Introduction to AI and Intelligent Systems

"It is not my aim to surprise or shock you--but the simplest way I can summarize is to say that there are now in the world machines that can think, that can learn and that can create. Moreover, their ability to do these things is going to increase rapidly until--in a visible future--the range of problems they can handle will be coextensive with the range to which the human mind has been applied." --Herbert Simon

- *Intelligence* is their ability to understand and learn things. 2 *Intelligence* is the ability to think and understand instead of doing things by instinct or automatically.
  (Essential English Dictionary, Collins, London, 1990)

- In order to think, someone or something has to have a brain, or an organ that enables someone or something to learn and understand things, to solve problems and to make decisions. So we can define intelligence as the ability:

  - to learn and understand,
  - to solve problems, and
  - to make "*appropriate*" decisions.

What is Artificial Intelligence (AI)?

- AI is an applied sub-field of computer science, which is a combination of
    - computer science,
    - physiology, and
    - philosophy.

- More broadly:

  AI is a very general investigation of the nature of intelligence and the principles and mechanisms required for understanding or replicating it.

Three main goals in AI research:

1. **Empirical:**

   Empirical modelling of existing intelligent systems - work done in close collaboration with work in psychology, linguistics, philosophy

2. **Theoretical:**

   Theoretical analysis and exploration of possible intelligent systems

3. Practical

Solving practical problems in the light of the above two goals, namely: designing useful new intelligent or semi-intelligent machines

Turing Test

- One of the most significant papers on machine intelligence, "*Computing Machinery and Intelligence*", was written by the British mathematician ***Alan Turing*** over fifty years ago.

- It stands up well under the test of time, and the Turing's approach remains universal.

- The questions asked are:

  1. Is there thought without experience?
  2. Is there mind without communication?
  3. Is there language without living?
  4. Is there intelligence without life?

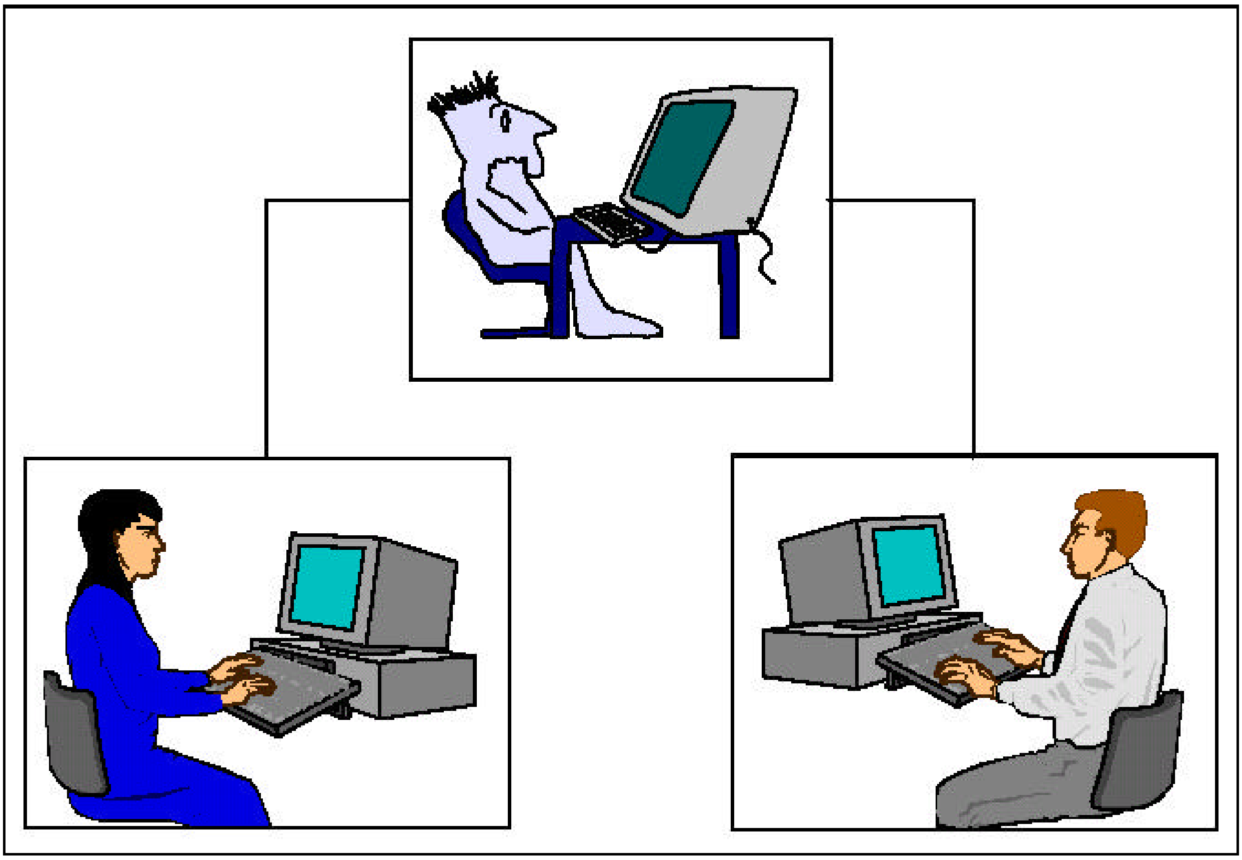
- All these questions are just variations on the fundamental questions of artificial intelligence, *Can Machine Think?*
- He invented the *Turing Imitation Game* to determine artificial intelligence.
- The imitation game originally included two phases.

