Introduction to Artificial Intelligence

Why AI ?

AI - Attempts to understand intelligent entities.

- Learn more about ourselves.
- Constructed intelligent entities are interesting and useful.

Is AI possible?

- Look in the mirror to see an example of an intelligent system.
- AI has turned out to be more difficulty than many at first imagined.
- AI still has openings for a full time Einstein.

What is AI ?

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

Figure 1: Some definitions of AI.

They are organized into four categories:

Systems that think like humans. Systems that think rationally
Systems that act like humans. Systems that act rationally

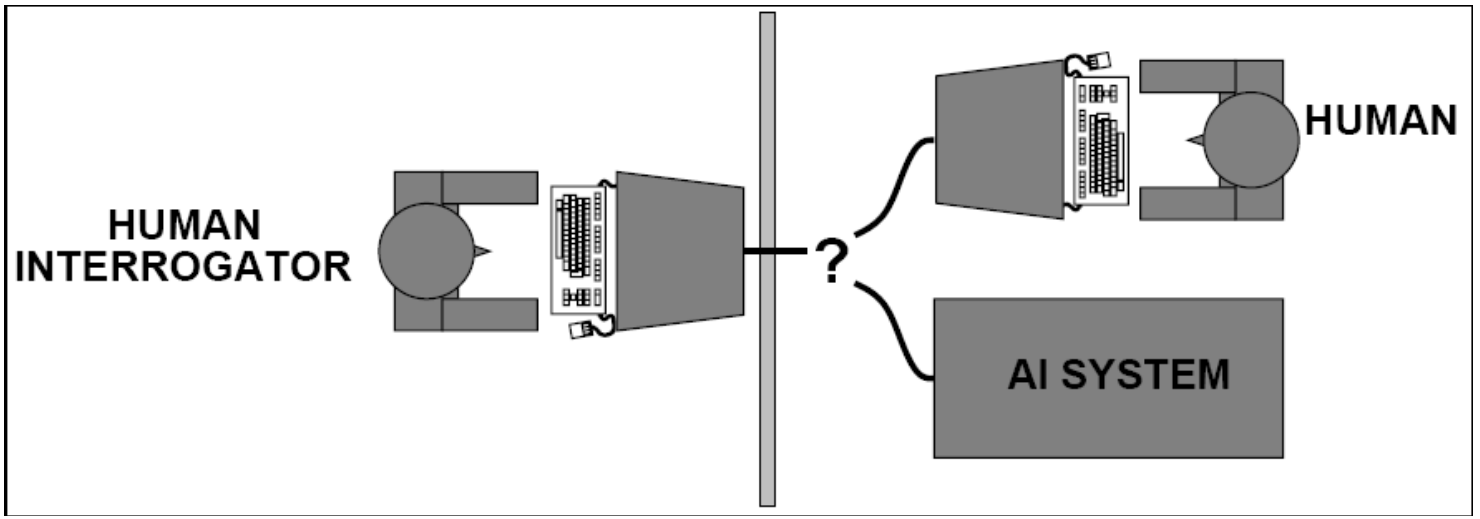
Thought Process and Reasoning

Human Performance	Rationality (Does the right thing)
Empirical Science **(經驗科學)** **Hypothesis, Experimental Confirmation**	**Mathematics & Engineering**

Behavior

Acting Humanly : The Turing Test approach (By Alan Turing, 1950)

Turing Test -- Defines the intelligent behavior as the ability to achieve human-level performance in all cognitive tasks, sufficient to fool an interrogator.



To pass the test, a computer would need to posses the following capabilities:

1. **Natural language processing**
2. **Knowledge representation**
3. **Automated reasoning**
4. **Machine learning**

For the **Total Turing Test**, additional abilities are needed :

5. **Computer vision**
6. **Robotics**

An example interaction

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Good morning. How are you today?

An example interaction

Good morning. How are you today?
Fine, I guess.

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Now we shall begin the test. You must find out if I am a human or a computer.

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OK, No problem.
Please Ask your questions.

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Fine, I guess.
Now we shall begin the test. You must find out if I am a human or a computer.
OK, No problem.
Please Ask your questions.
Anything?

An example interaction

Good morning. How are you today?
Fine, I guess.
Now we shall begin the test. You must find out if I am a human or a computer.
OK, No problem.
Please Ask your questions.
Anything?
Yes.

An example interaction

Good morning. How are you today?
Fine, I guess.
Now we shall begin the test. You must find out if I am a human or a computer.
OK, No problem.
Please Ask your questions.
Anything?
Yes.
Are you a computer?

