Introduction to Artificial Intelligence

Introduction

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Winter Term 2004/2005

What is Artificial Intelligence (AI)?

"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models" (Charniak and McDermott, 1985)
"The study of how to make computers do things at which, at the moment, people are better" (Rich and Knight, 1991)	"The branch of computer science that is concerned with the automation of intelligent behavior" (Luger and Stubblefield, 1993)

What is Artificial Intelligence (AI)?

Views of AI fall into four categories

Thinking humanly	Thinking rationally
Acting humanly	Acting rationally

Most AI researchers in Computer Science go for acting rationally

Acting humanly: The Turing test

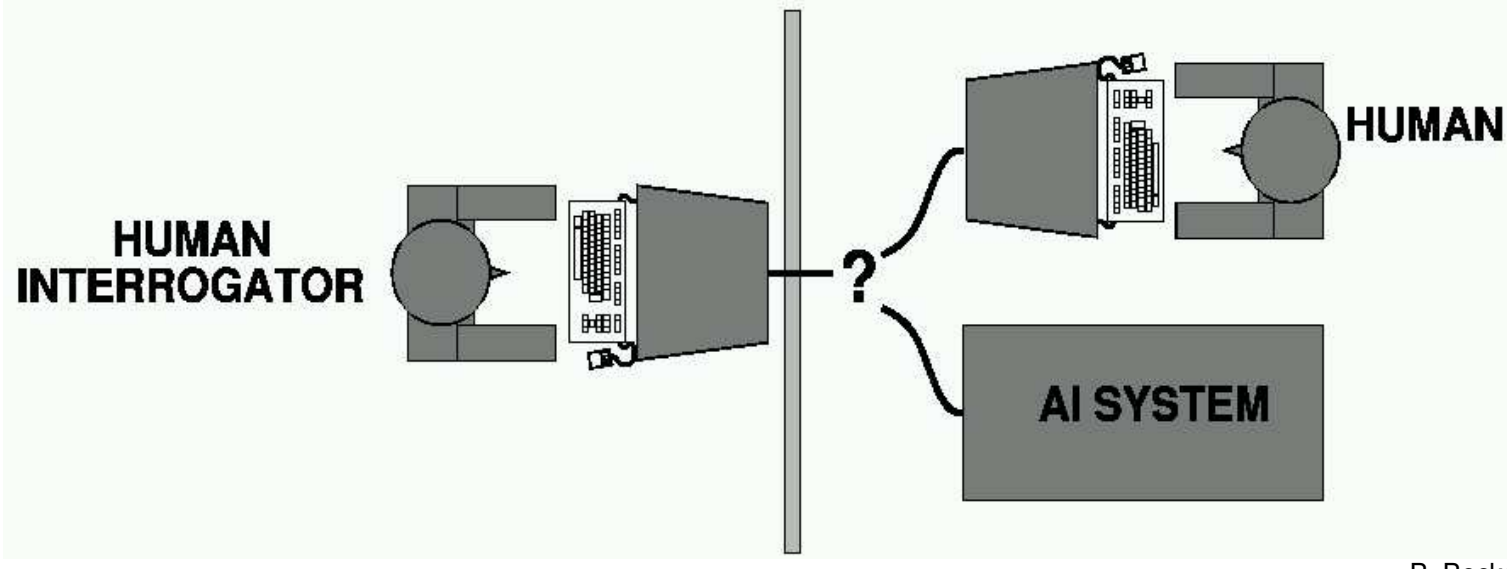
Turing (1950): *Computing machinery and intelligence*

- "Can machines think?'

  "Can machines behave intelligently?"

- Operational test for intelligent behavior: the Imitation Game

Classical Turing test



Acting humanly: The Turing test

Total Turing test

Includes physical interactions with environment

- **speech recognition**
- **computer vision**
- **robotics**

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Problem of Turing test

Turing test is

- **not reproducible**
- **not constructive**
- **not amenable to mathematical analysis**

Acting humanly: The Turing test

Turing's predictions

- 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 representation, reasoning, language understanding, learning

Turing's paper online available at

`http://www.abelard.org/turpap/turpap.htm`

The Turing Test and Subfields of AI

- Knowledge Representation
- Searching
- Automated Reasoning (Deduction)
- Machine Learning
- Natural Language Processing
- Computer Vision
- Robotics

Turing's and other Tests

Loebner Prize

A restricted Turing test, held annually in the form of a competition

> **The Loebner Prize is awarded annually for the computer program that best emulates natural human behavior. During the contest, a panel of independent judges attempts to determine whether the responses on a computer terminal are being produced by a computer or a person, along the lines of the Turing Test. The designers of the best program each year win a cash award and a medal. If a program passes the test in all its particulars, then the entire fund will be paid to the program's designer and the fund abolished.**

`http://www.loebner.net/Prizef/loebner-prize.html`

Turing's and other Tests

Robot World Cup Initiative (RoboCup)

Uses playing a soccer game as a standard problem, where a wide range of technologies can be integrated and examined. Carried out for various classes of robots and software agents.
Goal: By the year 2050, develop a team of fully autonomous humanoid robots that can win against the human world soccer champions.

