Department of
Mathematics &
Computer Science

1. Introduction to Artificial Intelligence

Introduction

- **Intelligence** is important to humans, and we have tried to understand **‘how we think’** since thousands of years.
- Currently, we do not completely understand ‘how we think’.
  - How a mere handful of matter can perceive, understand, predict, and manipulate a world far larger and more complicated the itself?

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  - How a mere handful of matter can perceive, understand, predict, and manipulate a world far larger and more complicated the itself?
- **Artificial Intelligence** is about 'understanding intelligence' and 'building intelligent' entities.
- AI encompasses a huge variety of subfields ranging from general to specific, such as playing chess, proving mathematical theorems, writing poetry, **driving a car on crowded street**, and diagnosing diseases.
- AI is relevant to any intellectual task and it is a **universal** field.

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   - The difference between "acting humanly" and "thinking humanly" is that the first is only **concerned with the actions**, the outcome or product of the human thinking process; whereas the latter is **concerned with modeling human thinking processes**

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3. AI means **thinking rationally**, i.e. modeling thinking as a logical process, where conclusions are drawn based on some type of symbolic logic
4. AI means **acting rationally**, i.e. performing actions that increase the value of the state of the agent or environment in which the agent is acting. For example, an agent that is playing a game will act rationally if it tries to win the game

1.1 What is AI? Four Main Views/Approaches

Definitions of AI can be organized into four categories:

These definitions are concerned with **thought process** and **reasoning**

Measure success in terms of **human performance**

___________**?**___________ (ex. problem solving, learning)	___________**?**___________ (ex. computations that make it possible to perceive, reason, and act)
___________**?**___________ (ex. disease diagnosis)	___________**?**___________ (ex. intelligent agents)

Measure success in terms of *ideal* performance measure **(rationality).**

These definitions address **human behavior**

1.1.1 Turing Test

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- "Instead of asking whether machines can think, we should ask whether machines can pass a behavioral intelligence test" - Alan Turing.
- **Turing Test:** The program is to have a conversation (via online typed messages) with an interrogator for five minutes. The interrogator has to guess if the conversation is with a program or a person. The program passess the test if it fools the interrogator 30% of the time.

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- Turing conjured that, by 2000, a computer with a storage of 10^9 units could be programmed well enough to pass the test.

1.1.1 Acting Humanly: The Turing Test Approach

- Many people have been fooled when they didn't know they might be chatting with a computer.
- The Loebner Prize competition, held annually since 1991, is the longest-running Turing Test like contest.
    - The competitions have led to better models of human typing errors.

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- However, in general, Turing was wrong - computer programs have yet to fool a sophisticated judge.
- Programming a computer to pass a rigorously applied test provides a plenty to work on.

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- The **total Turing test** includes a video signal so that the interrogator can test
    - the subject's perceptual abilities, and
    - The opportunity for the interrogator to pass physical objects "through the hatch"

1.1.1 Acting Humanly: The Turing Test Approach

Which of the following six capabilities are NOT needed for passing the Turing Test?

1. Natural Language Processing
    - To enable a computer to communicate successfully in English
2. Computer Vision
    - To perceive objects
3. Knowledge Representation
    - To store what the computer knows or hears
4. Automated Reasoning
    - To use stored information to answer questions and to draw new conclusions
5. Robotics
    - To manipulate objects and move about
6. Machine Learning
    - To adapt to new circumstances and to detect and extrapolate patterns

1.1.2 Thinking Humanly: The Cognitive Modeling Approach

- For us to say that a program thinks like a human, we need to determine how humans think.
  - We need to get **inside** the actual workings of human minds.
- There are three ways we can understand how we think:
  - Through introspection - trying to catch our own thoughts as they go by
  - Through psychological experiments - observing a person in action
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- The field of cognitive science brings together computer models from AI and experimental techniques from psychology to construct precise and testable theories of human mind.

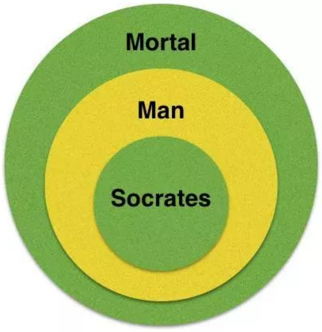
Acting Humanly vs Thinking Humanly

Think of an example of acting humanly but not thinking humanly.

1.1.3 Thinking Rationally: The “laws of thought” Approach

A **syllogism** is a kind of logical argument that applies deductive reasoning to arrive at a conclusion based on two or more propositions that are asserted or assumed to be true.