An example interaction

Good morning. How are you today?
Fine, I guess.
Now we shall begin the test. You must find out if I am a human or a computer.
OK, No problem.
Please Ask your questions.
Anything?
Yes.
Are you a computer?
Yes.

An example interaction

Good morning. How are you today?
Fine, I guess.
Now we shall begin the test. You must find out if I am a human or a computer.
OK, No problem.
Please Ask your questions.
Anything?
Yes.
Are you a computer?
Yes.
Got you!

An example interaction

Good morning. How are you today?
Fine, I guess.
Now we shall begin the test. You must find out if I am a human or a computer.
OK, No problem.
Please Ask your questions.
Anything?
Yes.
Are you a computer?
Yes.
Got you!
Nuts

Thinking Humanly : The cognitive modelling approach

How humans think ? Two ways to determine that:
- **Introspection(內省)--catch our own thoughts as they go by.**
- **Psychological(心理學的) Experiments.**

※The **cognitive science** (認知學)

- brings together both *computer models from AI* and *experimental techniques from psychology*, and
- tries to construct precise and testable theories of the workings of the human mind.

※Once there is a sufficiently precise theory of the mind, it becomes possible to express the theory as a computer program.

Thinking Rationally : The laws of thought approach

Syllogisms(三段論法 -- Aristotle) provides patterns for argument structures that always give correct conclusions given correct premise. It initiated the field of *formal logic*.

※For example:

Socrates is a man; all men are mortal; therefore Socrates is mortal.

※Formal logic provides a precise notation for statements about all kinds of things in the world and the relations between them.

※Logicists in AI hope to build programs, based on formal logic, to create intelligent systems.

※ Two main obstacles to this approach :

- Knowledge uncertainty, and
- Difference between being able to solve a problem “in principle” and “in practice”.

🗁 Acting Rationally : The rational agent approach

Acting rationally **means acting so as to achieve one's goal, given one's beliefs. An *agent* is just something that perceives and acts.**

※ In this approach, AI is viewed as the study and construction of rational agents.

- An agent usually **think** rationally before **act** rationally -- making correct inference is sometimes *part*(not *all*) a rational agent.
- Acting rationally may not involves inference, for example, pulling one's hand off of a hot stove -- a reflex action.
- All the "**cognitive skills**" needed for the Turing Test must be there to allow rational actions.

※ Thus, two advantages to study AI as rational agents:

- More general than the “laws of thought” approach -- correct inference is only a useful mechanism for achieving rationality, not a necessary one.
- More amenable to scientific development than approaches based on human behavior or human thought -- **rationality** is clearly defined.

※ **Limited rationality** is usually used to simplify problems.

The foundations of Artificial Intelligence

🗁 Philosophy(428 B.C. - present)

※**Initiators** : Socrates, Plato, Aristole:

- **Socrates:** When he asked "*what is characteristic of goodness which makes all actions good?*" -- he was asking an ***algorithm*** to distinguish goodness from badness.
- **Aristotle:** developed the **syllogisms** to formulate more precisely the laws governing the *rational part*, but not the *intuitive part*, of the mind.

※**Dualism(**二元論) : Rene Descartes (1596-1650)

In addition to the part that is governed by the physical laws, there is also a part of mind that is outside of nature, exempt from physical laws. *(http://swift.eng.ox.ac.uk/jdr/desc.html)*

※Materialism(唯物論)

All the world, including brain and mind, operate according to physical laws.

※ 中庸論

Metal Processes and consciousness are part of the physical world, but inherently unknowable; they are beyond rational understanding.

Some philosophers critical of AI have adopted exactly this position.

※Traditional AI philosophy

The mind was conceived of as a physical device operating principally by reasoning with the knowledge that it contained.

The next problem is to establish the source of knowledge:

- **empiricist :**

1. **induction** (David Hume) **:** General rules are acquired by exposure to repeated associations between their elements.

2. **logical positivism** (Bertrand Russell) **:** All knowledge can be characterized by logical theories connected, ultimately, to **observation sentences** that correspond to sensory inputs.

3. **confirmation theory** (Rudolf Carnap & Carl Hempel) : attempt to establish the nature of the connection between the observation sentences and the theories, *i.e. how knowledge can be acquired from experience*.

※Connection between knowledge and action

What for should this connection take, and how can particular actions be justified? -- vital to AI on building an **agent** whose actions are *justifiable*, or *rational*.

- **means-ends analysis :**

  Classifies things in terms of the functions they serve and oscillates among ends, functions required, and means that perform them.

