EBERHARD KARLS
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MATHEMATISCH-
NATURWISSENSCHAFTLICHE FAKULTÄT

Artificial Intelligence

Andreas Zell

After the Textbook: Artificial Intelligence,
A Modern Approach
by Stuart Russel and Peter Norvig (3rd Edition)

0. Organizational Issues

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- Textbook: Artificial Intelligence, A Modern Approach, by Stuart Russel and Peter Norvig (3rd Edition, 2009)
- http://aima.cs.berkeley.edu/
- The lecture will follow this book very closely
- All graphics and drawings not attributed otherwise are taken from this book
- My office hours are
  - Wed. 13:30 -15:00 in A310, Sand 1
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0. Organizational Issues

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1.1 What is Artificial Intelligence?

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We can group definitions of Artificial intelligence in the following 4 groups:

1. Systems that think like humans
2. Systems the think rationally
3. Systems that act like humans
4. Systems that act rationally

Historically, all four approaches to AI have been followed

Definitions of Artificial Intelligence

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Systems that think like humans

- "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, … such as decision making, problem solving, learning …" (Bellman, 1978)

Systems that think rationally

- "The study of mental faculties through the use of computational models." (Charniak & McDermott, 1985)
- "The study of computations that make it possible to perceive, reason, and act." (Winston, 1992)

Definitions of Artificial Intelligence

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Systems that act like humans

- "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)

Systems that act rationally

- "Computational intelligence is the study of the design of intelligent agents." (Poole et al., 1998)
- "AI … is concerned with intelligent behaviour in artifacts." (Nilsson, 1998)

Acting like Humans: The Turing Test

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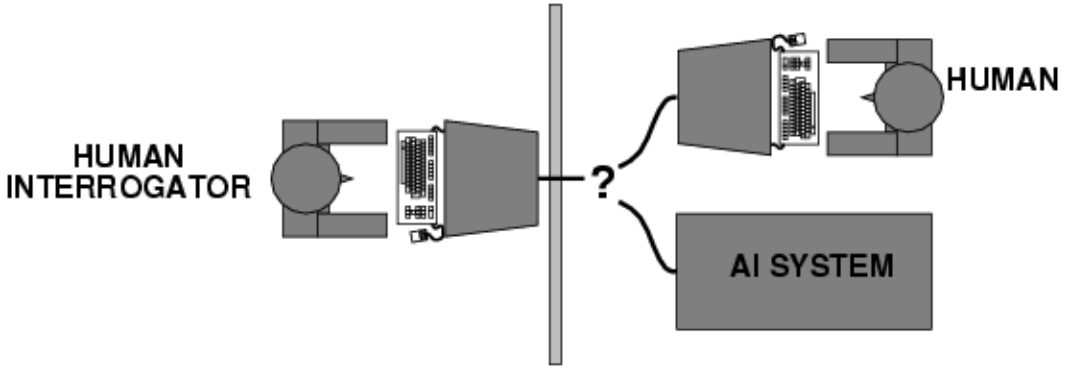
- Turing test, proposed by Alan Turing (1950)
- Human interrogator is connected to either another human or a machine in another room.
- Interrogator may ask text questions via a computer terminal, gets answers from the other room.



- If the human interrogator cannot distinguish the human from the machine, the machine is said to be intelligent.

Capabilities of an AI system

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- Natural language processing, to enable it to communicate efficiently,
- Knowledge representation, to store what it knows or hears,
- Automated reasoning, to use the stored information to answer questions and draw new conclusions
- Machine learning, to adapt to new circumstances and detect and extrapolate patterns
- Computer vision, to perceive objects,
- Robotics, to manipulate objects and move around.

Thinking humanly: Cognitive Science

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- Problem: need to determine how humans think
  - By introspection (but is this really how we think?)
  - By psychological experiments

- Cognitive Science brings together
  - Computer models from AI, and
  - Experimental techniques from psychology

  to try to construct precise and testable theories of the workings of the human mind.

- Some AI researchers (e.g. Newell & Simon with their General Problem Solver) tried to compare the trace of program reasoning with human reasoning steps.

