CSCI-331
Introduction to Intelligent Systems

Week01
Intro
History
Intelligent Agents

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A note on notes

- Much of the notes/materials used in this course this semester were developed by a committee of faculty members including but not necessarily limited to:

- Leon Reznik
- Zack Butler
- Roxanne Canosa
- Richard Zanibbi
- Roger Gaborski
- T.J. Borrelli

- There will also be supplemental material provided from other sources.

Questions

- What tasks are machines good at doing that humans are not?
- What tasks are humans good at doing that machines are not?
- What tasks are both good at?
- What does it mean to learn?
- How is learning related to intelligence?
- What does it mean to be intelligent? Do you believe a machine will ever be built that exhibits intelligence?
- Have the above definitions changed over time?
- If a computer were intelligent, how would you know?
- What does it mean to be conscious?
- Can one be intelligent and not conscious or vice versa?

Questions Addressed

- **Problem Area**
  - **What** *are* intelligent systems and agents?
  - **Why** are we interested in developing them?
- **Methodologies**
  - **What** kind of software is involved? What kind of math?
  - **How** do we develop it (software, repertoire of techniques)?
  - **Who** uses AI? (Who are practitioners in academia, industry, government?)
- **Artificial Intelligence as a Science**
  - What is AI?
  - What does it have to do with intelligence? Learning? Problem solving?
  - What are some interesting problems to which intelligent systems can be applied?
  - *Should I be interested in AI (and if so, why)?*
- **Today: Brief Tour of AI History**
  - Study of intelligence (classical age to present), AI systems (1940-present)
  - Viewpoints: philosophy, math, psychology, engineering, linguistics

<u>What is AI again?</u>: descriptive approach

- Although the term of AI has been widely used for quite a long time with steadily increasing amount of research and applications, there is no anonymously accepted definition. AI can mean many things to different people and various techniques are considered as belonging to AI.
- The term coined in 1956 by J. McCarthy at MIT
- Two branches: engineering discipline dealing with the creation of intelligent machines and empirical science concerned with the computational modeling of human intelligence
- The goal of AI is developing methods, which allow producing thinking machines that can solve problems
- Which problems?
- ill-defined and ill-structured
- complicated taxonomy or classifying
- Combinatorial optimization

What is AI again?:

- The great variety of AI techniques have been developed and applied over the history for solving the problems mentioned above.
- Some of these methodologies are”conventional” or “old” methods (1950s):
- Search algorithms
- Probabilistic reasoning
- Natural language processing
- Belief networks

- Others are “new” (1960s) – soft computing and computational intelligence

Foundations of Artificial Intelligence

- 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

- Economics – Utility, decision theory, game theory

- Neuroscience – How do brains process information?

- 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

What is AI again?
Systematic approach

- **Four Categories of Systemic Definitions**
  - **1. Think like humans**
  - **2. Act like humans**
  - **3. Think *rationally***
  - **4. Act *rationally***

What is AI again? Systematic approach

- **Thinking Like Humans**
  - ***Machines with minds*** **(Haugeland, 1985)**
  - **Automation of "decision making, problem solving, learning..." (Bellman, 1978)**
- **Acting Like Humans**
  - ***Functions*** **that** ***require intelligence when performed by people*** **(Kurzweil, 1990)**
  - **Making computers do things** ***people currently do better*** **(Rich and Knight, 1991)**
- **Thinking Rationally**
  - **Computational models of mental faculties (Charniak and McDermott, 1985)**
  - **Computations that make it possible to** ***perceive*****,** ***reason*****, and** ***act*** **(Winston, 1992)**
- **Acting Rationally**
  - **Explaining, emulating intelligent behavior via computation (Schalkoff, 1990)**
  - **Branch of CS concerned with automation of intelligent behavior (Luger and Stubblefield, 1993)**

What is AI?
Thinking and Acting Like Humans

- **Concerns: Human Performance (Figure 1.1 R&N, Left-Hand Side)**
  - Top: thought processes and reasoning (learning and inference)
  - Bottom: behavior (interacting with environment)
- **Machines With Minds**
  - Cognitive modeling
    - Early historical examples: problem solvers (see R&N Section 1.1)
    - Application (and one driving force) of cognitive science
  - Deeper questions
    - What is intelligence?
    - What is consciousness?
- **Acting Humanly: The Turing Test Approach**
  - Capabilities required
    - Natural language processing
    - Knowledge representation
    - Automated reasoning
    - Machine learning
  - Turing Test: can a machine appear indistinguishable from a human to an experimenter?