- Aristotle’s **syllogisms** provided patterns for argument structures that always yielded correct conclusions when given correct premises
  - For example, “Socrates is a man; all men are mortal; therefore, Socrates is mortal.
- These “laws of thought” were supposed to govern the operation of mind - and this initiated the field called **logic**.



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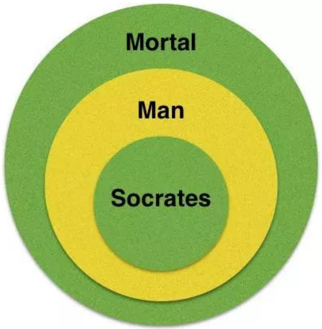
- By 1965, programs existed that could, in principle, solve any solvable problem described in logical notation.
- This **logisist tradition** within AI hopes to build on such programs to create intelligent systems.



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Two obstacles with the approach of defining AI as building rationally thinking agents:

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How will just a few hundred facts exhaust computational resources?

1.1.4 Acting Rationally: The Rational Agent Approach

- **Agent** - something that acts (this is not a formal definition)
  - All computer programs do something, but agents are expected to do more: operate autonomously, perceive the environment, persist over a prolonged time period, adapt to change, and create and pursue goals.
- **Rational Agent** - one that acts so as to achieve the best outcome or, when there is uncertainty, the best expected outcome.

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  - because one way to act rationally is to reason logically to the conclusion that a given action will achieve one’s goals and then to act to that conclusion
- However, ‘correct inference’ is NOT ALL of rationality
  - in some situations there is no provably correct thing to do, but something must still be done
- Example of an activity that is acting rational but not thinking rationally:
  - Recoiling from a hot stove (reflex action) is usually more successful that a slower action taken after careful deliberation

1.1.4 Acting Rationally: The Rational Agent Approach

The rational agent approach has two advantages over other approaches:

1. More general than the ‘laws of thought’ approach because correct inference is just one of several possible mechanisms for achieving rationality.
2. It is more amenable to scientific development than are approaches based on human behavior or human thought.

Modern AI therefore concentrates on general principles of rational agents and on components for constructing them.

1.2.4 Neuroscience

- **Neuroscience** is one of the fields that contributed ideas, viewpoints, and techniques to AI. It is the study of nervous system, particularly the brain.
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- The measurement of intact brain activity began in 1929 with the invention of electroencephalograph (EEG).
- The recent development of functional magnetic resonance imaging (fMRI) is giving neuroscientists unprecedentedly detailed images of brain activities
  - enabling measurements that correspond in interesting ways to ongoing cognitive processes
- These are further augmented by advances in single-cell recording of neuron activity. Individual neurons can be stimulated electrically, chemically, or even optically, allowing neuronal input-output relationships to be mapped.

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- These are further augmented by advances in single-cell recording of neuron activity. Individual neurons can be stimulated electrically, chemically, or even optically, allowing neuronal input-output relationships to be mapped.
- But we are still a long way from understanding how cognitive processes work.
    - In other words, how do brains cause minds?

1.2.4 Neuroscience

Raw computational resources available to IBM BLUE GENE supercomputer

	Supercomputer	Personal Computer	Human Brain
Computational units	10^4 CPUs, 10^{12} transistors	4 CPUs, 10^9 transistors	10^{11} neurons
Storage units	10^{14} bits RAM	10^{11} bits RAM	10^{11} neurons
	10^{15} bits disk	10^{13} bits disk	10^{14} synapses
Cycle time	10^{-9} sec	10^{-9} sec	10^{-3} sec
Operations/sec	10^{15}	10^{10}	10^{17}
Memory updates/sec	10^{14}	10^{10}	10^{14}

- Computers have cycle time that is a million times faster than a brain
  - Cycle time = start of one RAM access to the time when the next access can be started
- Brain makes up for that with far more storage and interconnection
- Even with a computer of virtually unlimited capacity, we still would not know how to achieve the brain’s level of intelligence

1.3.6 History of AI: AI Becomes and Industry (1980-present)

- AI industry boomed a few million dollars in 1980 to billions of dollars in 1988
  - including hundreds of companies building expert systems, vision systems, robots, and software and hardware specialized for these purposes
- The first successful commercial expert system, R1, began operation at the Digital Equipment Corporation.
  - By 1986 (in 4 yrs) it was saving the company an estimated $40 million a year.
  - By 1988, DEC's AI group had 40 expert systems deployed.
- Nearly every major U.S. corporation had its own AI group and was either using or investing in expert systems.

