Introduction to AI

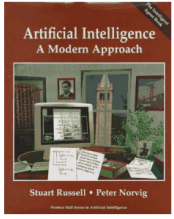
Chapter 1

Artificial Intelligence

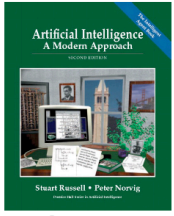
2019

Reference Book

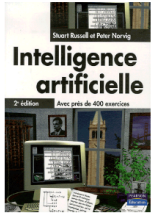
Artificial Intelligence: A Modern Approach
Stuart Russell and Peter Norvig



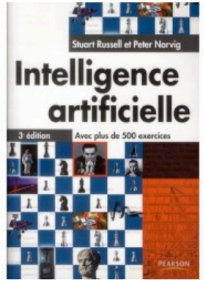
1st edition
1995

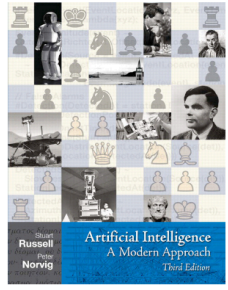


2nd edition
2003



2006





3rd edition
2010

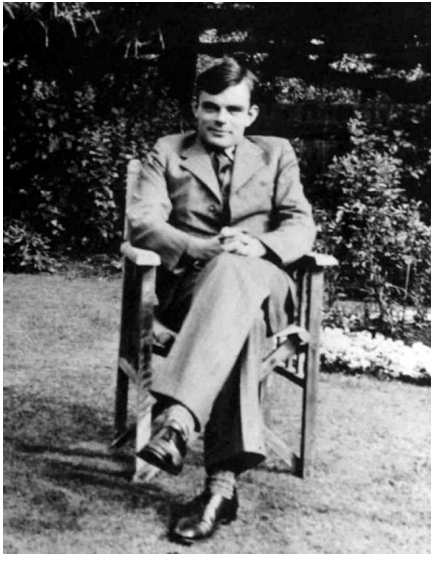
http://aima.cs.berkeley.edu/

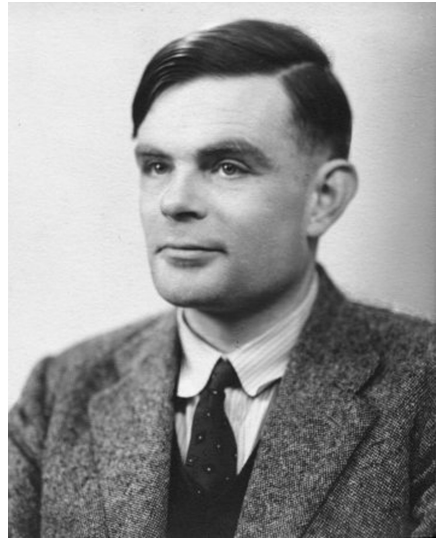
Some Other References

- 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/
- Nils J. Nilsson : http://ai.stanford.edu/~nilsson/
- 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?

Systems that think like humans	**Systems that think rationally**
Systems that act like humans	**Systems that act rationally**

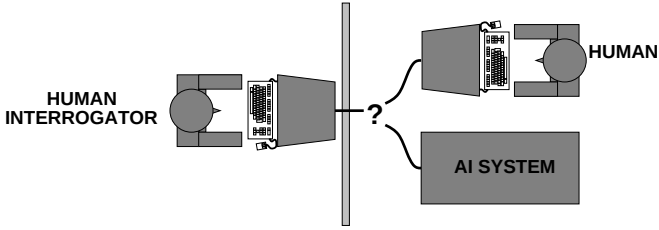




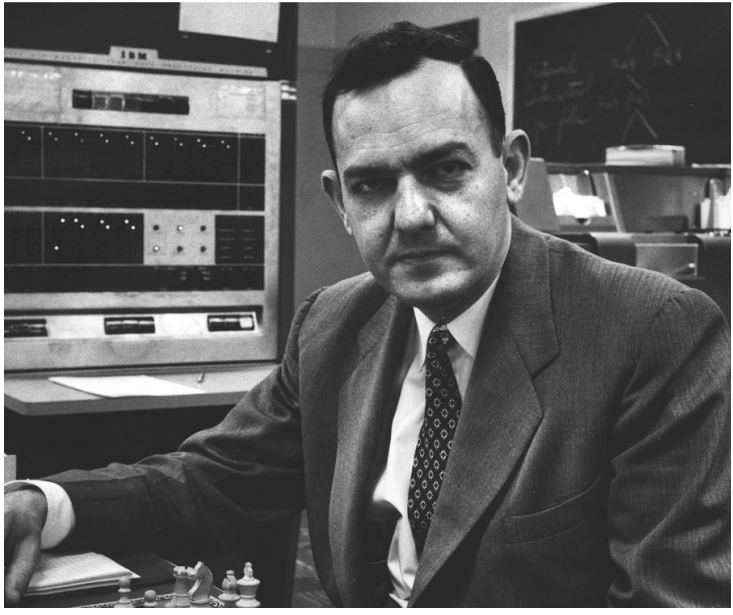
Acting humanly: The Turing test

Turing (1950) "Computing machinery and intelligence"

