CMPE 480
Introduction to Artificial Intelligence

Prof. Dr. H. Levent Akın

Instructor

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Course Requirements

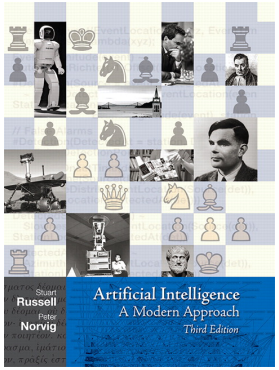
- 2 Midterms 20% each
  - October, 2019
  - November , 2019
- Final Exam 30%
- Projects 30% (Total)

Course Communication

- Course Wiki:
  - http://robot.cmpe.boun.edu.tr/~cmpe480/
- Course Mailing List:
  - Cmpe480@listeci.cmpe.boun.edu.tr

Recommended Text Book

- Stuart Russell , Peter Norvig Artificial Intelligence: A Modern Approach (3rd Edition), Pearson, 2009.



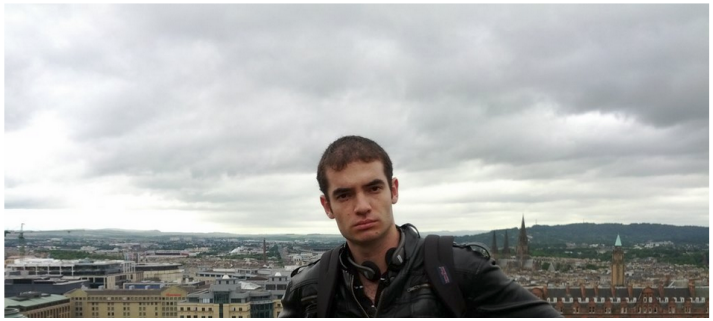
Course Outline

- Introduction
- Agents
- Problem Solving and Search
  - Uninformed Search
  - Informed Search
- Game Playing
- Constraint Satisfaction Problems
- Knowledge Representation
  - Logic
  - Semantic Networks
  - Frames
- Knowledge Based Systems
  - Knowledge Elicitation
- Uncertainty
  - Bayesian Approaches
  - Fuzzy Logic Certainty Factors Dempster-Shafer Machine Learning
- Machine Learning
  - Neural Networks
  - SVMs
  - Reinforcement Learning
  - HMM
  - Deep Learning
- Robotics
- Future of AI and AI Ethics
  -

Business and Job Opportunities

TECHNOLOGY The New York Times SUBSCRIBE LOG IN

A.I. Researchers Are Making More Than $1 Million, Even at a Nonprofit



The AI Effect

- The **AI effect** occurs when onlookers discount the behavior of an artificial intelligence program by arguing that it is not *real* intelligence.

"Every time we figure out a piece of it, it stops being magical; we say, 'Oh, that's just a computation."

Rodney Brooks

"A lot of cutting edge AI has filtered into general applications, often without being called AI because once something becomes useful enough and common enough it's not labelled AI anymore"

Nick Bostrom

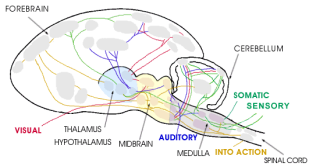
- AI is whatever hasn't been done yet!

What is “Intelligence”?

Capabilities of Intelligent Beings

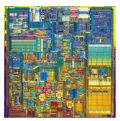
- Thinking and problem solving
- Learning and memory
- Language
- Intuition and creativity
- Consciousness
- Emotions
- Surviving in a complex world
- Perceptual and motor abilities