aaai.org/Library/AAAI/1980/aaai80-076.php

R1: An Expert in the Computer Systems Domain

John McDermott

R1 is a rule-based system that has much in common with other domain-specific systems that have been developed over the past several years. It differs from these systems primarily in its use of Match rather than Generate-and-Test as its central problem solving method; rather than exploring several hypotheses until an acceptable one is found, it exploits its knowledge of its task domain to generate a single acceptable solution. R1's domain of expertise is configuring Digital Equipment Corporation's VAX-11/780 systems. Its input is a customer's order and its output is a set of diagrams displaying the spatial relationships among the components on the order; these diagrams are used by the technician who physically assembles the system. Since an order frequently lacks one or more components required for system functionality, a major part of R1's task is to notice what components are missing and add them to the order. R1 is currently being used on a regular basis by DEC's manufacturing organization.

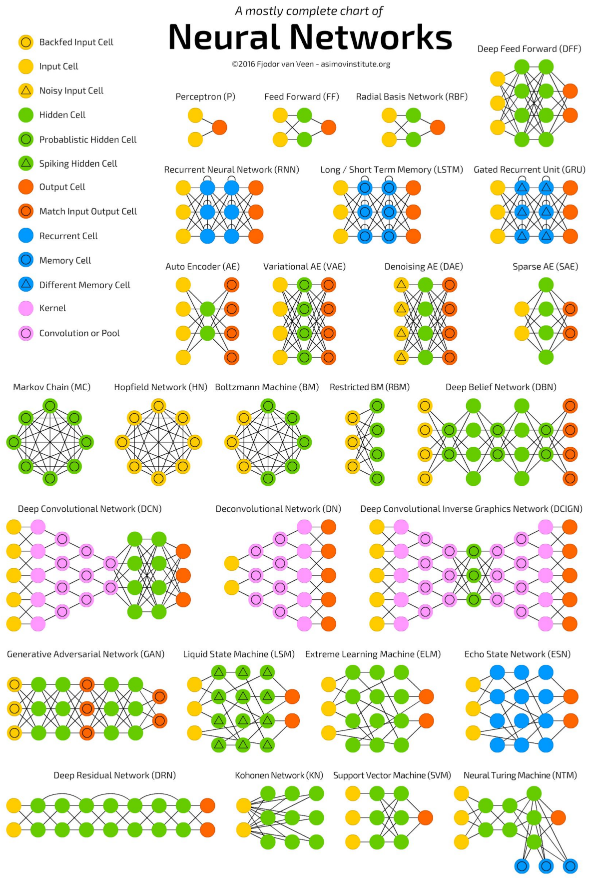
Google: R1: An Expert System

*** The abstract of the paper is important for tests.**

What did R1 do and how would it save DEC's money?

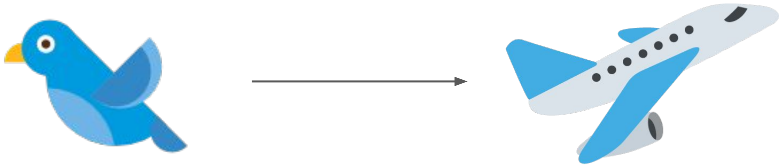
1.3.7 The Return of Neural Networks (1986-present)

- The **back-propagation algorithm** was applied to many learning problems in computer science and psychology, and it caused great excitement.
- Modern NN research has bifurcated into two fields:
  - One concerned with creating effective network architectures and algorithms and understanding their mathematical properties
  - The other concerned with careful modeling of empirical properties of actual neurons and ensembles of neurons



Is it a good idea to stick to think/act like Humans?

- How did we design airplanes?



- **How did we design wheels?** Not one animal rolls around upon a rotating body part: a biological wheel.

We thought beyond what we learnt from nature.

1.3.8 AI Adopts the Scientific Method (1987-present)

- It is now more common to build on existing theories than to propose brand-new ones,
  - to base claims on rigorous theorems or hard experimental evidence rather than on intuition,
  - and to show relevance to real-world applications rather than toy examples
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- In the recent years Hidden Markov Models (HMMs) have come to dominate the area; there is no scientific claim that humans use HMMs to recognize speech
  - HMMs are based on rigorous mathematical theory. This has allowed speech researchers to build on several decades of mathematical results developed in other fields.
  - HMMs are generated by a process of training on a large corpus of real speech data. This ensures that the performance is robust, and in rigorous blind tests the HMMs have been improving steadily.
- Similar gentle revolutions have occured in robotics, computer vision, and knowledge representation.