Thinking rationally: The laws of thought

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- Based on the syllogisms of the greek philosopher Aristotle
- Logical formalism: Predicate logic
- Programs as logic derivation, Theorem proving
- Logic programming: Prolog as computer language (program is logic specification)
- Japanese "5th generation computer project", ca. 1982-1988, ca. 450 Million $ Govt. funding
- PIM, parallel inference machines, parallel Prolog
- http://en.wikipedia.org/wiki/Fifth_generation_computer

Acting rationally: The rational agent

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- An agent is just something that acts.
- A rational agent is one that acts so as to achieve the best outcome or, under uncertainty, the best expected outcome.
- Here the emphasis is not on correct inference (as in logic programming), but on reasonable actions, given that information may be uncertain, incomplete or inconsistent and actions must frequently be taken in a limited amount of time.
- The Russel/Norvig book advocates this approach to artificial intelligence.

1.2 Foundations of Artificial Intelligence

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- Philosophy
- Mathematics
- Economics
- Neuroscience
- Psychology
- Computer Science and Computer Engineering
- Control Thery and Cybernetics
- Linguistics

(read the subsection in Russel/Norvig)

1.2 Foundations of Artificial Intelligence

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• Philosophy	Logic, methods of reasoning, mind as physical system foundations of learning, rationality
• Mathematics	Formal representation and proof, algorithms, computation, (un)decidability, (in)tractability, probability
• Economics	utility, decision theory
• Neuroscience	physical substrate for mental activity
• Psychology	phenomena of perception and motor control, experimental techniques
• Computer engineering	building fast computers
• Control theory	design systems that maximize an objective function over time
• Linguistics	knowledge representation, grammar

History of Artificial Intelligence 1

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Gestation of Artificial Intelligence (1943 – 1955)

- 1943 McCulloch & Pitts: Boolean circuit model of neurons,
- 1949 Donald Hebb: Hebbian learning rule
- 1950 Turing's “Computing Machinery & Intelligence”
- 1950 Marvin Minsky SNARC (first neural computer)

Birth of artificial Intelligence (1956)

- 1956 Dartmouth meeting (John McCarthy, Marvin Minsky, Claude Shannon, N. Rochester, Alan Newell, Herbert Simon, Arthur Samuel, Oliver Selfridge …): name “Artificial Intelligence”

History of Artificial Intelligence 2

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Early enthusiasm, great expectations (1952 – 1969)

- 1956 Newell & Simon: Logic Theorist (LT)
- … Newell & Simon: General Problem Solver (GPS)
- 1952 - 56 A. Samuel: checkers program (played better than its creator)
- 1958 John McCarthy: LISP, MIT AI Lab
- 1959 David Gelernter: Geometry Theorem Prover
- 1965 J. A. Robinson: Resolution, a complete algorithm for logical reasoning
- 1970 Patrick Winston: blocks world learning theory
- 1972 Terry Winograd: SHRDLU
- 1975 David Waltz, Vision & constraint propagation

History of Artificial Intelligence 3

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A dose of reality (1966 – 1973)

- 1966 - 73 AI systems do not scale up well
- Neural network research almost disappears
- Automatic translation fails

Knowledge-based systems (1969 – 1979)

- 1969 B. Buchanan: Dendral (expert system to infer the molecular structure from MS data)
- … Ed Feigenbaum et al. Heuristic Programming Project (Stanford U.)
- 1975 Shortliffe, Feigenbaum, Buchanan: MYCIN (expert system to diagnose blood infections)
- 1976 Newell & Simon: Physical Symbol Systems Hypothesis

History of Artificial Intelligence 4

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AI becomes an industry (1980 - 1988)

- 1982 Digital Equipment, R1, expert system to configure VAX computers
- Teknowledge (expert system company)
- Intellicorp (expert system company)
- … many industrial expert systems projects

The return of neural networks (1986 – 2000)

- 1982 John Hopfield, Hopfield networks
- 1985 Rumelhart, Hinton, Williams: Backpropagation,
- 1986 Rumelhart, McClelland: PDP books

History of Artificial Intelligence 5

AI becomes a science (1987 – 2000)

- Scientific method: hypothesis – rigorous empirical experiment – results
- Neats vs. scruffies
- Probabilistic framework
  - HMMs (Hidden Markov models)
  - Bayesian networks

The emergence of intelligent agents (1995 – 2005)

- SOAR, complete agent architecture (Newell, Laird, Rosenbloom)

