Introduction to AI
Chapter 1

Artificial Intelligence

2019
Reference Book
Artificial Intelligence: A Modern Approach
Stuart Russell and Peter Norvig

http://aima.cs.berkeley.edu/
Some Other References

- AFIA: https://afia.asso.fr
- Revue d'IA: http://ria.revuesonline.com/
- AAAI: http://www.aaai.org/
- AI Magazine: http://www.aaai.org/Magazine
- ACM SIGAI: http://sigai.acm.org/
- John McCarthy: http://www-formal.stanford.edu/jmc/
- Marvin Minsky: http://web.media.mit.edu/~minsky/
- JAIR: http://www.jair.org/
- IJCAI: http://www.ijcai.org/
- AI Journal: http://www.ida.liu.se/ext/aijd/
- ECCAI, ECAI: http://www.eccai.org/
- AI/Alife Howto: http://zhar.net/howto/
- ETAI: http://www.etaij.org/
- ...
What is AI?

<table>
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<th>Systems that think like humans</th>
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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
- But Turing test is not reproducible, constructive, or amenable to mathematical analysis
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
- Hence, all three fields share one principal direction!
Thinking rationally: Laws of Thought

- Normative (or prescriptive) rather than descriptive
- Aristotle: what are correct arguments/thought processes?
- Several Greek schools developed various forms of logic:
  - notation and rules of derivation for thoughts; may or may not have proceeded to the idea of mechanization
- Direct line through mathematics and philosophy to modern AI
- Problems:
  1) Not all intelligent behavior is mediated by logical deliberation
  2) What is the purpose of thinking? What thoughts should I have out of all the thoughts (logical or otherwise) that I could have?
Acting rationally

▷ **Rational** behavior: doing the right thing

▷ The right thing: that which is expected to maximize goal achievement, given the available information

▷ Doesn’t necessarily involve thinking—e.g., blinking reflex—but thinking should be in the service of rational action

▷ Aristotle (Nicomachean Ethics):

  *Every art and every inquiry, and similarly every action and pursuit, is thought to aim at some good*
Rational agents

- An agent is an entity that perceives and acts
- This course is about designing rational agents
- Abstractly, an agent is a function from percepts histories to actions:
  \[ f : \mathcal{P}^* \rightarrow \mathcal{A} \]
  For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- Caveat: computational limitations make perfect rationality unachievable
  → design best program for given machine resources
AI prehistory

- Philosophy (from -350, Aristotle)
  - logics, reasoning methods
  - mind as a physical system or not (dualism, materialism, ...)
  - foundations of learning, language, rationality
- Mathematics (from 825, Al-Khwārizmī)
  - formal logics, proof theory
  - algorithms, computation, (un)decidability, (in)tractability
  - probability
- Economics (from 1776, Adam Smith)
  - Utility, rational decision theory, Operation research, ...
AI prehistory (cont.)

- **Neuroscience (from 1861, Broca)**
  - plastic physical substrate for mental activity
- **Psychology (from 1879, Wundt)**
  - adaptation
  - phenomena of perception and motor control
  - experimental techniques (psychophysics, etc.)
- **Computer Science (from 1940, Stibitz)**
  - computer efficiency
- **Control theory (from 1948, Wiener)**
  - homeostatic systems, stability
  - simple optimal agent designs
- **Linguistics (from 1957, Chomsky)**
  - knowledge representation
  - grammar
Potted history of AI

1943 McCulloch & Pitts: Boolean circuit model of brain
1950 Turing’s “Computing Machinery and Intelligence”
1952–69 Look, Ma, no hands!
1950s Early AI programs, including Samuel’s checkers program,
      Newell & Simon’s Logic Theorist, Gelernter’s Geometry Engine
1956 Dartmouth meeting: “Artificial Intelligence” adopted
1965 Robinson’s complete algorithm for logical reasoning
1966–74 AI discovers computational complexity
      Neural network research almost disappears
1969–79 Early development of knowledge-based systems
1980–88 Expert systems industry booms
1985–95 Neural networks return to popularity
1988– Resurgence of probability; general increase in technical depth
      “Nouvelle AI”: ALife, GAs, soft computing
1995– Agents, agents, everywhere . . .
2003– Human-level AI back on the agenda
2010– Big data trend
2015– Deep Neural Networks, Alpha Go!
History of AI
From 1943 to 1955: infancy

- 1943: artificial neural networks, McCulloch & Pitts
- 1950: learning in ANN, Hebb
- 1950: article « Computing Machinery and Intelligence », Turing (Turing test, reinforcement learning, genetic algorithms, …)
- 1950’s: some software
  - Logic Theorist (Newell & Simon): theorem proof using IPL (Lisp precursor)
  - Checkers (Samuel)
History of AI (cont.)

