CSC 480: Artificial Intelligence

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Course Overview

- **Introduction**
- **Intelligent Agents**
- **Search**
  - problem solving through search
  - uninformed search
  - informed search
  - local search and constraint satisfaction
- **Games**
  - games as search problems
- **Knowledge and Reasoning**
  - reasoning agents
  - propositional logic
  - predicate logic
  - planning
  - knowledge-based systems
  - uncertain knowledge and reasoning
- **Learning**
  - learning from observation
  - reinforcement learning
  - neural networks
- **Natural Language Processing**
- **Robotics**
- **Philosophical, Ethical, Social Issues with AI**
- **Conclusions**

Chapter Overview Introduction

- **Logistics**
- **Motivation**
- **Objectives**
- **What is Artificial Intelligence?**
  - definitions
  - Turing test
  - cognitive modeling
  - rational thinking
  - acting rationally
- **Foundations of Artificial Intelligence**
  - philosophy
  - mathematics
  - psychology
  - computer science
  - linguistics
- **History of Artificial Intelligence**
- **Important Concepts and Terms**
- **Chapter Summary**

Instructor

- **Dr. Franz J. Kurfess**
- **Professor, CSC Dept.**
- **Areas of Interest**
  - Artificial Intelligence
  - Knowledge Management, Intelligent Agents
  - Neural Networks & Structured Knowledge
  - Human-Computer Interaction
  - User-Centered Design
- **Contact**
  - preferably via email: fkurfess@calpoly.edu
  - office hours: TBA, probably Wed afternoon
  - Web page http://www.csc.calpoly.edu/~fkurfess
  - office R 4.033

Logistics

- **Enrollment Issues**
- **Course Materials**
  - textbook
  - handouts
  - Web page
- **AI Nuggets**
  - first presentations
  - provide access on Google Docs or similar
- **Term Project**
  - topics and teams during lab time
- **Lab and Homework Assignments**
  - Lab 1 due on Tue, end of the day

Course Material

- **on the Web (http://www.csc.calpoly.edu/~fkurfess)**
  - syllabus
  - schedule
  - student presentation schedule
  - project information
  - homework and lab assignment descriptions
  - most lab assignment submissions
- **Administration**
  - PolyLearn/Moodle
  - grades
  - assignment and some lab submissions
- **Discussion boards**
  - Piazza
- **Project Repositories**
  - source code
    - github
  - project documentation
    - Google Docs
    - Dropbox

Term Project

- **development of a practical application in a team**
  - prototype, emphasis on conceptual and design issues, not so much performance
- **implementation must be accessible to others**
  - e.g. Web/Java
- **milestones/deliverables**
- **mid-quarter and final presentation/display**
- **peer evaluation**
  - each team evaluates the system of another team
- **information exchange on the Web**
  - course Web site
  - project repository

Homework and Lab Assignments

- **individual assignments**
- **some lab exercises in small teams**
  - documentation, hand-ins usually per person
- **may consist of questions, exercises, outlines, programs, experiments**

Exams

- **weekly quizzes**
  - typically 10 questions
  - most of them multiple choice
- **score improvement opportunities**
  - makeup questions ??
  - best 10 out of 15 or 16 quizzes ??
- **final exam**
  - 60% of the grade according to the course description
  - alternatives
    - written exam
    - oral exam
    - count work towards the exam with the option of improving the grade
      - e.g. through an oral examination

Motivation

- **scientific curiosity**
  - try to understand entities that exhibit intelligence
- **engineering challenges**
  - building systems that exhibit intelligence
- **some tasks that seem to require intelligence can be solved by computers**
- **progress in computer performance and computational methods enables the solution of complex problems by computers**
- **humans may be relieved from tedious tasks**

Objectives

- become familiar with criteria that distinguish human from artificial intelligence
- know about different approaches to analyze intelligent behavior
- understand the influence of other fields on artificial intelligence
- be familiar with the important historical phases the field of artificial intelligence went through