  1. **Aristotle :** We assume the end and consider how and by what means it is attained, and if it seems easily and best produced thereby.

  2. **Newell and Simon :** implemented the **GPS**(General Problem Solver), the main methods of which embody the heuristic of means-ends analysis.

🗁 Mathematics (A.C. 800 - present)

Three main areas that make AI to a formal science: **computation**, **logic**, and **probability**.

※Computation and Logic

- **al-Khowarazmi :** Arabic numerals and algebra -- expressing a computation as a formal **algorithm**.
- **George Bool :** formal language for making logic inference, 1847.
- **Gottlob Frege :** First order logic, 1879. Mostly used as the basic knowledge representation system.
- **Alfred Tarski(1902-1983) :** reference theory -- relates the objects in a logic to objects in the real world.

- **David Hilbert :** asked if there were fundamental limits to the power of effective proof procedures, 1900.
- **Kurt Godel : Incompleteness theorem**, 1931. In any language expressive enough to describe the properties of natural numbers, there are true statements that are undecidable.
- **Alan Turing :** state that Turing machine is capable of computing any computable function.
- ***Intractability :*** A class of problems is called intractable if the time required to solve instances of the class grows at least **exponentially** with the size of the instances. Must be solved by **reduction**.
- **Steven Cook and Richard Karp : NP-completeness** -- A method for recognizing intractable problems, 1971.

※Probability

- **Gerolamo Cardano (1501-1576) :** First framed the idea of probability.
- **James Bernoulli(1654-1705) :** Alternatively viewed probability as a *subjective* “degree of believe“ which can be updated as new evidence is obtained.
- **Thomas Bayes :** Proposed a rule, in 1763, for updating subjective probabilities in the light of new evidence -- the basis of the modern approach to uncertain reasoning in AI systems.
- **John Von Neumann and Oskar Morgenstern : *Decision theory***, 1944, combines probability theory with utility theory to provide the first general theory that can distinguish good actions from bad ones.

🗁 Psychology (1879 - present)

※Early stage

- **Hermann Von Helmholtz (1821-1894) and Wilhelm Wundt(1832-1920) :** Begun the scientific psychology -- apply scientific method to the study of human vision. They used **introspection**.

※Behaviorism

- **John Watson (1878-1958) and Edward Lee Thorndike (1874-1949) :** Rebelled against introspection. Insisted on:

objective measure

percepts(stimulus) ----**?**----> **actions**(response)

※Cognitive psychology

- **William James (1842-1910) :** Perception involved a form of unconscious logical inference.
- **Kenneth Craik :** Put back the missing mental step between stimulus and response.

  Claimed that **beliefs**, **goals**, and **reasoning steps** could be useful valid components of a theory of human behavior.

  Three key steps of a knowledge-based agent:

  1. the stimulus must be translated into an internal representation,
  2. the representation is manipulated be cognitive process to derive new internal representations, and
  3. these are in turn retranslated back to action.

※Modern psychology (1960-present)

Since the 1960s, ***Information-Processing*** view has dominated psychology.

Cognitive theory should be like a computer program -- means that the theory should describe cognition as consisting of well-defined transformation process operating at the level of the information carried by the input signal.

🗁 Computer Engineering(1940 - present)

🗁 Linguistic (1957 - present)

※Early works

Much of the early work in **knowledge representation** was tied to language and informed by research in linguistics.

- **B. F. Skinner :** Published ***Verbal Behavior***, a comprehensive behaviorist approach to language learning, but with a missing part on the notion of creativity in language.

- Norm Chomsky : ***Syntax structure*** theory. Explain, by using syntactic models, the missing part of behaviorist theory.

※Modern linguistics and AI

- A hybrid field called computational linguistics or natural language processing is the intersection of AI and linguistics.

The History of Artificial Intelligence

🗁 The gestation of artificial intelligence (1943-1956)

※Warren Mcculloch and Walter Pitts (1943)

- They drew on three sources :

1. Knowledge of the basic physiology and function of neurons in the brain; (---> **connectionist**)
2. Formal analysis of propositional logic due to Russell and Whitehead; (---> **logicist**)
3. Turing theory of computation.

- They proposed a model of artificial neurons and showed:

4. Any computable function could be computed by some network of connected neurons, and
5. All the logical connectives could be implemented by simple net structures.

※Marvin Minsky and Dean Edmons (Princeton, 1951)

Built the first neural network computer, the SNARC using 3000 vacuum tubes to simulate a network of 40 neurons.