1.4 The State of the Art

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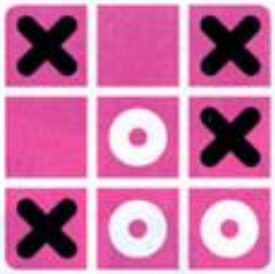
- Autonomous planning and scheduling
  - NASA's Remote agent program (scheduling of operations on a spacecraft), 2000
- Game playing
  - TD-Gammon (Tesauro, IBM) plays Backgammon at world champion level (1992)
  - Chinook becomes world champion in checkers (1994)
  - 9 Men's Morris (Mühle) solved (Gasser, 1996) http://library.msri.org/books/Book29/files/gasser.pdf
  - 8x8 Checkers is solved by Chinook (2007)
  - Deep Blue (IBM) defeats human world champion Garry Kasparov in Chess (1997)
  - AlphaGo (Google DeepMind) beats long-time top-ranked human Go player Lee Sedol in 5 matches in Go (2016)

The GAMES Computers Play

In two-player games without chance or hidden information, AIs have achieved remarkable success. However, 19-by-19 Go, with its staggering array of possible game positions, remains a challenge.

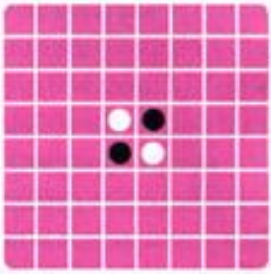
Game positions:
Computer strength:



TIC-TAC-TOE
10^4
PERFECT

OWARE
10^{11}
PERFECT

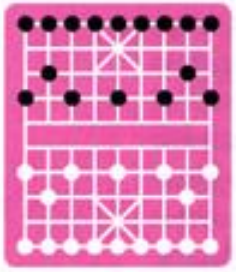
CHECKERS
10^{20}
PERFECT



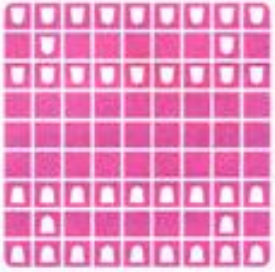
OTHELLO
10^{28}
SUPERHUMAN

9-BY-9 GO
10^{38}
BEST
PROFESSIONAL

CHESS
10^{45}
SUPERHUMAN



XIANGQI
(CHINESE CHESS)
10^{48}
BEST
PROFESSIONAL



SHOGI
(JAPANESE CHESS)
10^{70}
STRONG
PROFESSIONAL

19-BY-19 GO
10^{172}

AlphaGo

1.4 State of the Art

- Autonomous Cars
  - Autonomous cars by Uni der BW
  - Autonomous cars by DaimlerBenz
  - ALVINN neural network in NavLab (CMU) drives 2850 miles across USA 98% autonomously
  - Stanley (S. Thrun, Stanford & VW) wins DARPA Grand Challenge (2005) over 212 km through Mojave Dessert
  - BOSS (R. Whitacker, CMU & General Motors) wins DARPA Urban Challenge (2007)

1.4 State of the Art

- As of June 2016, Google had test driven their fleet of vehicles, in autonomous mode, a total of 1,725,911 mi (2,777,585 km)

- Daimler-Benz S500 Intelligent Drive drives the historical route of Bertha Benz from Mannheim to Pforzheim fully autonomously, with standard sensors, no 3D Lidar (2013)

1.4 State of the Art

- In 2014, Google created a driverless car that had neither a steering wheel nor pedals. In 2015 they built a fleet of ~100 such cars.
- First fatal accident of autonomous car, Tesla Model S in autonomous mode crashes into a crossing white truck (2016)

1.4 State of the Art

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- Diagnosis, Help systems, Scheduling
  - Medical diagnosis programs perform at expert level
  - Microsoft uses AI technology for help system in Windows 7 and Office programs
- Robotics
  - Many mobile robots with AI technology in research
  - Limited use of AI concepts in commercial robots
- Language understanding
  - IBM's WATSON wins Jeopardy competition against strongest humans (2011)
    http://www.youtube.com/watch?v=qO1i7-Qx00k

1.4 State of the Art

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- **Siri** (2011) is a computer program that works as an intelligent personal assistant, part of Apple's iOS, watchOS and macOS. It uses a natural language user interface to answer questions, make recommendations, and perform actions by delegating requests to a set of Web services.
- **Cortana** (2014) is an intelligent personal assistant created by Microsoft in for Windows 10, Windows 10 Mobile, Xbox One, iOS and Android.
- **Google Assistant** (2016) is a similar assistant, based on Google Now (2012). Google Now, including Now cards, voice search and commands, is available in the Google app for Android and iOS.