Exercise: Intelligent Systems

- **select a task that you believe requires intelligence**
  - examples: playing chess, solving puzzles, translating from English to German, finding a proof for a theorem
- **for that task, sketch a computer-based system that tries to solve the task**
  - architecture, components, behavior
- **what are the computational methods your system relies on**
  - e.g. data bases, hash tables, matrix multiplication, graph traversal, linked lists,
- **what are the main challenges**
- **how do humans tackle the task**

Trying to define AI

- **so far, there is no generally accepted definition of Artificial Intelligence**
  - textbooks either skirt the issue, or emphasize particular aspects
    - frequently based on the specific interests or viewpoints of the authors
  - not uncommon in relatively young fields
    - is there a commonly accepted definition of "Computer Science"
      - is it a 'hard' or 'soft' science (or neither)

Statistics, Machine Learning, Data Mining and AI

- **Lab 10 Submission: AI and Humor -> Ohh the differences ....**
  - by Austin Dworaczyk Wiltshire - Tuesday, November 27, 2012, 3:10 PM

"What is the difference between statistics, machine learning, AI and data mining?

If there are up to 3 variables, it is statistics.
If the problem is NP-complete, it is machine learning.
If the problem is PSPACE- complete, it is AI.
If you don't know what is PSPACE-complete, it is data mining."

https://www.facebook.com/alangsmello/posts/4832538494908

PSPACE-complete Decision Problem

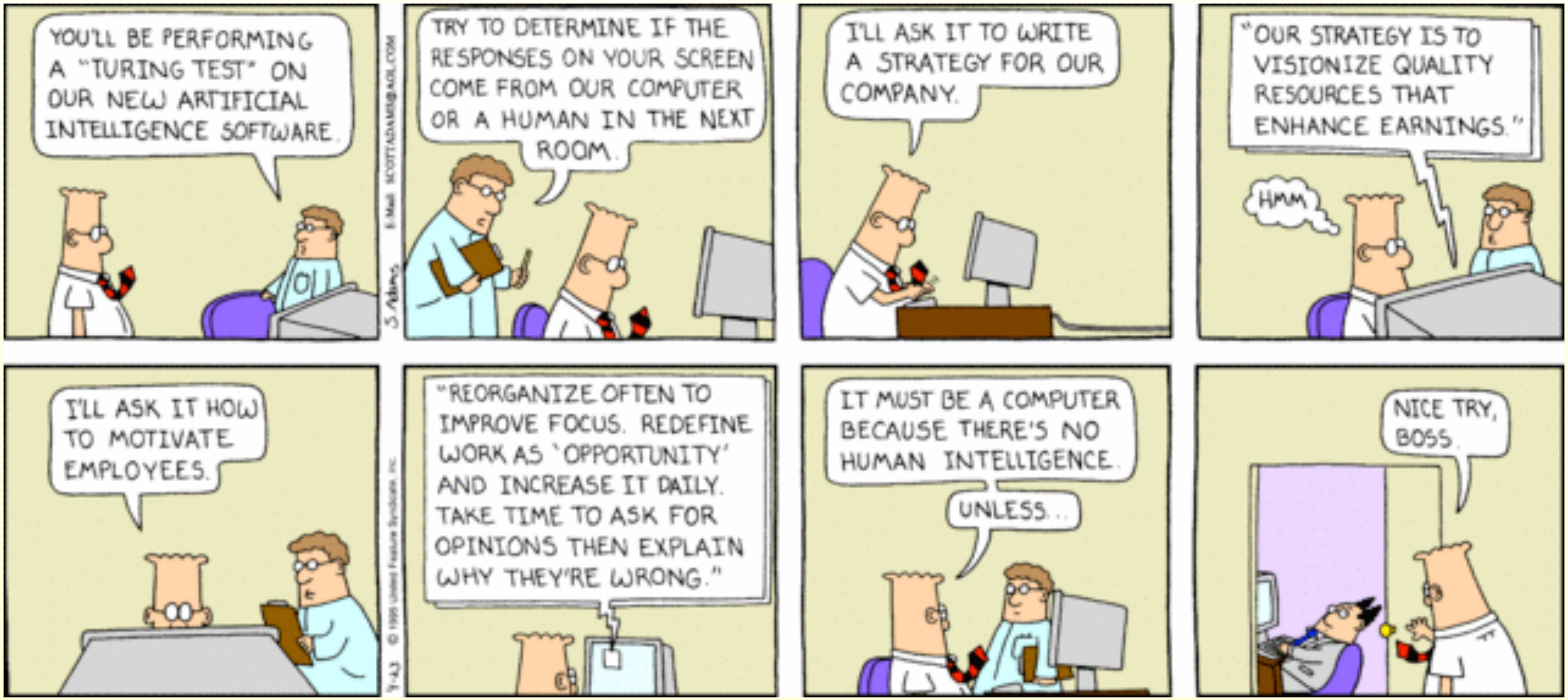
- **computational complexity theory**
- **can be solved using an amount of memory that is polynomial in the input length (polynomial space), and**
- **every other problem that can be solved in polynomial space can be transformed to it in polynomial time.**
- **PSPACE-complete problems can be thought of as the hardest problems in PSPACE**
  - a solution to any one such problem could easily be used to solve any other problem in PSPACE
- **PSPACE-complete problems are widely suspected to be outside of the more famous complexity classes P and NP**
  - that is not known.
  - it is known that they lie outside of the class NC (a class of problems with highly efficient parallel algorithms),
    - problems in NC can be solved in an amount of space polynomial in the logarithm of the input size, and
    - the class of problems solvable in such a small amount of space is strictly contained in PSPACE by the space hierarchy theorem