※Dartmouth workshop, summer 1956

- Newell and Simon present a reasoning program, the Logic Theorist(LT) and claimed the program can think nonnumerically.
- The agreement to adopt John McCarthy‘s name of the field, artificial intelligence.

🗁 Early enthusiasm, great expectations (1952-1969)

※Newell and Simon : GPS (CMU), 1961

Designed to imitate human problem-solving protocols, it was the first program to embody the “thinking humanly” approach.

※At IBM

- **Herbert Gelernter (1959) *: Geometry Theorem Prover***, using numerical representation of a diagram to cut down reasoning paths.
- **Arthur Samuel (1952-):** Wrote a series of programs for checker(draughts) that eventually proved to **learn** to play a better (tournament- level) game than its creator.

※John McCarthy at MIT (1958) :

- Defined the high-level language **LISP**.
- Invented the time sharing conception.
- Advice Taker. (in *Programs with Common Sense* paper) -- A hypothetical program. It used knowledge to search for solutions to problems.

  Unlike Logic Theorist and Geometry Theorem Prover, it was to embody **general** knowledge of the world.

  The first complete AI system resembled a rational agent.

  Advance by the resolution method (a complete theorem-proving algorithm for first-order logic) by J. A. Robinson.
- Shakey robotics project (Stanford Research Institute -- SRI), the first to demonstrate the complete integration of logical reasoning and physical activity.

※Marvin Minsky at MIT (moved to in 1958) :

- Begin to concentrate on limited problem domains, the **microworlds**.
- Tom Evens‘s ANALOGY program (1968).

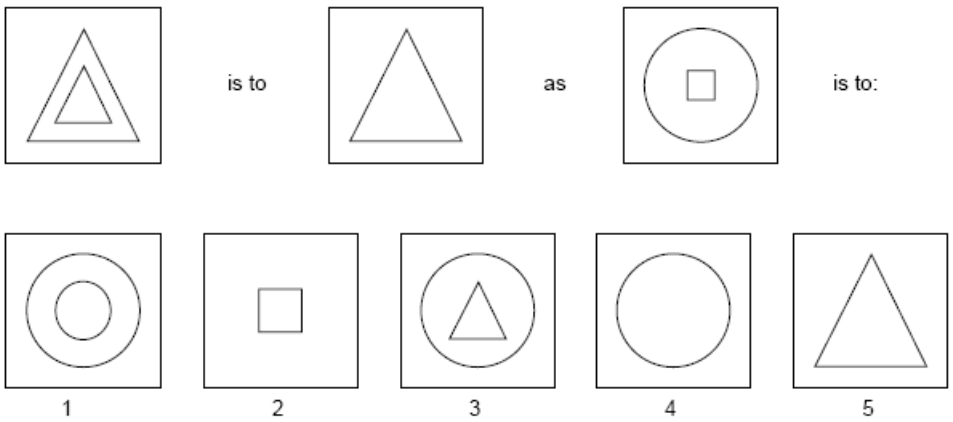

Figure 2: An example problem solved by Evans's ANALOGY program.

- **Blocks world** :