- 1956, official birthday: Dartmouth workshop (6 weeks, 10 people)
  - McCarthy coined the term « Artificial Intelligence », 1955
- West Joint Computer Conference in Los Angeles :
  - Session on Learning Machines
  - Pattern recognition, image processing, chess player, neural networks, …
- 1958 : Symposium « Mechanization of Thought Processes » in Teddington (UK)
- Funding INRIA: 1967 (Calcul framework)
History of AI (cont.)

1950’s – 1960’s: exploration

- Pattern recognition
  - Recognition of typographic writing
  - Artificial neural networks (perceptron)
  - Aerial reconnaissance (military applications)
  - Handwriting recognition for Fortran programs
  - Statistical methods (nearest neighbors ...)

- Heuristic search
  - Tree search: list structure, transformation rules and success test
  - Geometry, games, ...
    - General Problem Solver

- Semantic representation
  - Need for more complex structures
  - Geometric analogy: statement storage and answers to NL questions
  - Entities and relations, exception mechanism
  - Semantic networks (Sowa, Quillian, ...): the meaning of a term is given by its position and ties with its neighbors, concept of similarity by counting the number of arc between two words, ...

- Natural language processing
  - Understanding a text (stored in a model act accordingly), translation
  - Chomsky: rules, tree-based syntax
History of AI (cont.)

1950’s – 1960’s: exploration

- Domain-specific programming language (Lisp in 1958, McCarthy)
- Public and private AI laboratories are created (late 50’s in USA, mid-60’s in Europe)
- **Strong optimism**: computers will equal the human intelligence
- But intelligence is a multi-faceted concept: on some points it’s OK, but on other this is a **disillusion**
History of AI (cont.)

Mid 60’s to mid 70’s: effervescence

- Computer vision (2D image interpretation, robots that see and manipulate, face recognition)
- Knowledge representation and reasoning, first-order logics as a choice, Robinson’s resolution rule (1965), situation calculus, Planner (1971), Prolog (1972), semantic networks, scripts and frames, Conceptual graph
- Mobile robotics (A*, STRIPS, learning)
- NLP, games ($\alpha - \beta$, challenges, …)
History of AI (cont.)

Mid 60’s to mid 70’s: effervescence

- **DENDRAL Heuristic**: using expert knowledge to deduce acyclic molecular structures
- **May 1969 in Washington DC**: first IJCAI
  - 600 attendants
  - 63 talks from 9 countries
  - Biannual conference since 1969
  - All proceedings are available online for free
- **Creation of the Special Interest Group for ARTificial intelligence** of ACM (SIGART) in 1966
- **Journal and books are edited**
History of AI (cont.)
70’s to 80’s: boom of applications

- Speech recognition and understanding (HEARSAY, blackboard)
- MYCIN: expert system on bacterial infections (IF-THEN rules and certainty coefficients, separation of expert knowledge and inference engines), then generalized in EMYCIN
- Other expert systems : PROSPECTOR, XCON and R1 (alg. Rete), ...
- Companies emerges in these niches
- Progresses in NLP, vision, ...

> Speech recognition and understanding (HEARSAY, blackboard)
> MYCIN: expert system on bacterial infections (IF-THEN rules and certainty coefficients, separation of expert knowledge and inference engines), then generalized in EMYCIN
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History of AI (cont.)

mid-80’s

- NN are back
- Statistical approaches rise
- AI is a science (formalization, specialization, complexity, ...)
- From mid 80’s to mid 90’s: **AI winter**
  - Over-optimistic promises?
  - Funding agencies (public and private) have expected too much
- Since mid 90’s: unifying approach « intelligent agent »
AI today
AI is everywhere

- Autonomous planning (NASA), logistics (Army)
- Games (AlphaGo)
- Automatic control (self-driving cars)
- Diagnostic (expert level, in Medicine)
- Robotics
- Many application fields:
  - smart home, driving assistance, BRMS, recommendation, image recognition to unlock, personal assistants, smart grids, ...
AI today

Sub-fields

Sessions at IJCAI, proceedings: 5200+ pages 2017

▶ Agent-based and Multiagent Systems
▶ Constraints, Satisfiability, and Search
▶ Knowledge Representation, Reasoning, and Logic
▶ Machine Learning
▶ Natural-Language Processing
▶ Planning and Scheduling
▶ Robotics and Vision
▶ Uncertainty in AI
▶ Web and Knowledge-based Information Systems
▶ Multidisciplinary Topics And Applications
▶ AI and Computational Sustainability
State of the art

Which of the following can be done at present?

▶ Play a decent game of table tennis
State of the art

Which of the following can be done at present?

- Play a decent game of table tennis
- Drive safely along a curving mountain road
State of the art

Which of the following can be done at present?

▶ Play a decent game of table tennis
▶ Drive safely along a curving mountain road
▶ Drive safely along Telegraph Avenue
State of the art

Which of the following can be done at present?

- Play a decent game of table tennis
- Drive safely along a curving mountain road
- Drive safely along Telegraph Avenue
- Buy a week’s worth of groceries on the web
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Which of the following can be done at present?

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