Lecture 1

INTRODUCTION TO ARTIFICIAL INTELLIGENCE
Why would you study artificial intelligence?

• Artificial intelligence is quickly emerging from the laboratory and is venturing into the **commercial marketplace**

• Its impact on society is growing rapidly: in speech and language technology, strategic planning and diagnosis, process and system control, vision and authentication systems, information retrieval and data-mining and many other contexts

• The many **new realizations** continually redefine which applications we can achieve and push existing technology to its limits

• Today a knowledge society is emerging and reasoning with knowledge is becoming a central issue. The mere fact that **knowledge is power** makes the importance of artificial intelligence indisputable

• Due to the **rapidly expanding role of artificial intelligence** in our current and future society, there is an urgent need for **academically trained people** with the variety of backgrounds who are familiar with the fundamentals of artificial intelligence, aware of its reasonable expectations, and have practical experience in solving problems related to artificial intelligence
Greek myths of Hephaestus and Pygmalion incorporate the idea of intelligent robots. Many other myths in antiquity involve human-like artifacts. Many mechanical toys and models were actually constructed, e.g., by Hero, Daedalus and other real persons.

5th century B.C.

- Aristotle invented syllogistic logic, the first formal deductive reasoning system.

13th century

- Talking heads were said to have been created, Roger Bacon and Albert the Great reputedly among the owners.

- Ramon Llull, Spanish theologian, invented machines for discovering nonmathematical truths through combinatories.

15th century

- Invention of printing using moveable type. **Gutenberg Bible** printed (1456).
15th - 16th century
- Clocks, the first modern measuring machines, were first produced using lathes

17th century
- Early in the century, **Descartes** proposed that bodies of animals are nothing more than complex machines. Many other 17th century thinkers offered variations and elaborations of **Cartesian mechanism**
- Hobbes published the *The Leviathan*, containing a material and combinatorial theory of thinking
- Pascal created the first **mechanical digital calculating machine** (1642)
- **Leibniz** improved **Pascal's machine** to do multiplication and division (1673) and envisioned a universal calculus of reasoning by which arguments could be decided mechanically
The history of artificial intelligence: ancient history (3)

18th century
• The 18th century saw a profusion of mechanical toys, including the celebrated mechanical duck of Vaucanson and von Kempelen's phony mechanical chess player, The Turk (1769)

19th century
• Luddites (led by Ned Ludd) destroy machinery in England (1811-1816)
• George Boole developed a binary algebra representing (some) "laws of thought"
• Charles Babbage and Ada Byron (Lady Lovelace) worked on programmable mechanical calculating machines
20th century - first half

- **Bertrand Russell** and **Alfred North Whitehead** published *Principia Mathematica*, which revolutionized formal logic. Russell, **Ludwig Wittgenstein** and **Rudolf Carnap** lead philosophy into logical analysis of knowledge.

- **Karel Kapek's** play "R.U.R. " (Rossum's Universal Robots) opens in London (1923) - first use of the word "robot" in English.


- Arturo Rosenblueth, **Norbert Wiener** and Julian Bigelow coin the term "cybernetics" in a 1943 paper. Wiener's popular book by that name published in 1948.

- **Vannevar Bush** published *As We May Think* (Atlantic Monthly, July 1945) a prescient vision of the future in which computers assist humans in many activities.

- **A. M. Turing** published "Computing machinery and Intelligence" (1950) - introduction of Turing's Test as a way of operationalizing a test of intelligent behavior.

- **Claude Shannon** published detailed analysis of chess playing as a search (1950).
The history of artificial intelligence: modern history (1)

1950: Alan Turing publishes "Computing Machinery and Intelligence"

1956: John McCarthy coined the term "artificial intelligence" as the topic of the Dartmouth Conference, the first conference devoted to the subject

1956: Demonstration of the first running AI program at Carnegie Mellon University

1958: John McCarthy invents the Lisp language, an AI programming language, at Massachusetts Institute of Technology (MIT)

1952-62: Arthur Samuel (IBM) wrote the first game-playing program, for checkers, to achieve sufficient skills to challenge a world champion. Samuel's machine learning programs were responsible for the high performance of the checkers player

1962: First industrial robot company, Unimation, founded
1963: Thomas Evan's program, ANALOGY, written as part of his PhD work at MIT, demonstrated that computers can solve the same analogy problems as are given on IQ tests.