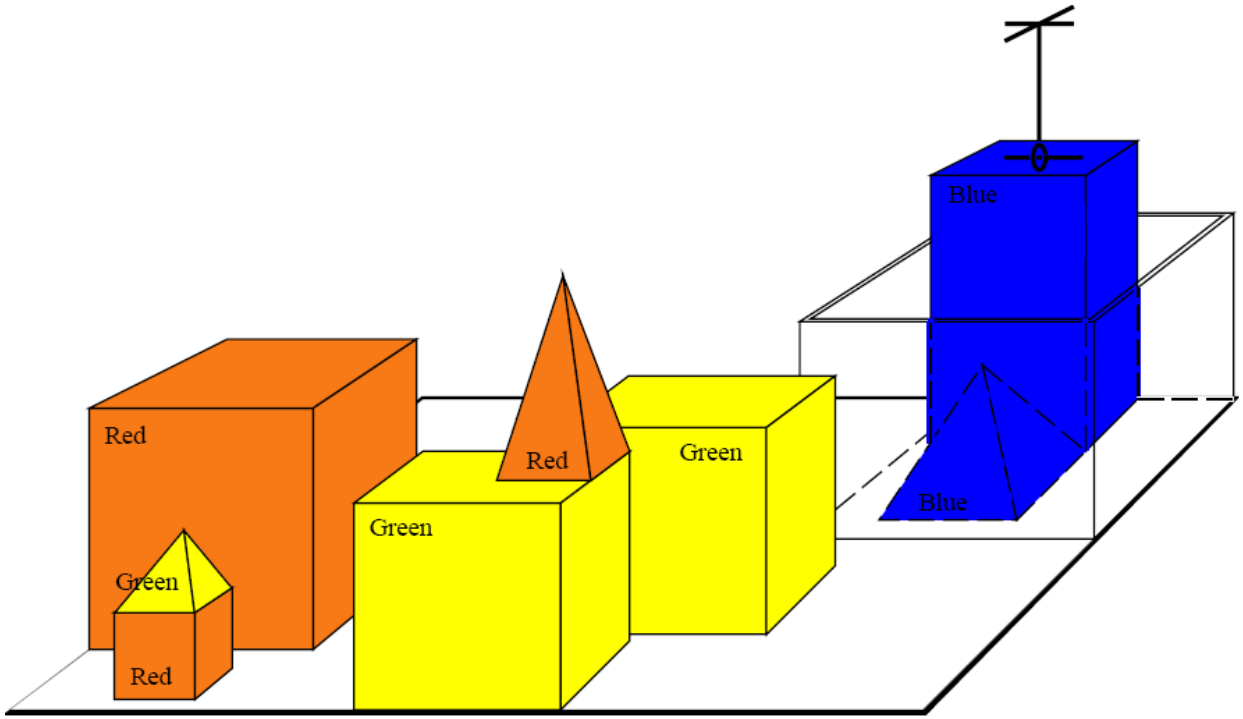

Figure 3: A scene from the blocks world. A task for the robot might be "Pick up a big red block", expressed either in natural language or in a formal notation

※Neural networks :

- **Adalines** (Bernie Widrow, 1962) and **Perceptrons** (Frank Rosenblatt, 1962) both enhance Hebb‘s learning method.
- Rosenblatt‘s **perceptron convergence theorem** shows that the learning algorithm could adjust the connection strengths of a perceptron to match any input data.

🗁 A dose of reality (1966-1974)

Demonstration ≠ Practical use

※The first kind of difficulty :

Programs often contained little or no knowledge of their subject matter, and succeeded by means of simple syntactic manipulations.

"Where there is a will, there is a way."

有意愿的地方，有一種模式。.

※The second kind of difficulty :

- Most of the early AI programs always attempted to solve tough and intractable problems based on the success in a **microworld**.
- *The fact that a program can find a solution in principle does not mean that the program contains any of the mechanism needed to find it in practice.*
- The illusion of unlimited computational power can be find in both **resolution theorem proving** and **machine evolution** (**genetic algorithm**).

※The third kind of difficulty :

Some fundamental limitations existed on the basic structures which were used to generate intelligent behavior.

- For example, a two-input perceptron could not be trained to recognize when its two inputs were different.

🗁 Knowledge-based systems: The key to power? (1969-1979)

※From weak methods era to knowledge-intensive systems :

- DENERAL (Buchanan *et al*., 1969 Stanford) : used expertise derived from large numbers of special-purpose rules. It is for inferring molecular structure.
- The **expert systems** methodology appeared.
- MYCIN : Blood infection diagnose system, 450 rules initially. The first system to include rules reflecting uncertainty associated with (medical) knowledge using **certainty factors**.
- Domain knowledge also started to be used in the area of understanding natural language.
- Many **knowledge representation languages** were developed, e.g. **Prolog**, **PLANNER**, **OPS5**.

🗁 AI becomes an industry (1980-1988)

※R1 at Digital Equipment Corporation(DEC)

※The Fifth Generation Computer System(FGCS) project in Japan -- 10 years plan.

※MCC --a research consortium to counter Japan‘s FGCS project

🗁 The return of neural networks (1986-present)

After a few years‘ work, large collections of simple neurons could be understood in much the same way as large collections of atoms in solid.

※The real impetus(動力)

Reinvention of the **back-propagation learning algorithm** first found in 1969 by Bryson and Ho.

🗁 Recent events (1987-present)

It is now more common :

- to build on existing theories than to propose brand new ones,
- to based claims on rigorous theorems or hard experimental evidence rather than on intuition, and
- to show relevance to real-world applications rather than toy examples.

※Speech recognition -- Hidden Markov Models

- Based on a rigorous mathematical theory
- Generated by a process of training on a large corpus of real speech data.

※Planning

※Probability and decision theory

※Starting to look at the “whole agent” problem

Aims to understand the workings of agents embedded in real environment with continuous sensory inputs.

The State of The ART

AI systems are helping people in doing a lot of jobs, **advising**, **monitoring**, **game playing**, **information gathering**, even **driving**.

} 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
} 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