http://en.wikipedia.org/wiki/PSPACE-complete

Examples PSPACE-complete Decision Problems

- **Regular expressions**
  - Given a regular expression R, determining whether it generates every string over its alphabet is PSPACE-complete.
- **Context-sensitive grammars**
  - The first known PSPACE-complete problem was the word problem for deterministic context-sensitive grammars.
- **Quantified Boolean formulas (QBF)**
  - a generalization of the first known NP-complete problem, the Boolean satisfiability problem (SAT)
    - SAT is the problem of whether there are assignments of truth values to variables that make a Boolean expression true
    - in QBF both universally and existentially quantified variables are allowed
- **Games and Puzzles**
  - many puzzles are NP-complete
  - many games are PSPACE-complete
    - may have to be generalized, eg. by using a n × n board
    - may have to be placed under a polynomial bound for the number of moves

Dilbert's Turing Test



http://dilbert.com/strips/comic/1995-04-23/

Examples of Definitions

- **cognitive approaches**
  - emphasis on the way systems work or “think”
  - requires insight into the internal representations and processes of the system
- **behavioral approaches**
  - only activities observed from the outside are taken into account
- **human-like systems**
  - try to emulate human intelligence
- **rational systems**
  - systems that do the “right thing”
  - idealized concept of intelligence

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, activities such as decision-making, problem solving, learning …" [Bellman, 1978]

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 Think Rationally

- "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]

Systems That Act Rationally

- "A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" [Schalkhoff, 1990]
- "The branch of computer science that is concerned with the automation of intelligent behavior" [Luger and Stubblefield, 1993]

The Turing Test

- **proposed by Alan Turing in 1950 to provide an operational definition of intelligent behavior**
  - the ability to achieve human-level performance in all cognitive tasks, sufficient to fool an interrogator
- **the computer is interrogated by a human via a teletype**
- **it passes the test if the interrogator cannot identify the answerer as computer or human**

Movie poster for The Imitation Game

Basic Capabilities

for passing the Turing test

- **natural language processing**
  - communicate with the interrogator
- **knowledge representation**
  - store information
- **automated reasoning**
  - answer questions, draw conclusions
- **machine learning**
  - adapt behavior
  - detect patterns