Hardware

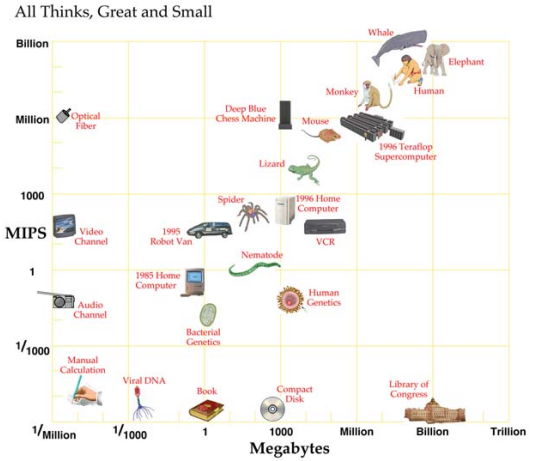


10^{11} neurons
10^{14} synapses
cycle time: 10^{-3} sec

10^{7} transistors
10^{10} bits of RAM
cycle time: 10^{-9} sec

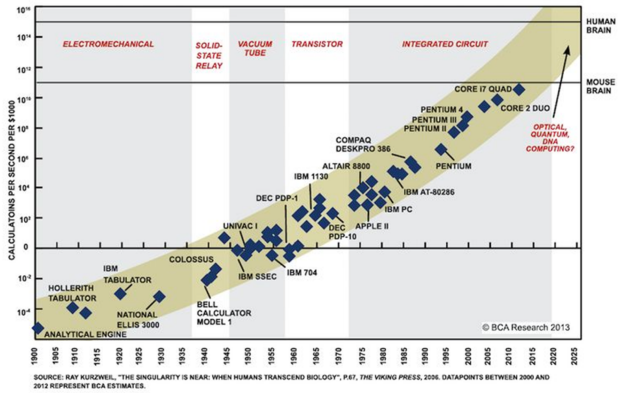


Computer vs. Brain



From ROBOT, *Moravec*, Oxford, 1998

Evolution of Computers

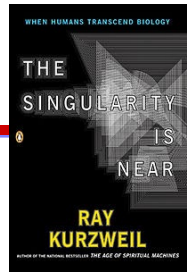


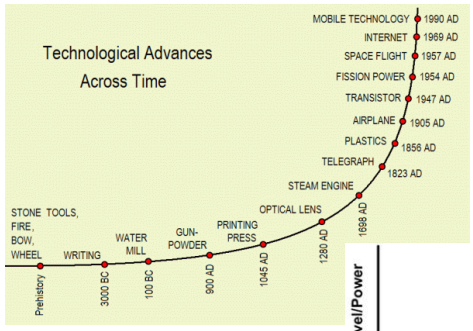
SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

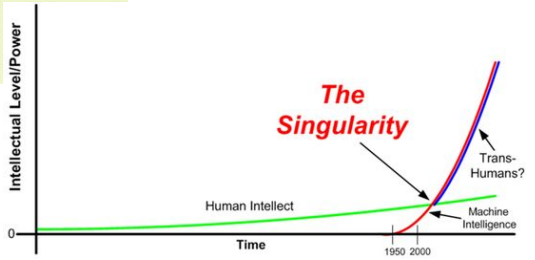
Effect of Hardware

- In the near future we can have computers with as many processing elements as our brain, but:
  - Far fewer interconnections (wires or synapses)
  - Much faster updates.
- Fundamentally different hardware may require fundamentally different algorithms!
  - Very much an open question.
  - e.g. Artificial neural networks research or quantum computers

The Coming Singularity?







Aims in AI

- Strong AI
  - Artificial General Intelligence
- Weak AI
  - Tools that use AI techniques

What is AI?

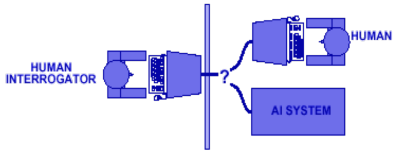
■The exciting new effort to make computers think … *machine with minds,* in the full and literal sense" (Haugeland 1985)	■"The study of mental faculties through the use of computational models" (Charniak et al. 1985)
■"The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990)	■A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" (Schalkol, 1990)

Views of AI fall into four categories:

Thinking humanly	Thinking rationally
Acting humanly	Acting rationally

Acting humanly: The Turing test

- Turing (1950) "Computing machinery and intelligence":
- "Can machines think?" ⇒"Can machines behave intelligently?"
- Operational test for intelligent behavior: the Imitation Game



- Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes
- Anticipated all major arguments against AI in following 50 years
- Suggested major components of AI: knowledge, reasoning, language understanding, learning

Turing Test

- The computer would need to possess the following capabilities:
  - **Natural language processing** to enable it to communicate successfully in English (or some other human language);
  - **Knowledge representation** to store information provided before or during the interrogation;
  - **Automated reasoning** to use the stored information to answer questions and to draw new conclusions;
  - **Machine learning** to adapt to new circumstances and to detect and extrapolate patterns.

Acting Humanly: The Full Turing Test

- Problem:
  1. Turing test is not reproducible, constructive, and amenable to mathematic analysis.
  2. What about physical interaction with interrogator and environment?
- Total Turing Test: Requires physical interaction and needs perception and actuation.

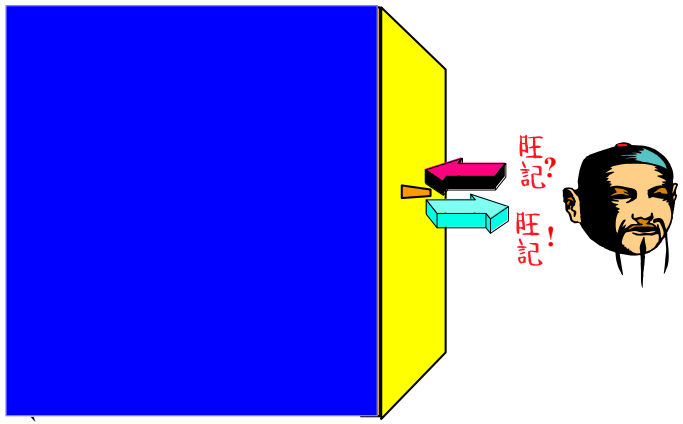
What would a computer need to pass the Total Turing test?