- "Can machines think?" $\longrightarrow$ "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**


IBM

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

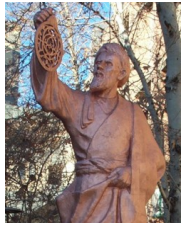
Rational agents

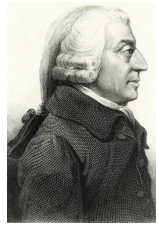
- An agent is an entity that perceives and acts
- This course is about designing rational agents
- Abstractly, an agent is a function from percepts histories to actions:

  $$f : \mathcal{P}^* \to \mathcal{A}$$

  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**
  $\to$ design best program for given machine resources

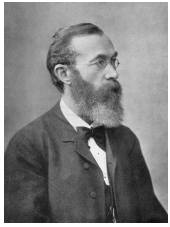
AI prehistory

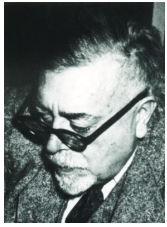
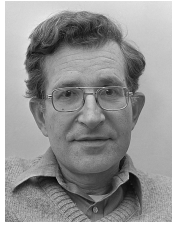




- Philosophy (from -350, Aristotle)
  - logics, reasoning methods
  - mind as a physical system or not (dualism, materialism, ...)
  - foundations of learning, language, rationality
- Mathematics (from 825, Al-Khwārizmī)
  - formal logics, proof theory
  - algorithms, computation, (un)decidability, (in)tractability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

AI prehistory (cont.)

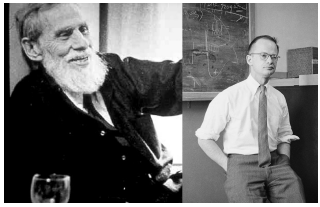
- Neuroscience (from 1861 Broca)
  - plastic physical substrate for mental activity
- Psychology (from 1879, Wundt)
  - adaptation
  - phenomena of perception and motor control
  - experimental techniques (psychophysics, etc.)
- Computer Science (from 1940, Stibitz)
  - computer efficiency
- Control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

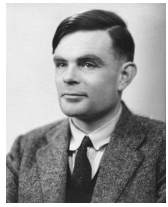
Potted history of AI

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
1988–93	Expert systems industry busts: "AI Winter"
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

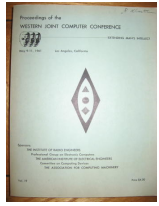
From 1943 to 1955: infancy

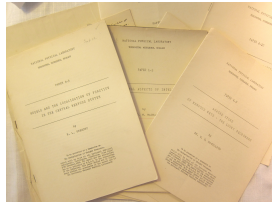




- 1943: artificial neural networks, McCulloch & Pitts
- 1950: learning in ANN, Hebb
- 1950: article « Computing Machinery and Intelligence », Turing (Turing test, reinforcement learning, genetic algorithms, . . .)
- 1950's: some software
  - Logic Theorist (Newell & Simon): theorem proof using IPL (Lisp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

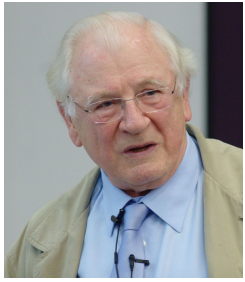
1950's – 1960's: exploration

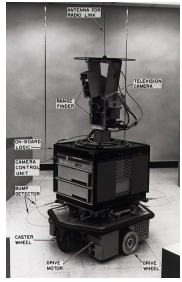
```
(defun m-length (list)
  (if (null list)
    0
    (+ 1 (m-length (cdr list)))))

(defun print-list (list)
  (if (not (null list))
    (progn
      (princ (car list))
      (print-list (cdr list)))))

((((1 5 x) o 1) a) 7 2 3)

(defun sum-numbers (list)
  (if
```

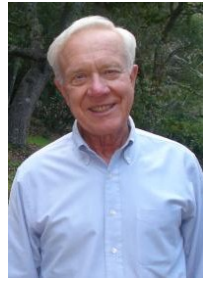
- Domain-specific programming language (Lisp in 1958, McCarthy)
- Public and private AI laboratories are created (late 50's in USA, mid-60's in Europe)
- **Strong optimism**: computers will equal the human intelligence
- But intelligence is a multi-faceted concept: on some points it's OK, but on other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

History of AI (cont.)