Relevance of the Turing Test

- **not much concentrated effort has been spent on building computers that pass the test**
- **Loebner Prize**
  - there is a competition and a prize for a somewhat revised challenge
  - see details at http://www.loebner.net/Prizef/loebner-prize.html
- **"Total Turing Test"**
  - includes video interface and a "hatch" for physical objects
  - requires computer vision and robotics as additional capabilities

Turing Test Extra Credit

- **[Lab 10 Submission: AI and Humor -> XKCD 329: Turing Test]**
  - by Brian Gomberg - Tuesday, November 27, 2012, 7:58 PM

http://imgs.xkcd.com/comics/turing_test.png

Cognitive Modeling

- **tries to construct theories of how the human mind works**
- **uses computer models from AI and experimental techniques from psychology**
- **most AI approaches are not directly based on cognitive models**
  - often difficult to translate into computer programs
  - performance problems

Rational Thinking

- **based on abstract “laws of thought”**
  - usually with mathematical logic as tool
- **problems and knowledge must be translated into formal descriptions**
- **the system uses an abstract reasoning mechanism to derive a solution**
- **serious real-world problems may be substantially different from their abstract counterparts**
  - difference between “in principle” and “in practice”

Rational Agents

- **an agent that does “the right thing”**
  - it achieves its goals according to what it knows
  - perceives information from the environment
  - may utilize knowledge and reasoning to select actions
  - performs actions that may change the environment

Behavioral Agents

- **an agent that exhibits some behavior required to perform a certain task**
  - the internal processes are largely irrelevant
  - may simply map inputs (“percepts”) onto actions
  - simple behaviors may be assembled into more complex ones

Foundations of Artificial Intelligence

- philosophy
- mathematics
- psychology
- computer science
- linguistics

Philosophy

- **related questions have been asked by Greek philosophers like Plato, Socrates, Aristotle**
- **theories of language, reasoning, learning, the mind**
- **dualism (Descartes)**
  - a part of the mind is outside of the material world
- **materialism (Leibniz)**
  - all the world operates according to the laws of physics

Mathematics

- **formalization of tasks and problems**
- **logic**
  - propositional logic
  - predicate logic
- **computation**
  - Church-Turing thesis
  - intractability: NP-complete problems
- **probability**
  - degree of certainty/belief

Psychology

- **behaviorism**
  - only observable and measurable percepts and responses are considered
  - mental constructs are considered as unscientific
    - knowledge, beliefs, goals, reasoning steps
- **cognitive psychology**
  - the brain stores and processes information
  - cognitive processes describe internal activities of the brain