- **Vision**: to recognize the examiner's actions and various objects presented by the examiner.
- **Motor control:** to act upon objects as requested.
- **Other senses:** such as audition, smell, touch, etc.

Total Turing Test ?

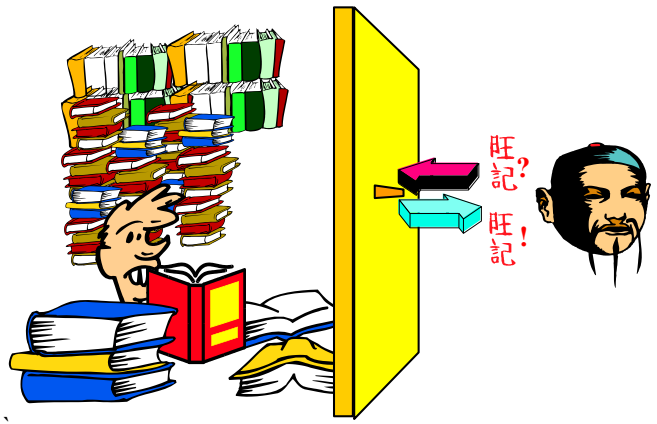
Repliee Q1
http://www.androidscience.com/links.html

The Chinese Room



The Chinese Room

- The Chinese Room



Thinking humanly: Cognitive Science

- 1960s “cognitive revolution": information-processing psychology replaced prevailing orthodoxy of behaviorism
- Requires scientific theories of internal activities of the brain
  - What level of abstraction? “Knowledge" or “circuits"?
  - How to validate? Requires
    1) Predicting and testing behavior of human subjects (top-down) or
    2) Direct identification from neurological data (bottom-up)
- Both approaches (roughly, Cognitive Science and Cognitive Neuroscience) are now distinct from AI
- Both share with AI the following characteristic:
  - The available theories do not explain (or engender) anything resembling human-level general intelligence

Thinking Rationally: Laws of Thought

- Aristotle (~ 450 B.C.) attempted to codify “right thinking”
  - What are correct arguments/thought processes?
  - e.g., “Socrates is a man, all men are mortal; therefore Socrates is mortal”
- Several Greek schools developed various forms of logic:
  - Notation plus rules of derivation for thoughts.

Thinking Rationally: Laws of Thought

- **Problems:**
  - Uncertainty: Not all facts are certain (e.g., the flight might be delayed).
  - Resource limitations:
    – Not enough time to compute/process
    – Insufficient memory/disk/etc.
    – etc.

Acting Rationally: The Rational Agent

- Rational behavior: Doing the right thing!
- The right thing: That which is expected to maximize the expected return
- Provides the most general view of AI because it includes:
  - Correct inference (“Laws of thought”)
  - Uncertainty handling
  - Resource limitation considerations (e.g., reflex vs. deliberation)
  - Cognitive skills (NLP, AR, knowledge representation, ML, etc.)
- Advantages:
  - More general
  - Its goal of rationality is well defined

Rational Agents

- An agent is just something that acts (The term agent comes from the Latin word *agere*, to do).
- Attributes that distinguish agents from mere "programs" include:
  - Operating under autonomous control,
  - Perceiving their environment,
  - Persisting over a prolonged time period,
  - Adapting to change, and
  - Being capable of taking on another's goals.
- A rational agent is one that acts so as to achieve the best outcome, or when there is uncertainty, the best expected outcome.

Origin Sciences of AI

Philosophy	logic, methods of reasoning
	mind as physical system
	foundations of learning, language, rationality
Mathematics	formal representation and proof
	algorithms, computation, (un)decidability, (in)tractability
	probability
Psychology	adaptation
	phenomena of perception and motor control
	experimental techniques (psychophysics, etc.)
Economics	formal theory of rational decisions
Linguistics	knowledge representation
	grammar
Neuroscience	plastic physical substrate for mental activity
Control theory	homeostatic systems, stability
	simple optimal agent designs

AI State of the art

- Have the following been achieved by AI?
  - Play a decent game of table tennis
  - Drive safely along a curving mountain road
  - Drive safely along Hisarüstü ?
  - Buy a week's worth of groceries on the web
  - Buy a week's worth of groceries at a hipermarket
  - Play a decent game of bridge
  - Discover and prove a new mathematical theorem
  - Design and execute a research program in molecular biology
  - Write an intentionally funny story
  - Give competent legal advice in a specialized area of law
  - Translate spoken English into spoken Turkish in real time
  - Converse successfully with another person for an hour
  - Perform a complex surgical operation
  - Unload any dishwasher and put everything away