Mid 60's to mid 70's: effervescence



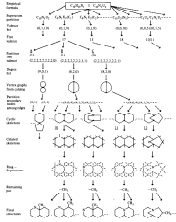


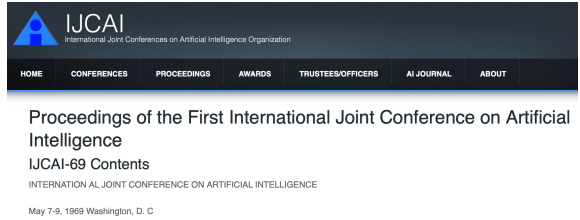


- Computer vision (2D image interpretation, robots that see and manipulate, face recognition)
- Knowledge representation and reasoning, first-order logics as a choice, Robinson's resolution rule (1965), situation calculus, Planner (1971), Prolog (1972), semantic networks, scripts and frames, Conceptual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

History of AI (cont.)

Mid 60's to mid 70's: effervescence

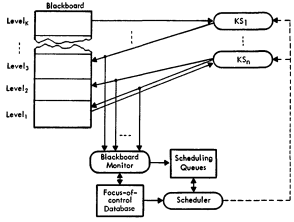


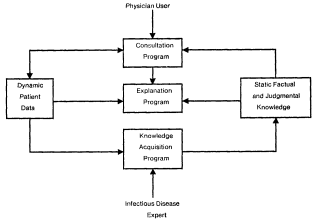


- DENDRAL Heuristic: using expert knowledge to deduce acyclic molecular structures
- May 1969 in Washington DC : first IJCAI
  - 600 attendants
  - 63 talks from 9 countries
  - Biannual conference since 1969
  - All proceedings are available online for free
- Creation of the **Special Interest Group 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

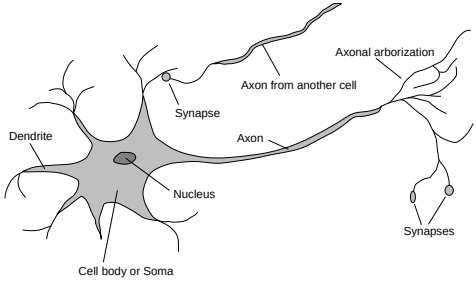


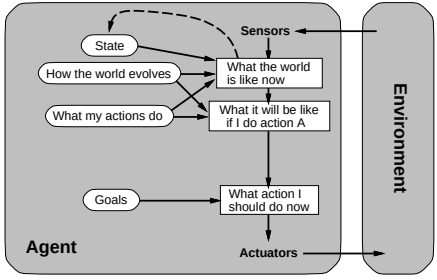


- Speech recognition and understanding (HEARSAY, blackboard)
- MYCIN: expert system on bacterial infections (IF-THEN rules and certainty coefficients, separation of expert knowledge and inference engines), then generalized in EMYCIN
- Other expert systems : PROSPECTOR, XCON and R1 (alg. Rete), ...
-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

History of AI (cont.)

mid-80's

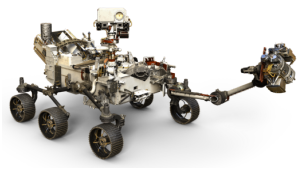


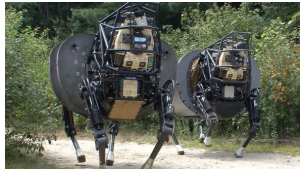


- NN are back
- Statistical approaches rise
- AI is a science (formalization, specialization, complexity, ...)
- From mid 80's to mid 90's : **AI winter**
  - Over-optimistic promises?
  - Funding agencies (public and private) have expected too much
- Since mid 90's: unifying approach « intelligent agent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

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

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
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- Buy a week's worth of groceries on the web
- Buy a week's worth of groceries at Berkeley Bowl

State of the art

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- 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
- Play a decent game of bridge

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
- 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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- 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
- Discover and prove a new mathematical theorem
- Design and execute a research program in molecular biology

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- Drive safely along Telegraph Avenue
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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
- 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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- 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 Swedish in real time

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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

State of the art

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- 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

State of the art

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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