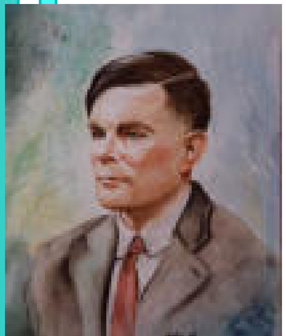
Thinking and Acting Like Humans

- **According to Evolutionary Biologist Richard Dawkins: Adaptationism is defined as 'that approach to evolutionary studies which assumes without further proof that all aspects of the morphology, physiology and behavior of organisms are adaptive optimal solutions to problems.'**

- **Dawkins does not put much stock in this belief.**
- **Take for example: the human eye**

What is AI? Thinking and Acting Rationally

- **Concerns: Human Performance (Figure 1.1 R&N, Right-Hand Side)**
  - Top: thought processes and reasoning (learning and inference)
  - Bottom: behavior (interacting with environment)
- **Computational Cognitive Modelling**
  - Rational ideal
    - In this course: rational agents
    - Advanced topics: learning, utility theory, decision theory
  - Basic mathematical, computational models
    - Decisions: automata Search
    - Concept learning
- **Acting Rationally: The Rational Agent Approach**
  - Rational action: *acting to achieve one's goals, given one's beliefs*
  - Agent: entity that perceives and acts
  - Focus of next topic
    - "Laws of thought" approach to AI: correct inferences (reasoning)
    - Rationality not *limited to* correct inference