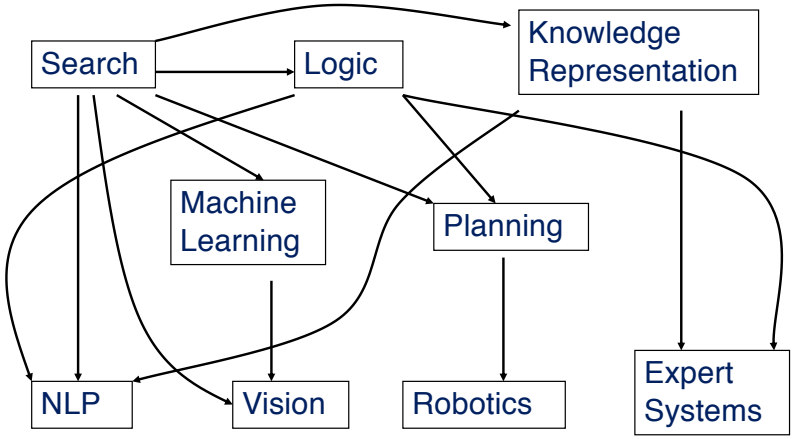
Recurrent Themes

- Neural nets vs AI
  - McCulloch & Pitts 1943
  - Died out in 1960's, revived in 1980's
    - Neural nets vastly simplified model of real neurons, but still useful & practical – massive parallelism
    - particular family of learning and representation techniques
- Logic vs Probability
  - In 1950's logic seemed more computationally & expressively attractive (McCarthy, Newell)
    - attempts to extend logic "just a little" to deal with the fact that the world is uncertain!
  - 1988 – Judea Pearl's work on Bayes nets
    - provided efficient computational framework
  - Today – no longer rivals
    - hot topic: combining probability & first-order logic

The Main Topics in AI

- Artificial intelligence can be considered under a number of headings:
  - Search (includes Game Playing).
  - Representing Knowledge and Reasoning with it.
  - Planning.
  - Learning.
  - Natural language processing.
  - Expert Systems.
  - Interacting with the Environment
    - Vision,
    - Speech recognition,
    - Robotics

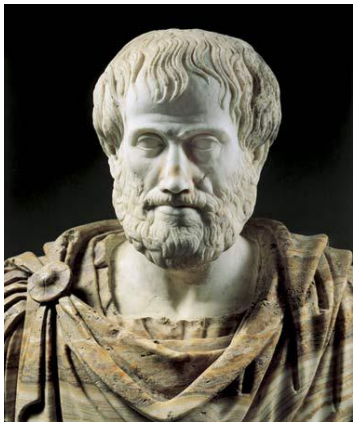
Areas of AI and Some Dependencies



AI Pre-History

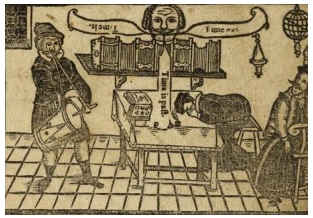
4th Century BC

- Aristotle invented logic.
- Deductive reasoning



13th Century

- The first ”Talking heads” were made.



- Al Jazari designed the first programmable humanoid robot

17th Century Calculators

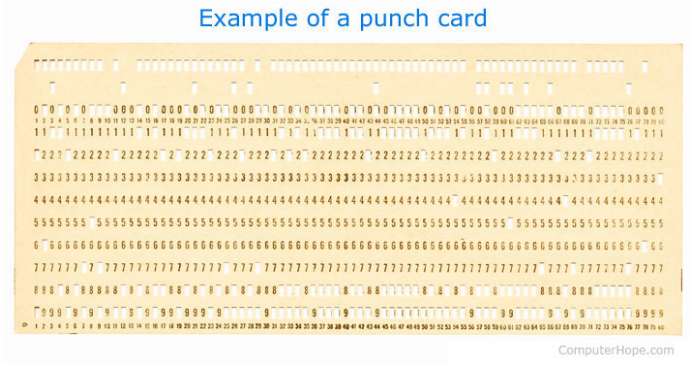
- Pascal's calculator (Pascaline)

- Samuel Morland's arithmetic machines

Jacquard's Weaving Machine

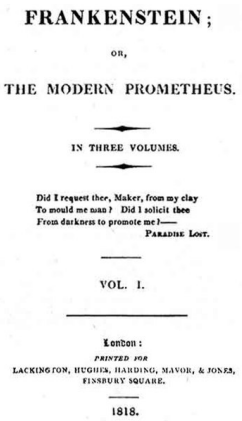
- Joseph-Marie Jacquard invented the first programmable machine in 1801.

Punch Card



Frankenstein or Modern Prometheus

- Mary Shelley published the story of Frankenstein's monster in 1818.



FRANKENSTEIN;

OR,

THE MODERN PROMETHEUS.

IN THREE VOLUMES.

Did I request thee, Maker, from my clay
To mould me man? Did I solicit thee
From darkness to promote me?—
PARADISE LOST.