1.3.9 The Emergence of Intelligent Agents (1995-present)

- Some influential founders of AI have expressed discontent with the progress of AI.
- They think that AI should put less emphasis on creating ever-improved versions of applications that are good at specific task, such as driving a car, playing chess, or recognizing speech.
- Instead, they believe that AI should return to its roots of striving for “machines that think, that learn and that create.” This effort is known as **human-level AI** or HLAI, and it requires very large knowledge bases.
- A related subfield is **Artificial General Intelligence** - AGI looks for a universal algorithm for learning and acting in any environment.

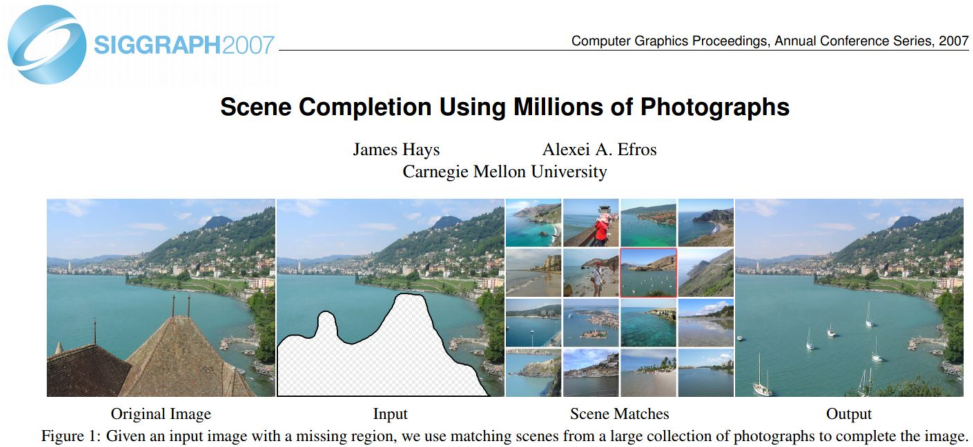
1.3.10 The Availability of Very Large Datasets (2001-present)

- In the 60-year history of computer science, the emphasis has been on the algorithm as the main subject of study.
- Some recent work in AI suggests that for many problems, it makes more sense to worry about the data and be less picky about what algorithm to apply. This is true because of the increasing availability of very large data sources.

Example - The problem of filling holes in a photograph.

Google: [Scene Completion using Millions of Photographs]

*** The abstract of the paper is important for tests.**


SIGGRAPH2007 Computer Graphics Proceedings, Annual Conference Series, 2007

Scene Completion Using Millions of Photographs

James Hays Alexei A. Efros
Carnegie Mellon University

Original Image Input Scene Matches Output

Figure 1: Given an input image with a missing region, we use matching scenes from a large collection of photographs to complete the image.

What problem do the authors solve?

1.3.10 The Availability of Very Large Datasets (2001-present)

- Knowledge bottleneck in AI - the problem of how to express all the knowledge that a system needs
- Such works suggest that the “knowledge bottleneck” in AI may be solved in many applications by learning methods rather than hand-coded knowledge engineering
  - provided the learning algorithm has enough data to go on.

1.4 The State of The Art

Robotic vehicles - A driverless robotic car named STANLEY sped through the rough terrain of Mojave desert at 22 mph, finishing a 132-mile course first to win the 2005 DARPA Grand Challenge.

Speech Recognition - Google Duplex - A.I. Assistant Calls Local Businesses To Make Appointments

Autonomous Planning and Scheduling - A hundred million miles from Earth, NASA's Remote Agent program became the first on-board autonomous planning program to control the scheduling of operations for a spacecraft.

Game Playing - Google's AI won the game Go by defying millennia of basic human instinct

Protein Folding - AlphaFold won the CASP13 protein folding competition

1.4 The State of The Art

Spam Fighting - Because spammers are continually updating their tactics, it is difficult for a static programmed approach to keep up, and learning algorithms work best.

Logistics Planning - During the Persian Gulf crisis of 1991, U.S. forces deployed a Dynamic Analysis and Replanning Tool (DART) to do automated logistic planning and scheduling for transportation. This involved 50,000 vehicles, cargo, and people at a time, and had to account for starting points, destinations, routes, and conflict resolution among all parameters.

Robotics - The iRobot Corporation has sold over 10 million Roomba robotic vacuum cleaners for home use.

Machine Translation - A computer program automatically translates from Arabic to English, allowing an English speaker to see headlines.

Summary

- Different people approach AI with different goals in mind. Two important questions to ask are: Are you concerned with thinking or behavior? Do you want to model humans or work from an ideal standard?
- Neuroscientists discovered some facts about how the brain works and the ways in which it is similar to and different from computers.
- AI has advanced more rapidly in the past decade because of greater use of the scientific method in experimenting with and comparing approaches.