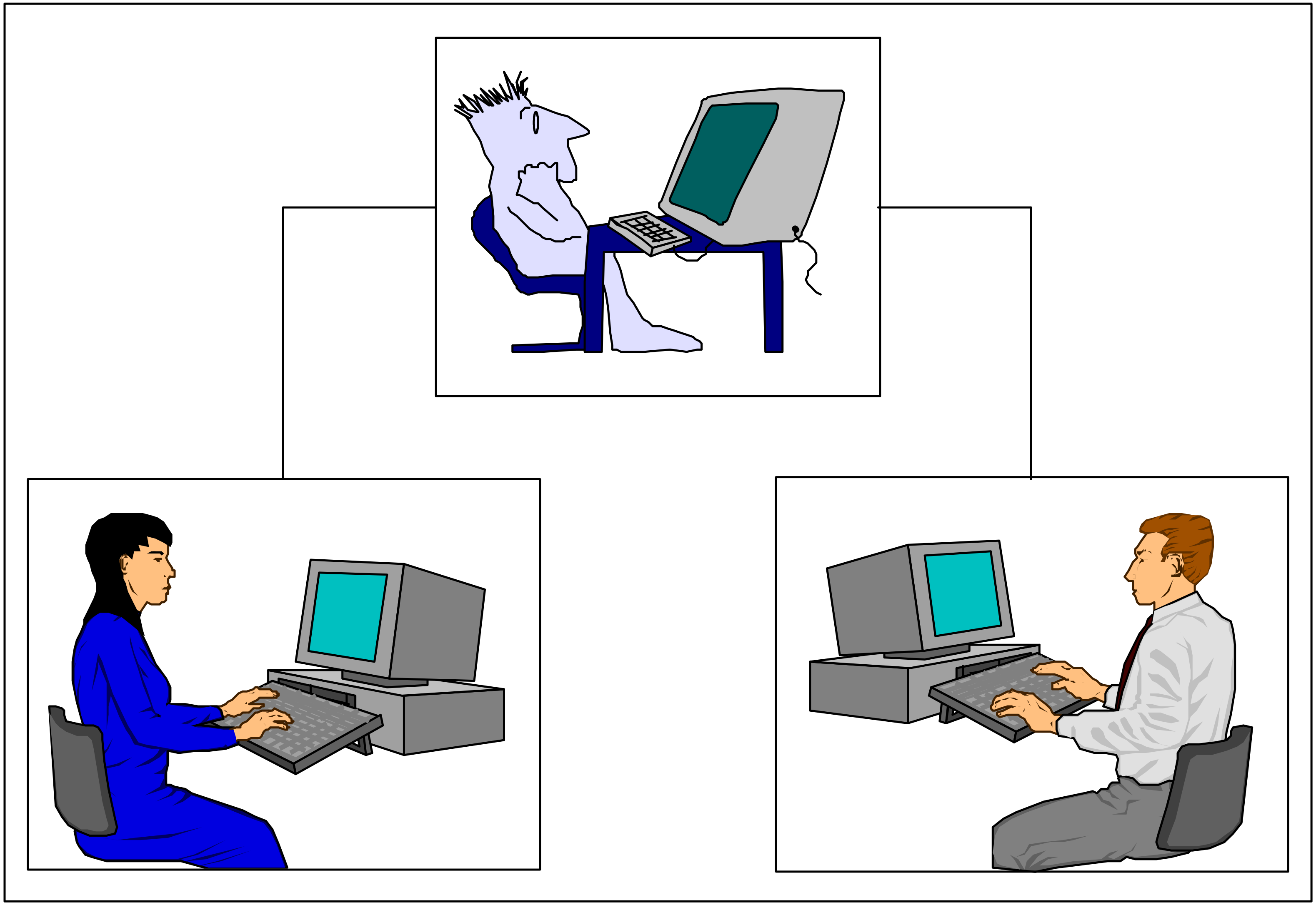


Significant paper on machine intelligence: ***"Computing Machinery and Intelligence" (1950) -*** by the British mathematician ***Alan Turing*** – still stands up "well" under the test of time

He asked: ***Is there thought without experience? Is there mind without communication? Is there language without living? Is there intelligence without life?*** All these questions, as you can see, are just variations on the fundamental question of artificial intelligence, ***Can machines think?***

- Turing did not provide definitions of machines and thinking, he just avoided semantic arguments by inventing a game, the ***Turing Imitation Game***.
- The imitation game originally included two phases.
  - 1st phase - interrogator, a man and a woman are each placed in separate rooms – interrogator's job is to work out who is the man and who is the woman by questioning them.
    - The man should attempt to deceive the interrogator that *he* is the woman, while the woman has to convince the interrogator that *she* is the woman.