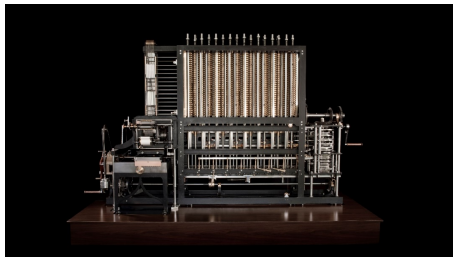
VOL. I.

London:
PRINTED FOR
LACKINGTON, HUGHES, HARDING, MAVOR, & JONES,
FINSBURY SQUARE.

1818.

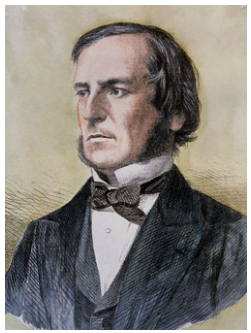
The Analytical Machine

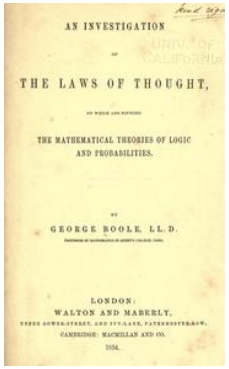
- Charles Babbage and Ada Byron (Lady Lovelace) designed the programmable mechanical calculator (Analytical Machine) in 1832.
- The first programs were written by Ada Byron.
- The first working Analytical Machine was made in 2002.



Boolean Algebra

- George Boole developed a binary algebra that represented some "laws of thought" and published it in 1854 in his book "The Laws of Thought."





AN INVESTIGATION

OF

THE LAWS OF THOUGHT,

ON WHICH ARE FOUNDED

THE MATHEMATICAL THEORIES OF LOGIC
AND PROBABILITIES.

BY

GEORGE BOOLE, LL.D.

LONDON:
WALTON AND MABERLY,

CAMBRIDGE: MACMILLAN AND CO.

Propositional Logic

- Gottlob Frege published his modern propositional logic in his book "Begriffsschrift“ in 1879.

BEGRIFFSSCHRIFT,

EINE DER ARITHMETISCHEN NACHGEBILDETE

FORMELSPRACHE

DES REINEN DENKENS.

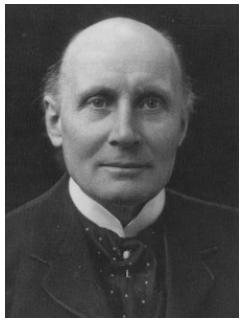
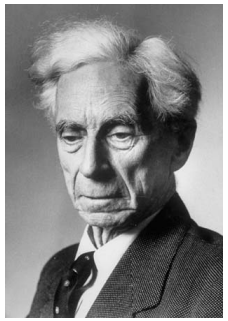
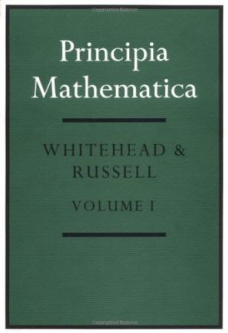
VON

Dr. GOTTLOB FREGE

HALLE a/S.
VERLAG VON LOUIS NEBERT.
1879.

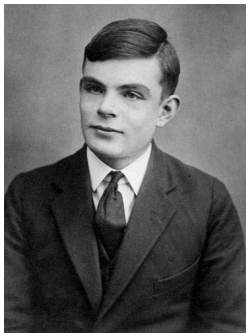
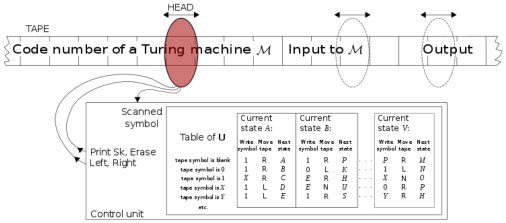
Principia Mathematica

- Principia Mathematica, the turning point of formal logic written by Alfred North Whitehead and Bertrand Russell, was first published in three volumes in 1910, 1912 and 1913.

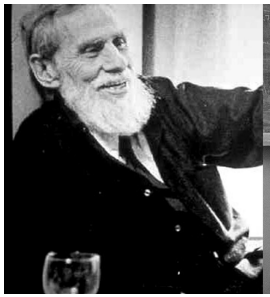
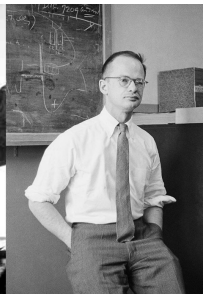
Universal Turing Machine

- The Universal Turing Machine was developed by Alan Turing in 1936-37.
- This is the forerunner of the stored programmed computer concept.

