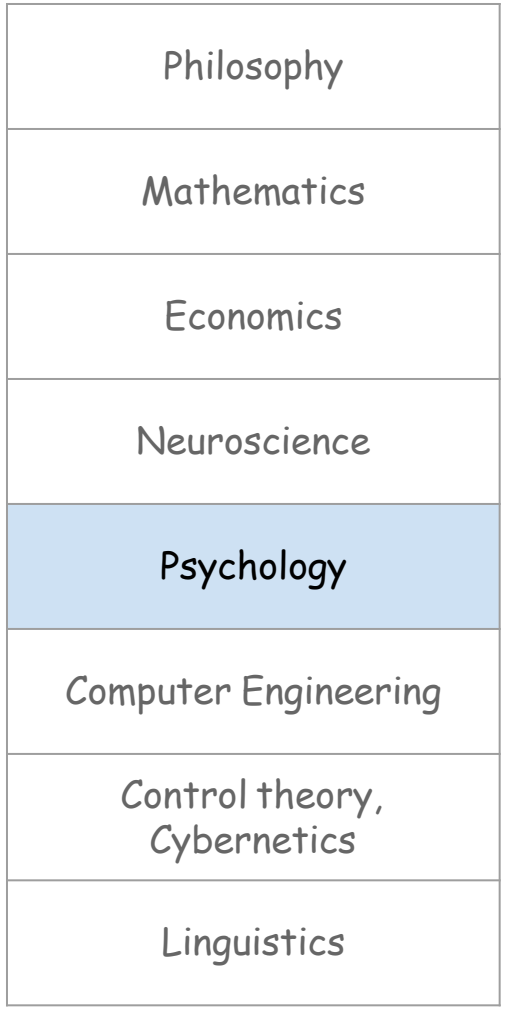
Areas Contributing to AI

- Philosophy
- Mathematics
- Economics
- **Neuroscience**
- Psychology
- Computer Engineering
- Control theory, Cybernetics
- Linguistics

	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}



Areas Contributing to AI



How do humans and animals think and act?

- *Cognitive Psychology* - Brain as an information-processing device
- Two months after the dartmouth workshop, a workshop in MIT gave birth to *Cognitive Science*
  - George Miller, Noam Chomsky, Allen Newell and Herbert Simon - roles of computer models to address the psychology of memory, language, and logical thinking, issues..

"*a cognitive theory should be like a computer program*" (Anderson, 1980);

Areas Contributing to AI

Philosophy
Mathematics
Economics
Neuroscience
Psychology
Computer Engineering
Control theory, Cybernetics
Linguistics

Computers & Programming Languages

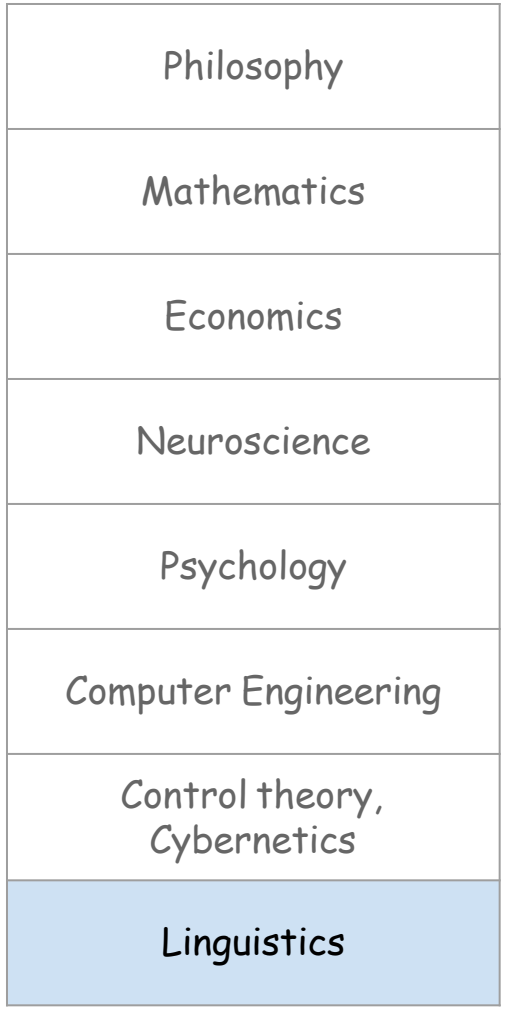
Areas Contributing to AI

Philosophy
Mathematics
Economics
Neuroscience
Psychology
Computer Engineering
Control theory, Cybernetics
Linguistics

Control theory

- Deals with the behaviour of dynamic systems
  - behaviour must ensure the error between the current state and goal state is minimized
- Cybernetics - Book by Wiener
  - (Norbert Wiener, 1948) : Scientific study of control and communication in the animal and the machine
- Ashby's Design for a Brain (1948, 1952):
  - Intelligence could be created by the use of homeostatic devices containing appropriate feedback loops to achieve stable adaptive behavior
  - Led to the idea of *design of systems that maximize an objective function over time*

Areas Contributing to AI



- How does language relate to thought?

  Verbal Behavior (1957, B. F. Skinner) :
  - Behaviorist approach to language learning
  - Reviewed by Noam Chomsky
    - criticised lack of notion of creativity in language
- Syntactic Structures (1957, Noam Chomsky)
  - Computational linguistics / natural language processing as a part of AI
    - Understanding a language is realized as more complex than ever
    - Context, subject matter knowledge
    - complicated it further
    - Representing language consumed volume of work done in NLP, in early t

Thank You

Required Reading:

AIMA - Chapter # 1.1
AIMA - Chapter # 1.2 - Must Read & Google a lot

Note : Some of the slides are adopted from AIMATB materials