1964: Danny Bobrow's dissertation at MIT shows that computers can understand natural language well enough to solve algebra word problems correctly.

1965: Joseph Weizenbaum (MIT) built ELIZA, an interactive problem that carries on a dialogue in English. It was a popular toy at AI centers on the ARPA-net when a version that "simulated" the dialogue of a psychotherapist was programmed.

1966: Ross Quillian (PhD dissertation at Carnegie Inst. of Technology now CMU) demonstrated semantic nets.

1971: Terry Winograd's PhD thesis (MIT) demonstrates the ability of computers to understand English sentences in a restricted world of children's blocks, in a coupling of his language understanding program, SHRDLU, with a robot arm that carried out instructions typed in English.

1973: The Assembly Robotics group at Edinburgh University builds **Freddy**, the Famous Scottish Robot, capable of using vision to locate and assemble models.

Mid 70's: Alan Key and Adele Goldberg (Xerox PARC) developed the Smalltalk language, establishing the power of object-oriented programming and of icon-oriented interfaces.

1978: **Herb Simon** wins the Nobel Prize in Economics for his theory of bounded rationality, one of the cornerstones of AI known as "satisficing".

1979: The first computer-controlled autonomous vehicle, the Stanford Cart, is built.
1983: Danny Hillis co-founds Thinking Machines, the first company to produce massively parallel computers

1985: The drawing program, Aaron, created by Harold Cohen, is demonstrated at AI conference

1990s: Major advances in all areas of AI. Significant demonstrations in machine learning, intelligent tutoring, case-based reasoning, multi-agent planning, scheduling, uncertain reasoning, data mining, natural language understanding and translation, vision, virtual reality and games

1997: The Deep Blue chess program beats the current world chess champion, Garry Kasparov, in a widely followed match

Late 90's: Web crawlers and other AI-based information extraction programs become essential in widespread use of the world-wide-web

2000: Interactive robot pets become commercially available. MIT displays Kismet, a robot with a face that expresses emotions. Carnegie Mellon robot Nomad explores remote regions of Antarctica and locates meteorites
Roots of artificial intelligence (1)

- PHILOSOPHY (428 b.c. - present)
  - Can **formal rules** be used to draw **valid conclusions**?
  - How does the **mental mind** arise from a **physical brain**?
  - Where does **knowledge come from**?
  - How does **knowledge lead to action**?

- MATHEMATICS (c. 800 - present)
  - What are the **formal rules** to draw **valid conclusions**? (**formal logic**)
  - What can be **computed**? (**algorithms**)
  - How do we **reason** with uncertain information? (**probability theory, fuzzy sets**, etc.)
Roots of artificial intelligence (2)

- **ECONOMICS (1776 - present)**
  - How should we **make decisions** so as to maximize payoff? (utility theory and decision theory)
  - How should we do this when others may not go along? (game theory)
  - How should we do this when the payoff may be far in the future? (operations research, Markov decision processes)

- **NEUROSCIENCE (1861 - present)**
  - How do human brains **process information**? (neural networks)

- **PSYCHOLOGY (1879 - present)**
  - How do humans and animals think and act? (behaviorism, cognitive psychology, cognitive science)
Roots of artificial intelligence (3)

- **COMPUTER ENGINEERING** (1940 - present)
  - How can we build an *efficient computer*?

- **CONTROL THEORY AND CYBERNETICS** (1948 - present)
  - How can artifacts operate under their own *control*?

- **LINGUISTICS** (1957 - present)
  - How does *language* relate to thought?
    (natural language processing, knowledge representation)
Definitions of artificial intelligence (1)

• Today we still don’t have an unambiguous and comprehensive definition of artificial intelligence

• Some examples of definitions are:
  - Artificial intelligence is that branch of science which makes machines perform tasks which would require intelligence when performed by humans (Marvin Minsky)
  - Artificial Intelligence is the study of the formal (that is, mechanical or computational) properties of problems and problem-solving methods, with the aim of equipping computers with problem-solving capabilities that are comparable to those of a human being
Actually definitions of artificial intelligence can be grouped in 4 main categories:

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<th>Systems that think like humans</th>
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### Definitions of artificial intelligence (3)