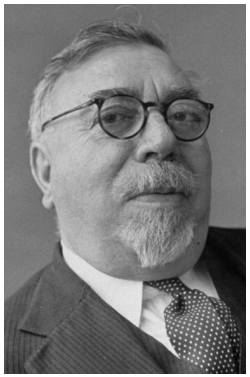
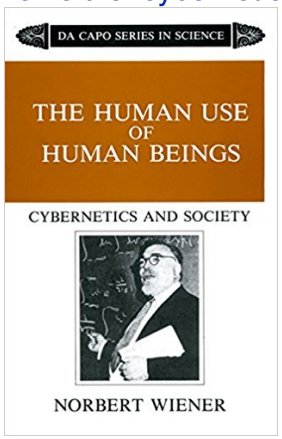
Perceptron

- Warren McCulloch and Walter Pitts published the article "A Logical Calculus of the Ideas Immanent in Nervous Activity" in 1943.
- This publication started the Artificial Neural Network studies.

Cybernetics

- Arturo Rosenblueth, Norbert Wiener and Julian Bigelow introduced the field of cybernetics in 1943.

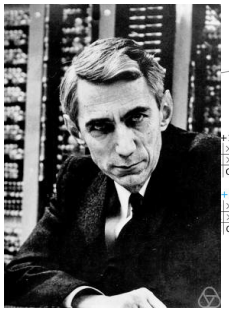



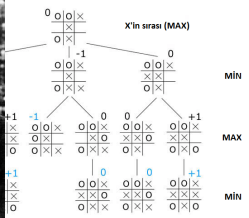
Expert Systems

- In 1943, Emil Post proved that rule-based systems, the forerunners of expert systems, is a general computing mechanism.

Game Trees

- Claude Shannon published a detailed analysis of chess playing in his work "Computer Programming for Playing Chess" (1950).





Modern History

Artificial Intelligence is christened

- Artificial Intelligence was named by John McCarthy.
- For the first time in the *Summer of Artificial Intelligence Research Project* held in Dartmouth in 1956, researchers from this field came together.

2006, Those were the days!

The First AI Program

- The first running AI program, Logic Theorist, written by Allen Newell, J.C. Shaw and Herbert Simon was introduced in 1956.
- The Logic Theorist later proved 38 out of the first 52 theorems in the second chapter of Principia Mathematica. One of these proofs was more elegant than the one in Principia Mathematica.

General Problem Solver

- The demonstration of the General Problem Solver developed by Newell, Shaw and Simon was made in 1957.

The First Game Playing Program

- Arthur Samuel wrote the first game playing program in 1959, which plays checkers to challenge a world champion. This program was also the first learning program.

The First Chatbot ELIZA

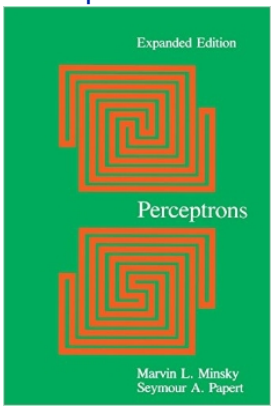
- In 1965, ELIZA was developed as the first program to enter into dialogue with users. Especially the psychotherapist version of ELIZA was very popular.

The First Knowledge Based Program

- Edward Feigenbaum, Joshua Lederberg, Bruce Buchanan and Georgia Sutherland showed that the Dendral program, developed in 1967, can interpret the mass spectrum containing organic chemical compounds. It was the first successful knowledge-based program for scientific reasoning.

The First Autumn of Artificial Neural Networks

- Marvin Minsky and Seymour Papert published the book "Perceptrons" in 1968, which shows the limitations of simple artificial neural networks.

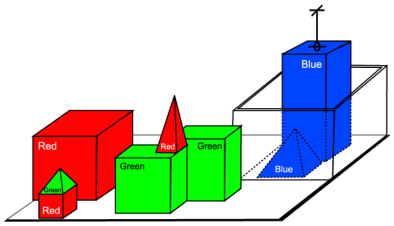


Developments in Natural Language Processing

- Jaime Carbonell developed SCHOLAR in 1970, an interactive program for computer-aided instruction based on semantic networks.

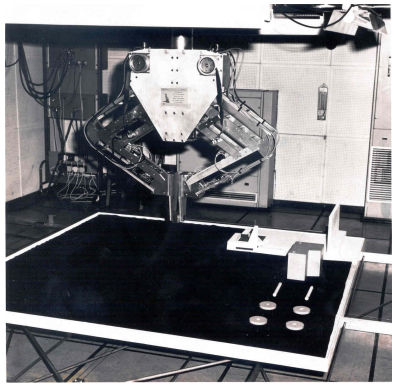
SHRDLU

- In 1971, Terry Winograd's doctoral dissertation (MIT) demonstrated the ability of computers to understand English sentences in limited children's worlds, combined with a robotics and language learning program (SHRDLU) that fulfills the instructions in English.