Turing Imitation Game: Phase 1

- The interrogator, a man and a woman are each placed in separate rooms.

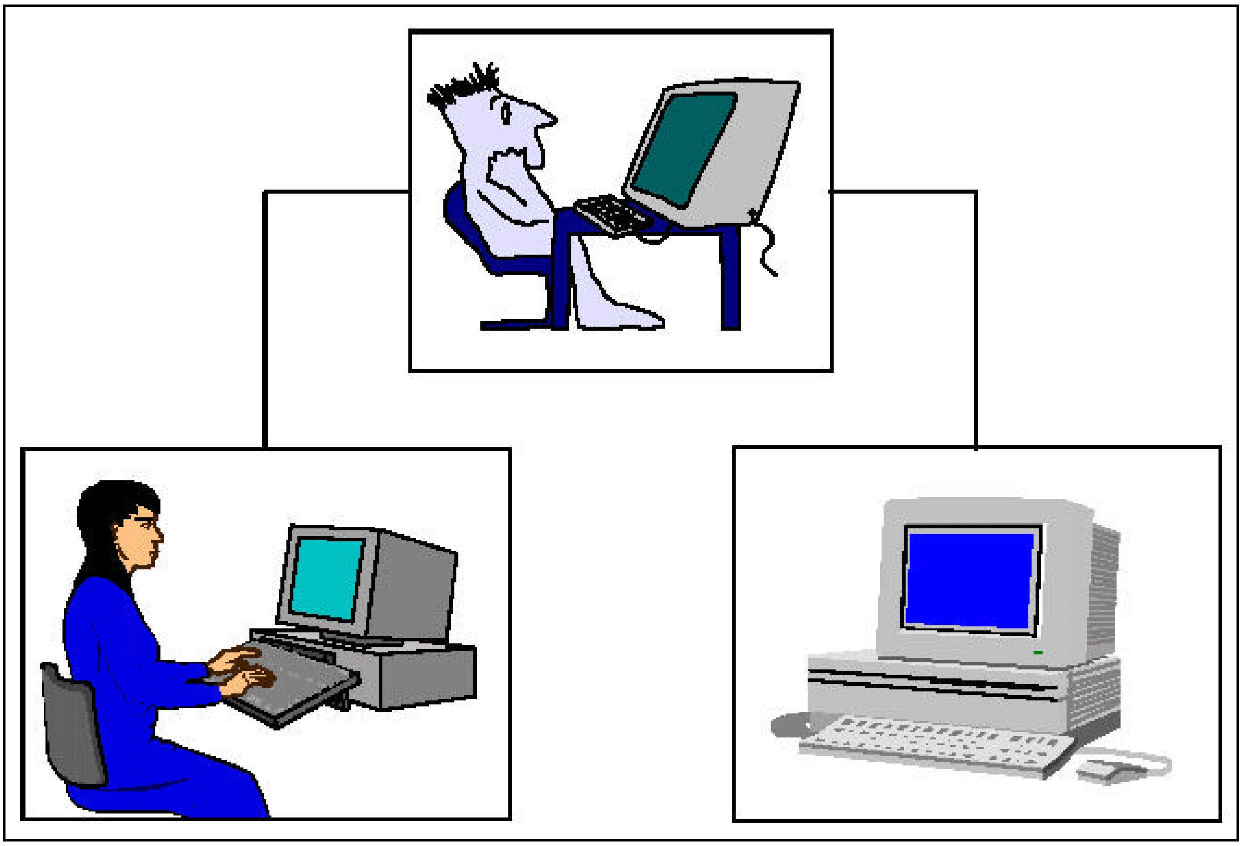
- The interrogator's objective is to work out who is the man and who is the woman by questioning them.