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<td>The existing new effort to make computers think … <strong>machines with minds</strong>, in the full and literal sense (Haugeland, 1985)</td>
<td>The study of <strong>mental faculties</strong> through the use of computational models (Charniak and McDermont, 1985)</td>
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<td>The automation of activities that we associate with <strong>human thinking</strong>, activities such as decision-making, problem solving, learning… (Bellman, 1978)</td>
<td>The study of the <strong>computations</strong> that make it possible to perceive, reason, and act (Winston, 1992)</td>
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<td>The art of <strong>creating machines</strong> that <strong>perform functions</strong> that require intelligence when performed by people (Kurzweil, 1990)</td>
<td><strong>Computational intelligence</strong> is the study of the design of <strong>intelligent agents</strong> (Poole et. al., 1998)</td>
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<td>The study of how to make <strong>computers do things</strong> at which, at the moment, people are better (Rich and Knight, 1991)</td>
<td>Artificial Intelligence … is concerned with <strong>intelligent behavior</strong> in artifacts (Nilsson, 1998)</td>
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The previously mentioned categories of definitions can be considered along 2 dimensions:

**Definitions related to thinking processes and reasoning**

- Systems that think like humans
- Systems that think rationally

**Definitions related to behaviour**

- Systems that act like humans
- Systems that act rationally
Definitions of artificial intelligence (5)

The other dimensions can be the following:

- Definitions that evaluate a success of an intelligent artificial system in terms of human action/operation/performance

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Definitions that evaluate a success of an intelligent artificial system in terms of an ideal intelligence called rationality
Definitions of artificial intelligence (6)

• SYSTEMS THAT THINK LIKE HUMANS
  - If we want to develop a computer that thinks like humans we need to know how people think
  - Cognitive science integrates computational models developed in the area of artificial intelligence with techniques from psychology in order to develop theories about how the human mental mind works

• SYSTEMS THAT THINK RATIONALLY
  - This approach is related to logics, that is, logical rules make the mental mind of humans
  - For example, if we know that All people have a head and Alex is one of people, than we can conclude that Alex has a head
Definitions of artificial intelligence (7)

- SYSTEMS THAT ACT LIKE HUMANS
  - In this approach computer capabilities are compared with human capabilities
  - For this purpose a special **test of intelligent behavior** is defined. The test is called the **Turing test**
  - The idea of the test is the following. There are 3 rooms. In the first one there is an artificial intelligence, in the second room- a person or natural intelligence, and in the third room there is a tester. The tester asks questions to both intelligences. If it is impossible to determine which answers were given by the person and which ones by the machine, than the machine has intelligence
Definitions of artificial intelligence (8)

- SYSTEMS THAT ACT LIKE HUMANS (continued)

  To pass the Turing test the computer must have the following capabilities:

  - Natural language processing
  - Knowledge representation
  - Automated reasoning
  - Machine learning
Definitions of artificial intelligence (9)

• SYSTEMS THAT ACT LIKE HUMANS (continued)

- However, the Turing test excludes direct physical contact between the machine and the tester. The so called the Total Turing test brings forward two more requirements:

  ➢ The computer must have computer vision in order to perceive objects, and

  ➢ robotics in order to move objects
Definitions of artificial intelligence (10)

- It is the rational agent approach:
  - The **agent** is just something that acts (agents comes from the Latin agere, to do)
  - A **rational agent** is one that acts so as to achieve the best outcome or, when there is uncertainty, the best expected outcome
Today there are 2 main research directions in artificial intelligence:

**BIONICS**: approaches that have focus on humans and based on empirical knowledge acquired during different experiments

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**PRAGMATIC DEVELOPMENT OF COMPUTER PROGRAMS**: approaches based on rationality and combining mathematics and computer engineering
Tasks of artificial intelligence

• Routine tasks
  - Perception (visual, speech)
  - Natural language processing
  - Good sense judgments
  - Control of robots

• Formal tasks
  - Games
  - Mathematics

• Expert tasks
  - Technical design
  - Scientific analysis
  - Medical diagnostic
  - Financial analysis
Physical symbol system hypothesis

Today intelligent machines are built on the basis of the Physical symbol system hypothesis (Newell and Simon, 1976) that says “intelligent activity, in either human or machine, is achieved through the use of:

- **Symbol patterns** to represent significant aspects of a problem domain
- **Operations** on these patterns to generate potential solutions to problems
- **Search** to select a solution from among these possibilities

As a result 2 main research objects of artificial intelligence are: search and knowledge representation