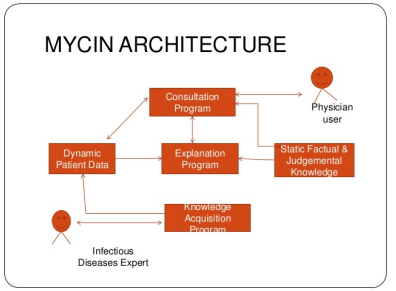
Freddy

- The Manufacturing Robotics group at Edinburgh University produced Freddy in 1973, who could use vision to find and combine models.



MYCIN

- Ted Shortliffe's doctoral dissertation study (Stanford) completed in 1974 on MYCIN showed the power of rule-based systems for the representation and inference of knowledge in the field of medical diagnostics and therapy.

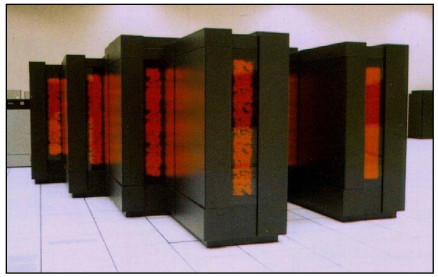


Meta-Dendral

- The Meta-Dendral learning program demonstrated in 1975 the first scientific discoveries made by a computer, in the field of chemistry (some mass spectrometry rules).

Connection Machine

- Danny Hillis designed the Connection Machine in 1981, which has a large parallel architecture that brings new power to AI and to general computation.
- This machine had 512 MB of memory and a 25GB hard drive.

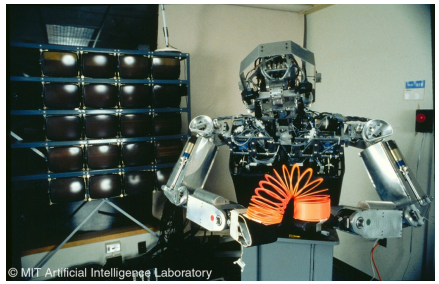


ALVINN

- Developed by Dean Pomerleau from CMU, ALVINN travelled the US in 1989, autonomously 4587 km.

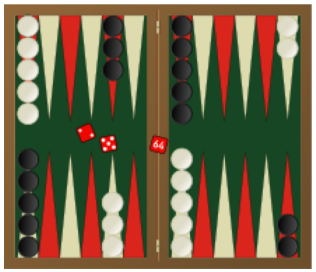
COG Project

- Rodney Brooks's COG project in the 1990s paved the way for significant improvements in the development of humanoid robots.



TD-Gammon

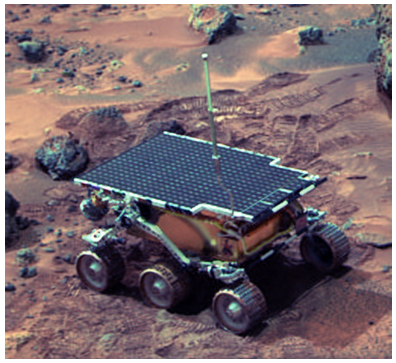
- Developed in 1992 by Gerry Tesauro using reinforcement learning on an artificial neural network, TD-Gammon plays at the championship level.



Chess: Kasparov vs. Deep Blue - 1997

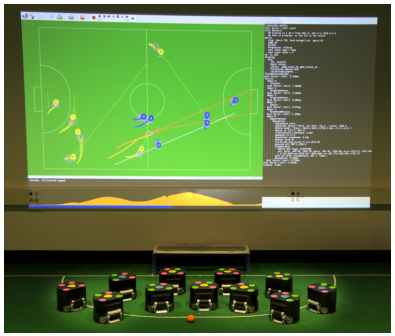
Sojourner

- Sojouner, which landed on Mars in 1997, conducted successful research as an autonomous robot.



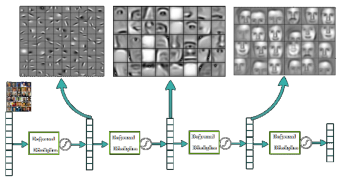
RoboCup Begins

- The first official RoboCup match was held in 1997, Nagoya.



Deep Learning

- Methods for learning in artificial neural networks with a very large number of layers have been developed since 2000.
- Particularly, deep learning had great success in such subjects as face and handwriting recognition.

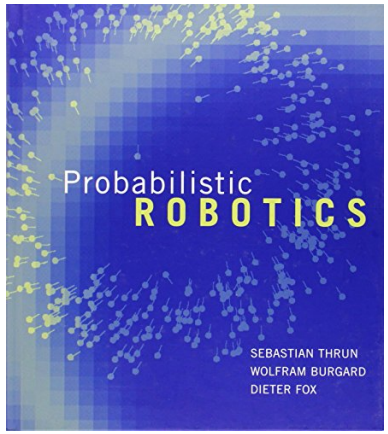


DARPA Competitions

- The autonomous vehicle competition to compete on a 240 km track on the Mojave desert was held in 2004. In a very short time, all vehicles were out of order.
- In 2005, 5 vehicles successfully completed the race.