Computer Science

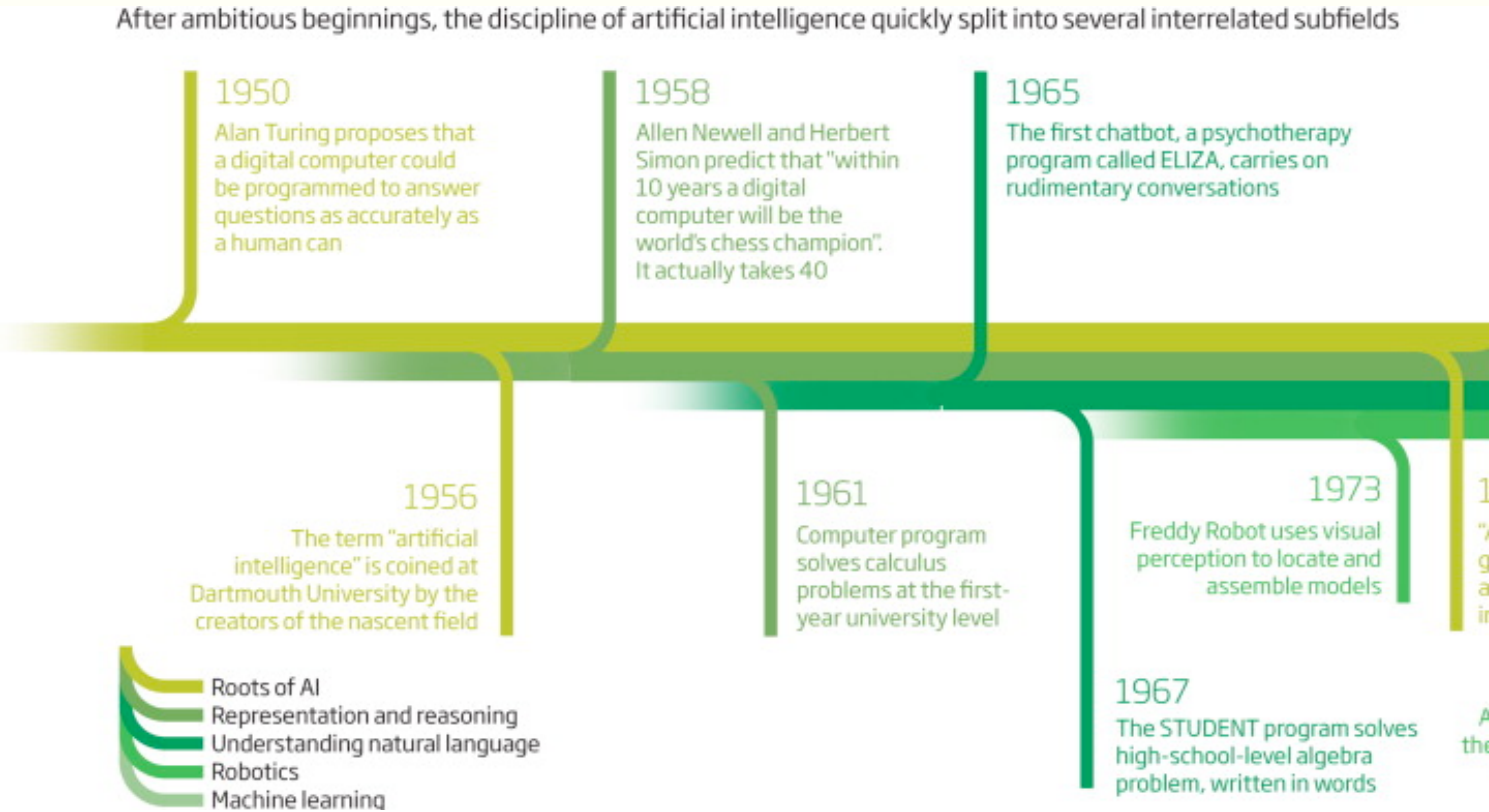
- provides tools for testing theories
- programmability
- speed
- storage
- actions

Linguistics

- **understanding and analysis of language**
  - sentence structure, subject matter, context
- **knowledge representation**
- **computational linguistics, natural language processing**
  - hybrid field combining AI and linguistics

AI through the ages

AI Timeline: 1950 - 1973



Peter Norvig, Artificial intelligence: Early ambitions, New Scientist, Volume 216, Issue 2889, 3 November 2012, Pages ii-iii, ISSN 0262-4079, 10.1016/S0262-4079(12)62783-3.
(http://www.sciencedirect.com/science/article/pii/S0262407912627833)