- 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 2

- 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 behaviour test.



- The Turing Test has two remarkable qualities that make it really universal.

  1. By maintaining communication between the human and the machine via terminals, the test given us an objective standard view on intelligence.

  2. 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.

- 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, organise and use human expert knowledge in some narrow area of expertise.
- 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 pass the Turing test, it provides a basis for the verification and validation of knowledge-based systems.

Intelligent systems normally can be classified into two main types:-

1.Computational Intelligence

- Artificial Neural Networks
- Fuzzy Set Theory / Fuzzy Logic
- Evolutionary Computation / Genetic Algorithms
- -Data Driven

2. Classical Artificial Intelligence

- Artificial Intelligence
- Knowledge-based Systems / Expert Systems
- -Logic Driven

Computational Intelligence

- Artificial Neural Networks/Connectionism

  An information technology based on the way neurons in the brain collectively process information.

- Fuzzy Set Theory/Fuzzy Logic

  An information technology based on the use of approximate information and uncertainty to generate decisions in a manner similar to human reasoning.

- Genetic Algorithms

  An information technology which mimics the processes of biological evolution with its ideas of natural selection and survival of the fittest to provide effective solutions for optimization problems.

Classical Artificial Intelligence

- Artificial Intelligence

  A set of information technologies which exhibit some ability for intelligent behaviour via artificial means.

- Knowledge-Based Systems/Expert Systems

  An information technology based on the application of rules derived from expert knowledge which can imitate some intelligent behaviour.

Much knowledge and expertise, little empirical data

Physical models
Rule-based expert systems
Fuzzy systems
Neuro-fuzzy systems
Artificial Neural Networks
Statistical methods

Much empirical data, little knowledge and expertise

History of Artificial Intelligence

The birth of Artificial Intelligence (1943 – 1956)

- The first work recognised in the field of AI was presented by **Warren McCulloch** and **Walter Pitts** in 1943. They proposed a model of an *artificial neural network and demonstrated that simple network structures could learn.*

- McCulloch, the second "founding father" of AI after Alan Turing, had created the corner stones of neural computing and artificial neural networks (ANN).

- The third founder of AI was **John von Neumann**, a Hugarian-born mathematician. He encouraged and supported two of his graduate students (**Marvin Minsky** and **Dean Edmonds**) in the Princeton mathematics department to build the *first neural network computer* in 1951.

- **Claude 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. Even if the new von Neumann-type computer could examine one move per microsecond, it would take $3 * 10^{106}$ years to make its first move. Thus Shannon *demonstrated the need to use heuristics in the search for the solution.*

- In 1956, **John McCarthy**, **Martin Minsky** and **Claude Shannon** organised a summer workshop to brought together researchers interested in the study of machine intelligence, artificial neural nets and automata theory. Although there were 10 researchers, this workshop *gave birth to a new science called Artificial Intelligence (AI)*.

The rise of AI (1956 - late 1960s)

- Works on neural computing and ANN started by McCulloch and Pitts were 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** developed a general-purpose program to simulate human-solving methods. They make use of *state space search* to determine 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 60s, 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*.

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

- By 1970, it is the downfall of AI. 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.

- Because AI researchers developed general methods for broad classes of problems, early programs contained little or even no knowledge about a problem domain.

- Many of the problems that AI attempted to solve were too broad and too difficult.

The technology of expert systems, or the key to success (early 1970s – mid-1980s)

- Probably the most important development in the 70s was the realisation that *the domain for intelligent machines had to be sufficiently restricted*.