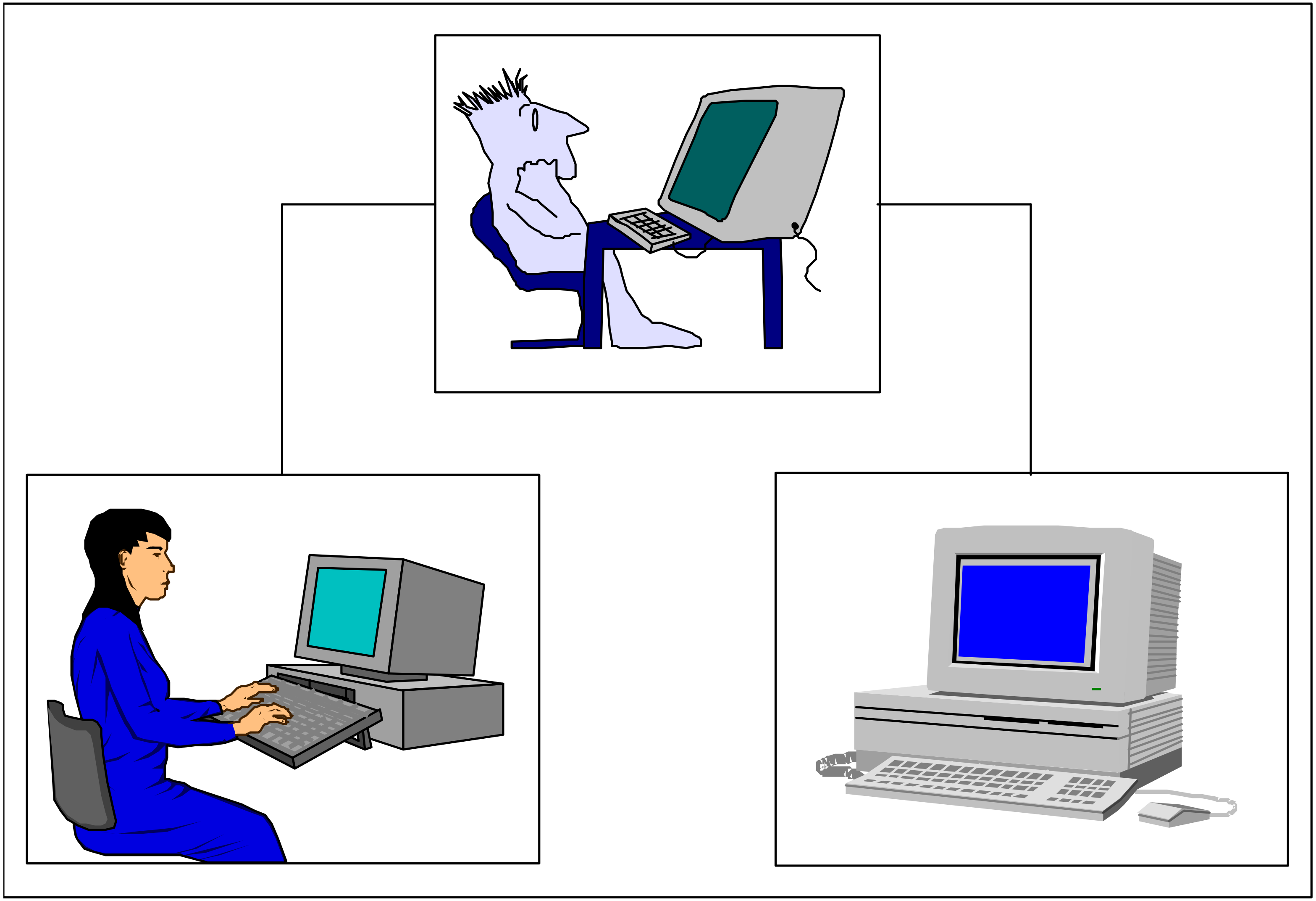
Turing Imitation Game: Phase 1



Turing Imitation Game: Phase 2

- In the second phase of the game, the man is replaced by a computer programmed to deceive the interrogator as the man did
- It would even be programmed to make mistakes and provide fuzzy answers in the way a human would
- If the computer can fool the interrogator as often as the man did, we may say this computer has passed the intelligent behavior test.

Turing Imitation Game: Phase 2



The Turing test has two remarkable qualities that make it interesting.

- By maintaining communication between the human and the machine via terminals, the test gives us an objective standard view on intelligence.
- The test itself is quite independent from the details of the experiment. It can be conducted as a two-phase game, or even as a single-phase game when the interrogator needs to choose between the human and the machine from the beginning of the test.

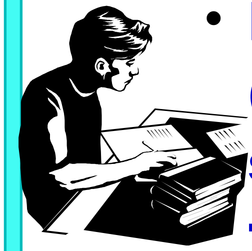
- Turing believed that by the end of the 20th century it would be possible to program a digital computer to play the imitation game
- Although modern computers still cannot consistently pass the Turing test, it provides a basis for the verification and validation of knowledge-based systems.
- **A program thought intelligent in some narrow area of expertise is evaluated by comparing its performance with the performance of a human expert.**
- To build an intelligent computer system, we have to capture, organize and use human expert knowledge in some narrow area of expertise.