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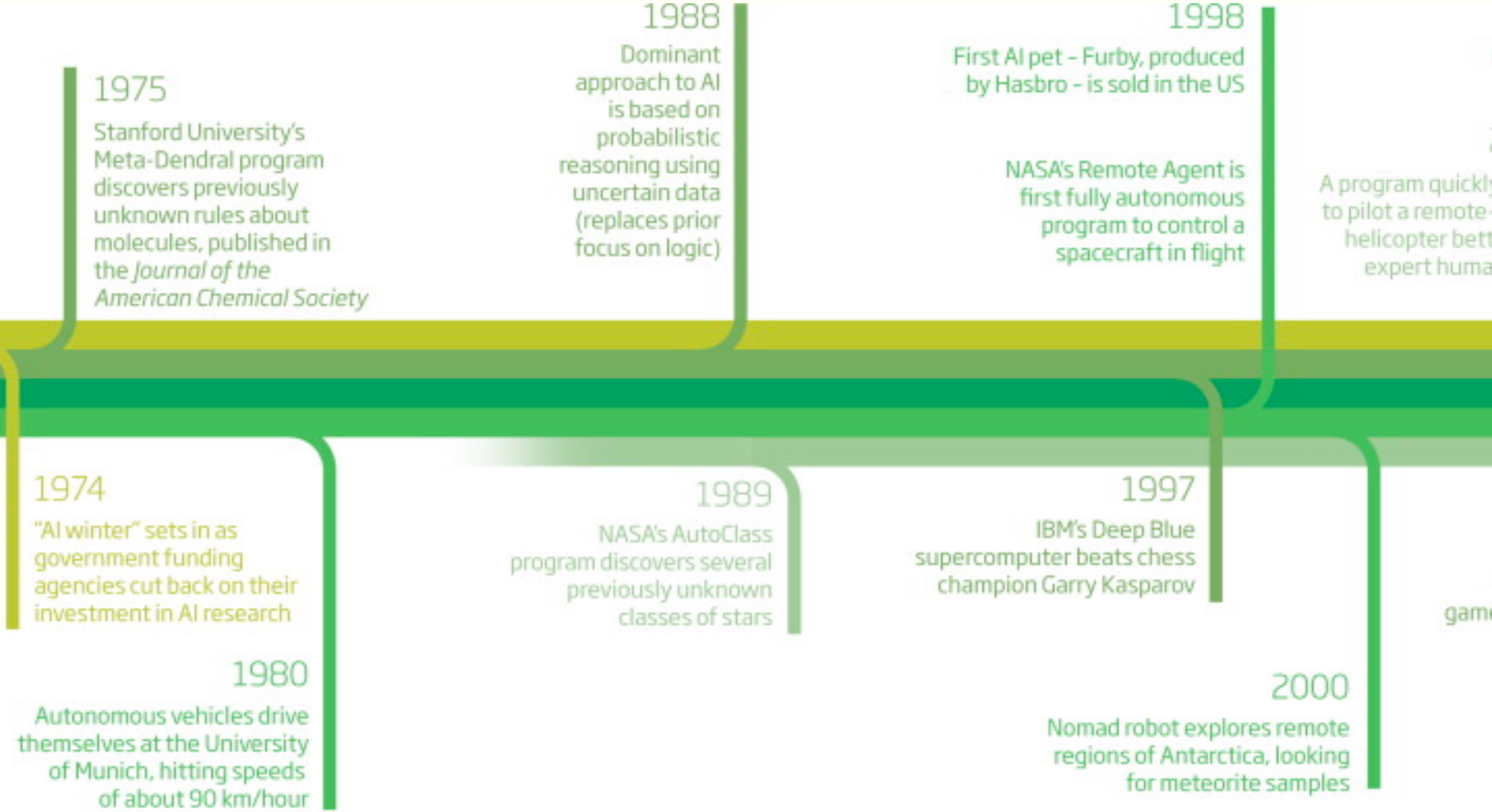
AI Timeline: 1974 - 2000