`http://www.robocup.org`

Thinking humanly: Cognitive Science

Cognitive revolution (1960s)

Information-processing psychology replaced prevailing orthodoxy of behaviorism

Requires scientific theories of internal activities of the brain . . .

- **What level of abstraction?**
- **“Knowledge” or “circuits”?**

and Validation

- **Predicting and testing behavior of human subjects (top-down)**
  $\Rightarrow$ Cognitive Science
- **Direct identification from neurological data (bottom-up)**
  $\Rightarrow$ Cognitive Neuroscience

Second-order / Epistemological knowledge

“We know what we know and what we don’t know”

Thinking rationally: Laws of Thought

Normative (prescriptive) rather than descriptive

Aristotle: What are correct arguments / thought processes?

Several Greek schools developed various forms of logic:

- **notation**
- **rules of derivation (syllogisms)**

Direct line through mathematics and philosophy to modern AI

Problems

- **Not all intelligent behavior is mediated by logical deliberation**
- **What is the purpose of thinking? What thoughts should I have?**
- **What is the logic of human reasoning?**

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)

Aristotle: *Nicomachean Ethics*

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

Acting rationally

A thoroughly pragmatic point of view

- In practical terms, so far the most fruitful road taken by AI
- Completely misses the perhaps most central aspect of being human:

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Consciousness

Philosophical / theological questions

Can machines have

- minds?
- souls?
- consciousness?

Do sufficiently intelligent machines (automatically) have

- minds?
- souls?
- consciousness?

Two theories

Dualism: Body and soul/mind are separate things

Materialism: There is no immaterial soul/mind
(J. R. Searle: “Brains cause minds”)

Rational agents

Agent

- An entity that perceives and acts
- A useful way to think about building AI programs is in terms of designing (and implementing) rational agents

Abstract definition

An agent is a function from percept histories to actions:

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

Rational agents

Optimal agent

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

$\Rightarrow$ Design best agent for given machine resources

AI: Historical Roots

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.)**
Linguistics	**knowledge representation** **grammar**
Neuroscience	**physical substrate for mental activity**
Control theory	**homeostatic systems, stability** **simple optimal agent designs**

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
1963	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–	Probabilistic methods; enormous increase in technical depth "Nouvelle AI": ALife, GAs, soft computing
1995–	Agents is the new buzzword

State of the art

An early effort in Machine Translation

“The spirit is willing, but the flesh is weak”

Russian

“The vodka is good, but the meat is rotten”

State of the art, more seriously

Which of the following can be done by an AI program/robot at present?

- Play a decent game of table tennis
- Drive along a curving mountain road
- Drive in the center of a big city
- Play a decent game of Bridge or Go
- *Discover* and prove a new mathematical theorem
- Write an intentionally funny story
- Give competent legal advice in a specialized area of law
- Translate spoken English into spoken German in real time

State of the art

AI programs . . .

- **Regularly win a chess game against grandmasters**

  `http://www.lkessler.com/cclinks.shtml`

- ***Roughly* translate a *text* from one language into another**

  `http://cslu.cse.ogi.edu/HLTsurvey/HLTsurvey.html`

- **Proved a mathematical problem that was open for 60 years**

  `http://www-unix.mcs.anl.gov/~{}mccune/papers/robbins/`

AI research challenges

- Reflective architecture for agents (epistemological reasoning)
- Compilation from deliberative reasoning to reflex system (e.g., reinforcement learning)
- Make use of massive parallelism in an effective way
- Bridge the gap between *human* and *rational* AI

Some promising application areas

Formal software and hardware verification (automated reasoning)

Intel spends up to 90 % of budget in processor development for verification

The Semantic Web (knowledge representation, learning)

From keyword-based search to content-based search

Data mining, automatic discovery of structures

From data to information, *Discovery Science*

Probabilistic methods, learning, fuzzy sets

Some promising application areas

Autonomous agents

- cleaning robots
- military applications
- etc.

Recognition of speech, gestures, facial expression

- handicapped people
- cars/planes
- surveillance & security

Automated translation from/to natural language

Summary

- Early success, exaggerated claims, “roller coaster” ride
- Spin-off to mainstream CS
  (e.g., search, knowledge representation, complexity theory)
- Unresolved dichotomy “soft”/human-oriented vs. “hard”/rational AI
- Hard AI gained much in depth and rigour in recent years
- Many impressive tasks can be achieved with AI technology today
- Technological developments
  - WWW
  - computerization of all devices (ubiquitous computing)
  - data explosion

  create highly promising application areas for AI

Quote: Alan Turing (1950)

We can only see a short distance ahead, but we can see that much remains to be done.