AI History (old)

- **Philosophy Foundations (400 B.C. – present)**
  - **Mind: dualism and rationalism(Descartes), materialism (Leibniz), empiricism (Bacon, Locke)**
  - **Thought: syllogism (Aristotle), induction (Hume), logical positivism (Russell)**
  - **Rational agentry (Mill) – acts to achieve the best expected outcome**
- **Mathematical Foundations (c. 800 – present)**
  - **Early: algorithms (al-Khowarazmi, 9th century Arab mathematician), Boolean logic**
  - **Computability (20th century – present)**
    - **Gödel's incompleteness theorem**
    - **Formal computational models: Hilbert's Entscheidungsproblem (decidability)**
    - **Turing Intractability**
    - **NP-completeness**

AI History (not too old)

- **Computer Engineering (1940 – present)**
- **Linguistics (1957 – present)**
- **Stages of AI**
  - **Gestation (1943 – c. 1956) – McCulloch and Pitts artificial neuron model, Hebbian learning**
  - **Birth of AI (1956) – 2 month workshop at Dartmouth (McCarthy, Minsky, Shannon, Rochester)**
  - **Infancy "Early enthusiasm, great expectations"(c. 1952 – 1969) – some early success in areas such as ANN, Lisp, GPS (general problem solver)**



  - **Disillusioned early (c. 1966 – 1974), later childhood (1969 – 1979) – the fact that a program can find a solution in principle does not necessarily mean that the program can find it in practice**

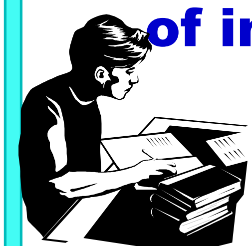
AI History (not too old)

- **“Early” (1969 – 1979) – knowledge based systems (DENDRAL – inferring molecular structure based on mass spec readings; MYCIN – medical diagnosis)**

- **“Middle” adolescence (c. 1980 – present) – AI becomes an industry**

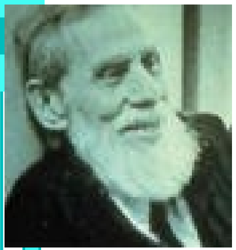
- **“Middle-late” Return of Neural Nets (1986-present)**

- **“Modern” – AI takes on scientific method; emergence of intelligent agents (1987 - present)**

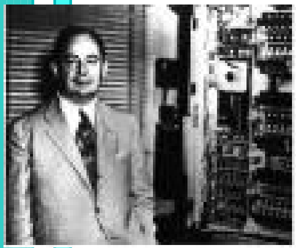


History of AI -- birth

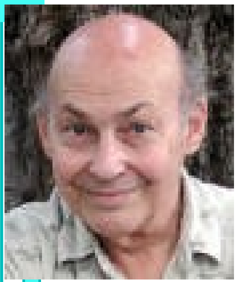
The birth of artificial intelligence (1943 – 1956)



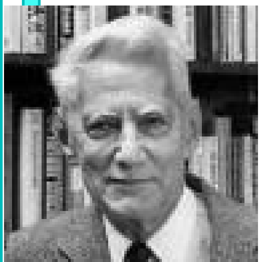
- First work recognized in AI was paper by **Warren McCulloch** and **Walter Pitts** (1943).
- They proposed a model of an artificial neural network
- Demonstrated that simple network structures could learn
- McCulloch – the second "founding father" of AI after Alan Turing, had created the corner stone of neural computing and artificial neural networks (ANN).



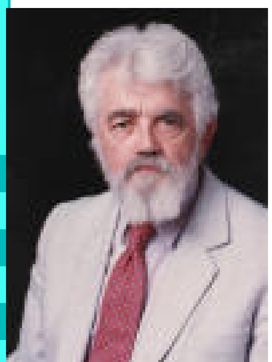
- The third founder of AI was **John von Neumann**, (Hungarian-born mathematician).
- In 1930 – joined Princeton, lecturing in mathematical physics.
- Was an adviser for the Electronic Numerical Integrator and Calculator project at the University of Pennsylvania
- Helped to design the **Electronic Discrete Variable Calculator**



- He was influenced by McCulloch and Pitts's neural network model.
- Encouraged **Marvin Minsky** and **Dean Edmonds** (at Princeton math department) to build first neural network computer in 1951



- Another of the first generation researchers was **Claude Shannon**.
- Graduated from MIT, joined Bell Telephone Laboratories in 1941.
- Shannon shared Alan Turing's ideas on the possibility of machine intelligence.
- In 1950, he published a paper on chess-playing machines, which pointed out that a typical chess game involved about 10^120 possible moves (Shannon, 1950).
- Even if the new von Neumann-type computer could examine one move per microsecond, it would take 3 x 10^106 years to make its first move.
- Thus Shannon demonstrated the need to use **heuristics** in the search for the solution.