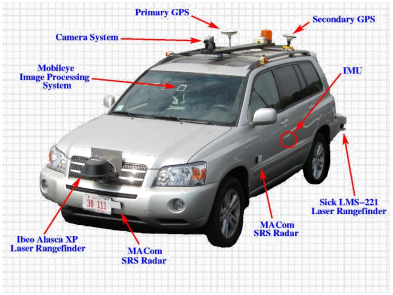
Probabilistic Robotics

- In 2005, the book "Probabilistic Robotics" by Sebastian Thrun, Wolfram Burgard and Dieter Fox revolutionized robotics.
- Sebastian Thrun's team won first place in the 2005 DARPA competition.



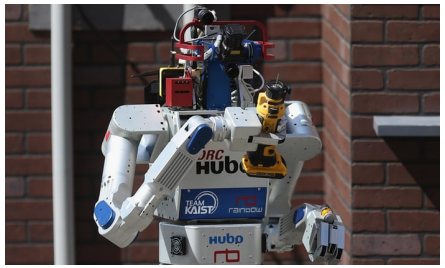
DARPA Urban Challenge

- The Challenge took place on a track in the form of a 96 km urban environment within an air base in 2007.
- Six teams have successfully completed.



DARPA Robot Challenges

- The Challenge was held in 2013-2015 to encourage the development of robots with complex skills that could be used for search and rescue.



Pepper

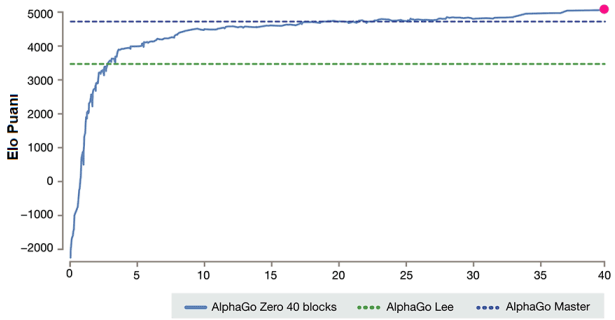
- Multipurpose emotional robot Pepper started to be used in 2015.

Go: Sedol vs. AlphaGo-2016

Poker: Libratus vs. Humans-2017

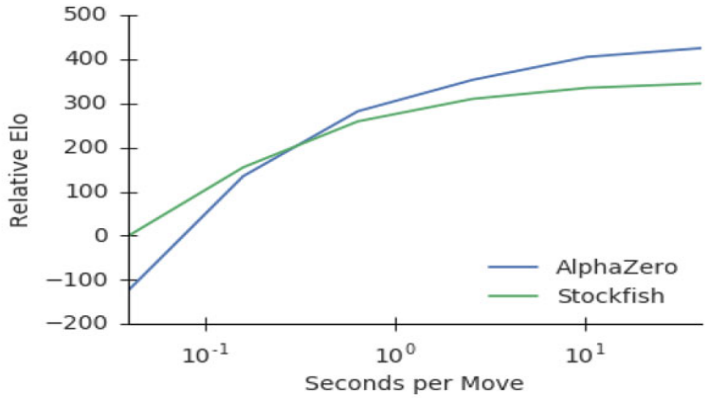
Go: AlphaGo vs. Alpha Go Zero-2017

- Alpha Go Zero learned to play Go using reinforcement learning at the highest level in 40 days.
- Alpha Go Zero beat Alpha Go 100-0

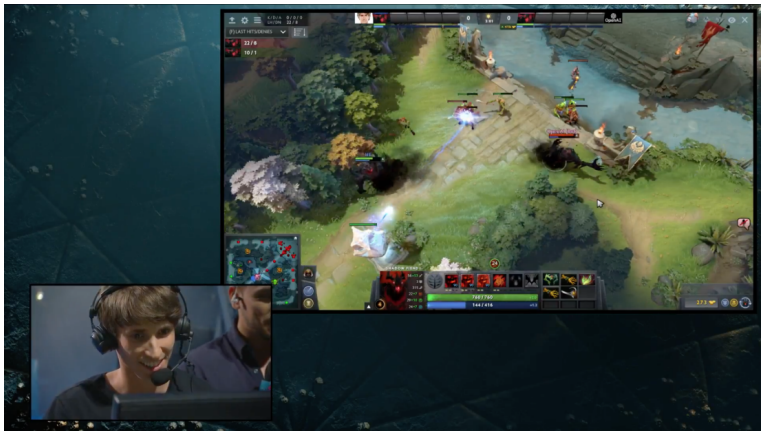


Alpha Zero-2017

- Alpha Zero has learned to play chess in a very short time and beat the current best chess program.



AI vs Dota 2 Single Player



OpenAI

Artificial General Intelligence

- When?