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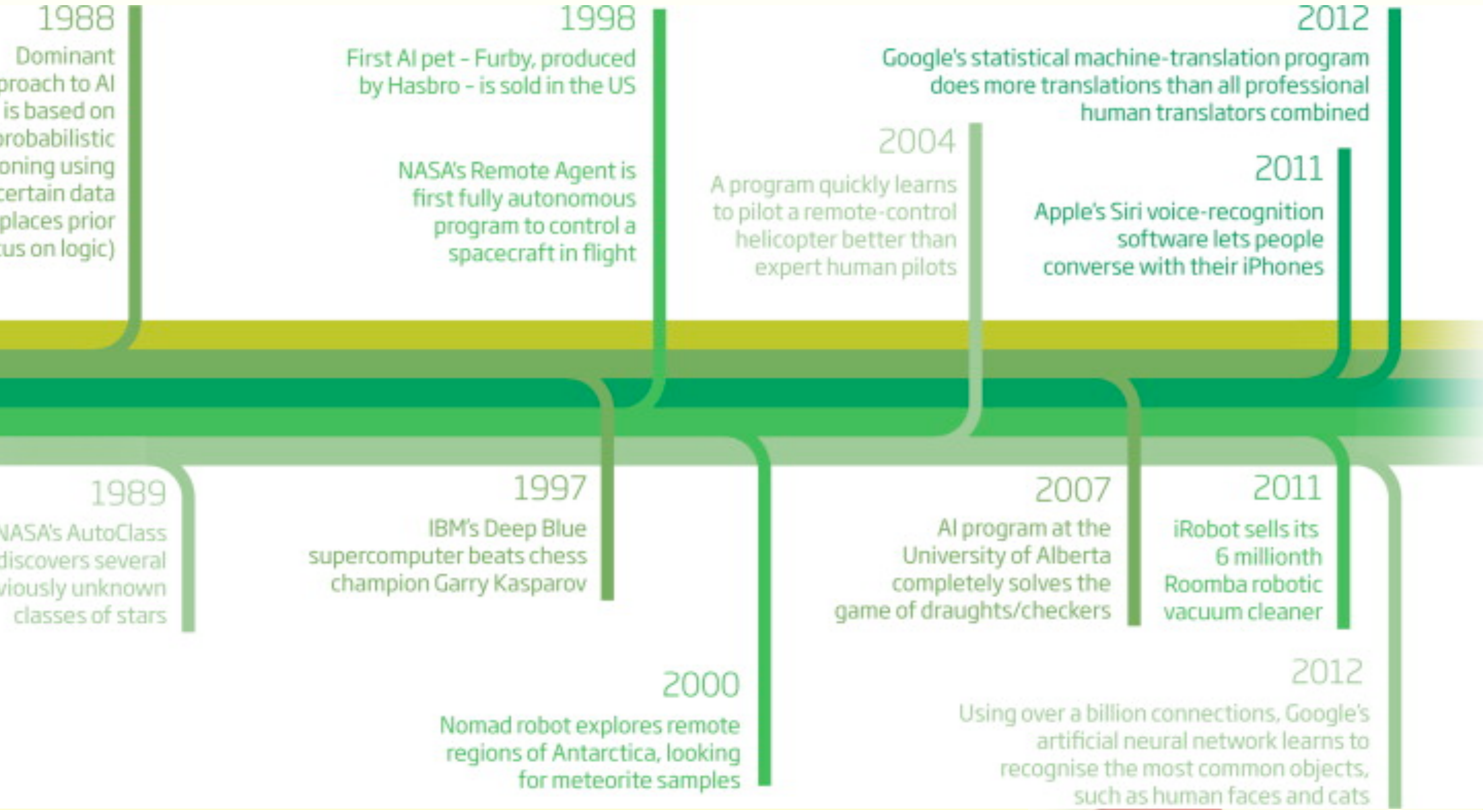
AI Timeline: 2000 - 2012



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Conception (late 40s, early 50s)

- artificial neurons (McCulloch and Pitts, 1943)
- learning in neurons (Hebb, 1949)
- chess programs (Shannon, 1950; Turing, 1953)
- neural computer (Minsky and Edmonds, 1951)

Birth: Summer 1956

- gathering of a group of scientists with an interest in computers and intelligence during a two-month workshop in Dartmouth, NH
- “naming” of the field by John McCarthy
- many of the participants became influential people in the field of AI

Baby steps (late 1950s)

- **demonstration of programs solving simple problems that require some intelligence**
  - Logic Theorist (Newell and Simon, 1957)
  - checkers programs (Samuel, starting 1952)
- **development of some basic concepts and methods**
  - Lisp (McCarthy, 1958)
  - formal methods for knowledge representation and reasoning
- **mainly of interest to the small circle of relatives**