- In 1956, **John McCarthy**, **Marvin Minsky** and **Claude Shannon** organized a summer workshop at Dartmouth College.
- They brought together researchers interested in the study of machine intelligence, artificial neural nets and automata theory.
- Although there were just ten researchers, this workshop gave birth to a new science called ***artificial intelligence***.

The rise of artificial intelligence, or the era of great expectations (1956 – late 1960s)

- The early works on neural computing and artificial neural networks started by McCulloch and Pitts was continued.
- Learning methods were improved and **Frank Rosenblatt** proved the ***perceptron convergence theorem***, demonstrating that his learning algorithm could adjust the connection strengths of a perceptron.

- One of the most ambitious projects of the era of great expectations was the **General Problem Solver (GPS)**.
- **Allen Newell** and **Herbert Simon** from the CMU developed a general-purpose program to simulate human-solving methods.
- Newell and Simon postulated that a problem to be solved could be defined in terms of ***states***.
- They used the means-end analysis to determine a difference between the current and desirable or *goal state* of the problem, and to choose and apply *operators* to reach the goal state.
- The set of operators determined the solution plan.

- However, GPS failed to solve complex problems.
- The program was based on formal logic and could generate an infinite number of possible operators.
- The amount of computer time and memory that GPS required to solve real-world problems led to the project being abandoned.
- In the sixties, AI researchers attempted to simulate the thinking process by inventing *general methods* for solving *broad classes of problems*.
- They used the general-purpose search mechanism to find a solution to the problem.
- Such approaches, now referred to as ***weak methods***, applied weak information about the problem domain.

- By 1970, the euphoria about AI was gone, and most government funding for AI projects was cancelled.
- AI was still a relatively new field, academic in nature, with few practical applications apart from playing games.
- So, to the outsider, the achieved results would be seen as toys, as no AI system at that time could manage real-world problems.

Unfulfilled promises, or the impact of reality (late 1960s – early 1970s)

The main difficulties for AI in the late 1960s were:

- Because AI researchers were developing general methods for broad classes of problems, early programs contained little or even no knowledge about a problem domain.
- To solve problems, programs applied a search strategy by trying out different combinations of small steps, until the right one was found.
- This approach was quite feasible for simple **toy problems**, so it seemed reasonable that, if the programs could be "scaled up" to solve large problems, they would finally succeed.

Many of the problems that AI attempted to solve were **too broad and too difficult**. A typical task for early AI was machine translation. For example, the National Research Council, USA, funded the translation of Russian scientific papers after the launch of the first artificial satellite (Sputnik) in 1957.

- **The spirit is willing but the flesh is weak**
- **The vodka is good but the meat is rotten**

- ***The story of this specific mistranslation is likely apocryphal**

- In 1971, the British government also suspended support for AI research. Sir **James Lighthill** had been commissioned by the Science Research Council of Great Britain to review the current state of AI.
- He did not find any major or even significant results from AI research, and therefore saw no need to have a separate science called “artificial intelligence”.

Why Study Artificial Intelligence?

New Computational Capabilities

- Advances in uncertain reasoning, knowledge representations
- Learning to act: robot planning, control optimization, decision support
- Database mining: converting (technical) records into knowledge
- Self-customizing programs: learning news filters, adaptive monitors
- Applications that are hard to program: automated driving, speech recognition

Why Study Artificial Intelligence?

- **Better Understanding of Human Cognition**
  - Cognitive science: theories of knowledge acquisition (e.g., through practice)
  - Performance elements: reasoning (inference) and *recommender* systems
- **Time is Right**
  - Recent progress in algorithms and theory
  - Rapidly growing volume of online data from various sources
  - Available computational power
  - Growth and interest of AI-based industries (e.g., data mining, planning)