- When weak methods failed, researchers finally realised that the only way to deliver practical results was to solve typical cases in narrow areas of expertise, making large reasoning steps.

- NASA supported the *DENDRAL* project that was developed at Stanford University to determine the molecular structure of Martian soil, based on the mass spectral data provided by a mass spectrometer.

- The project focuses on incorporating the expertise of an expert into a computer program to make it perform at a human expert level. Such programs were later called *expert system*.

- DENDRAL marked a major “paradigm shift” in AI: a shift from general-purpose, knowledge-sparse weak methods to domain-specific, knowledge-intensive techniques.

- The DENDRAL project originated the fundamental idea of expert systems – knowledge engineering, which encompassed techniques of capturing, analysing and expressing in rules an expert's "know-how".

- In 1986, in Waterman's survey reported a remarkable number of successful expert system applications in different areas: chemistry, electronics, engineering, geology, management, medicine, process control and military science.

- Although Waterman found nearly 200 expert systems, most of the applications were in the field of medical diagnosis.

- However,

    - Expert systems are restricted to a very narrow domain of expertise.

    - Expert systems can show the sequence of the rules they applied to reach a solution, but cannot relate accumulated, heuristic knowledge to any deeper understanding of the problem domain.

- Expert systems have difficulty in recognising domain boundaries. When given a task different from typical problem, an expert system might attempt to solve it and fail in rather unpredictable ways.

- Heuristic rules represent knowledge in abstract form and lack even basic understanding of the domain area. It makes the task of identifying incorrect, incomplete or inconsistent knowledge difficult.

- Expert systems, especially the first generation, have little or no ability to learn from their experience.

How to make machine learn, or the rebirth of neural networks (mid-1980 – onwards)

- In mid-80s, researchers found that building an expert system required much more than putting enough rules in it. They decided to have a new look at neural networks.

- By the late 60s, most of the basic ideas and concept necessary for neural computing had already been formulated. The solution only start to emerge in mid-80s. The major reason for the delay was technological: there were no PCs or powerful workstations to model and experiment with ANN.

- In 1980, **Grossberg** provided the basis for a new class of neural networks established using a new self-organisation theory (*adaptive resonance theory*).

- In 1982, **Hopfield** introduced neural networks with feedback – *Hopfield networks*, which attracted much attention in the eighties.

- In 1982, **Kohonen** introduced the *self-organising map*.

- In 1983, **Barto, Sutton and Anderson** introduced *reinforcement learning* and its application in control.

- The real breakthrough came in 1986 when the *back-propagation* learning algorithm, first introduced by **Bryson and Ho** in 1969, was reinvented by **Rumelhart and McClelland**.

The new era of knowledge engineering, or computing with words (late 1980s – onwards)

- Neural network technology offers more natural interaction with the real world than do systems based on symbolic reasoning.

- ANN can learn, adapt to changes in a problem’s environment, and establish patterns in situations where rules are not known.

- However, they lack explanation facilities and usually act as black box. The process of training neural networks with current technologies is slow, and frequent retraining can cause serious difficulties.

- Due to this, another branch of research that attracts attention is *fuzzy logic*. As this technology can deal with vague, imprecise and uncertain knowledge and data, it performs much better compare to classical expert system.

- Fuzzy Logic or fuzzy set theory was introduced by Professor Lotfi Zadeh in 1965. Eventually, fuzzy theory, ignored in the West, was taken seriously in the East – by the Japanese. It has been used successfully since 1987 in Japanese-designed dishwashers, washing machines, air conditioners, television sets, copiers, and even cars.

Characteristics of an Intelligent System (The wish list)

A truly intelligent system is characterised as one that can

- exhibit adaptive goal-oriented behaviour
- learn from experience
- use vast amounts of knowledge
- exhibit self awareness
- interact with humans using language
- tolerate error and ambiguity in communication
- respond in real time

Applications

- Some applications of intelligent systems can be found in agriculture, finance, gambling, medicine, music, robotics, and weather forecasting.
- Fuzzy logic and Neuro-fuzzy can also be found in some appliances like video camera, washing machine, rice cooker, and air-conditioner.

- What else can you think of?