Kindergarten (early 1960s)

- **child prodigies astound the world with their skills**
  - General Problem Solver (Newell and Simon, 1961)
  - Shakey the robot (SRI)
  - geometric analogies (Evans, 1968)
  - algebraic problems (Bobrow, 1967)
  - blocks world (Winston, 1970; Huffman, 1971; Fahlman, 1974; Waltz, 1975)
  - neural networks (Widrow and Hoff, 1960; Rosenblatt, 1962; Winograd and Cowan, 1963)
  - machine evolution/genetic algorithms (Friedberg, 1958)

Teenage years (late 60s, early 70s)

- sometimes also referred to as “AI winter”
- microworlds aren’t the real thing: scalability and intractability problems
- neural networks can learn, but not very much (Minsky and Papert, 1969)
- expert systems are used in some real-life domains
- knowledge representation schemes become useful

AI gets a job (early 80s)

- **commercial applications of AI systems**
  - R1 expert system for configuration of DEC computer systems (1981)
- **expert system shells**
- **AI machines and tools**

Some skills get a boost (late 80s)

- after all, neural networks can learn more -- in multiple layers (Rumelhart and McClelland, 1986)
- hidden Markov models help with speech problems
- planning becomes more systematic (Chapman, 1987)
- belief networks probably take some uncertainty out of reasoning (Pearl, 1988)

AI matures (90s)

- handwriting and speech recognition work -- more or less
- AI is in the driver's seat (Pomerleau, 1993)
  - but not allowed on regular roads
- wizards and assistants make easy tasks more difficult
- intelligent agents do not proliferate as successfully as viruses and spam

Intelligent Agents appear (mid-90s)

- **distinction between hardware emphasis (robots) and software emphasis (softbots)**
- **agent architectures**
  - SOAR
- **situated agents**
  - embedded in real environments with continuous inputs
- **Web-based agents**
- **the agent-oriented perspective helps tie together various subfields of AI**
- **but: “agents” has become a buzzword**
  - widely (ab)used, often indiscriminately

AI Vanishes (~2000)

- **more and more AI approaches are incorporated into generic computing approaches**
  - planning, scheduling
  - machine learning
  - natural language processing
  - reasoning
  - autonomy
- **or subsumed under the latest buzzwords**
  - Semantic Web
  - big data
  - smart <some computer-related term here>

A Lack of Meaning (~ 2005)

- **most AI methods are based on symbol manipulation and statistics**
  - e.g. search engines
- **the *interpretation* of generated statements is problematic**
  - often left to humans
- **the Semantic Web suggests to augment documents with metadata that describe their contents**
  - computers still don't "understand", but they can perform tasks more competently

AI Searches for Meaning (~2012)

- **statistical methods are augmented with knowledge-centric methods**
  - e.g., Google's Knowledge Graphs
- **computers still can't "understand", but they consider content-based relations**

Outlook

- **concepts and methods**
  - many are sound, and usable in practice
  - some gaps still exist: "neat" vs. "scruffy" debate
- **computational aspects**
  - most methods need improvement for wide-spread usage
  - vastly improved computational resources (speed, storage space)
- **applications**
  - reasonable number of applications in the real world
  - many are "behind the scene"
  - expansion to new domains
- **education**
  - established practitioners may not know about new ways
  - newcomers may repeat fruitless efforts from the past

Important Concepts and Terms

- agent
- automated reasoning
- cognitive science
- computer science
- intelligence
- intelligent agent
- knowledge representation
- linguistics
- Lisp
- logic
- machine learning
- microworlds
- natural language processing
- neural network
- predicate logic
- propositional logic
- rational agent
- rationality
- Turing test

Chapter Summary

- introduction to important concepts and terms
- relevance of Artificial Intelligence
- influence from other fields
- historical development of the field of Artificial Intelligence