

# Artificial Intelligence

## Course Learning Outcomes

At the end of this course:

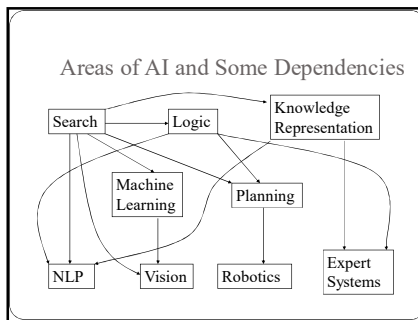
- Knowledge and understanding  
You should have a knowledge and understanding of the basic concepts of Artificial Intelligence including Search, Game Playing, KBS (including Uncertainty), Planning and Machine Learning.
- Intellectual skills  
You should be able to use this knowledge and understanding of appropriate principles and guidelines to synthesise solutions to tasks in AI and to critically evaluate alternatives.
- Practical skills  
You should be able to use a well known declarative language (Prolog) and to construct simple AI systems.
- Transferable Skills  
You should be able to solve problems and evaluate outcomes and alternatives

## Attendance

You are expected to attend all the lectures. The lecture notes (see below) cover all the topics in the course, but these notes are concise, and do not contain much in the way of discussion, motivation or examples. The lectures will consist of slides (Powerpoint), spoken material, and additional examples given on the blackboard. In order to understand the subject and the reasons for studying the material, you will need to attend the lectures and take notes to supplement lecture slides. This is your responsibility. If there is anything you do not understand during the lectures, then ask, either during or after the lecture. If the lectures are covering the material too quickly, then say so. If there is anything you do not understand in the slides, then ask.

In addition you are expected to supplement the lecture material by reading around the subject, particularly the course text.

**Must use text book and references.**



## What is Artificial Intelligence ?

- making computers that think?
- the automation of activities we associate with human thinking, like decision making, learning ... ?
- the art of creating machines that perform functions that require intelligence when performed by people ?
- the study of mental faculties through the use of computational models ?

## What is Artificial Intelligence ?

- the study of computations that make it possible to perceive, reason and act ?
- a field of study that seeks to explain and emulate intelligent behaviour in terms of computational processes ?
- a branch of computer science that is concerned with the automation of intelligent behaviour ?
- anything in Computing Science that we don't yet know how to do properly ? (!)

## What is Artificial Intelligence ?

THOUGHT	Systems that think like humans	Systems that think rationally
	Systems that act like humans	Systems that act rationally
BEHAVIOUR		
	HUMAN	RATIONAL

## Systems that act like humans: Turing Test

- "The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil)
- "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight)

## Systems that act like humans



- You enter a room which has a computer terminal. You have a fixed period of time to type what you want into the terminal, and study the replies. At the other end of the line is either a human being or a computer system.
- If it is a computer system, and at the end of the period you cannot reliably determine whether it is a system or a human, then the system is deemed to be intelligent.

## Systems that act like humans

- The Turing Test approach
  - a human questioner cannot tell if
    - there is a computer or a human answering his question, via teletype (remote communication)
  - The computer must behave intelligently
- Intelligent behavior
  - to achieve human-level performance in all cognitive tasks

## Systems that act like humans

- These cognitive tasks include:
  - *Natural language processing*
    - for communication with human
  - *Knowledge representation*
    - to store information effectively & efficiently
  - *Automated reasoning*
    - to retrieve & answer questions using the stored information
  - *Machine learning*
    - to adapt to new circumstances

## The total Turing Test

- Includes two more issues:
  - *Computer vision*
    - to perceive objects (seeing)
  - *Robotics*
    - to move objects (acting)

## What is Artificial Intelligence ?

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## Systems that think like humans: cognitive modeling

- Humans as observed from 'inside'
- How do we know how humans think?
  - Introspection vs. psychological experiments
- Cognitive Science
  - "The exciting new effort to make computers think ... machines with *minds* in the full and literal sense" (Haugeland)
  - "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning ..." (Bellman)

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## Systems that think 'rationally' "laws of thought"

- Humans are not always 'rational'
- Rational - defined in terms of logic?
- Logic can't express everything (e.g. uncertainty)
- Logical approach is often not feasible in terms of computation time (needs 'guidance')
- "The study of mental facilities through the use of computational models" (Charniak and McDermott)
- "The study of the computations that make it possible to perceive, reason, and act" (Winston)

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## Systems that act rationally: "Rational agent"

- **Rational** behavior: doing the right thing
- **The right thing**: that which is expected to maximize goal achievement, given the available information
- Giving answers to questions is 'acting'.
- I don't care whether a system:
  - replicates human thought processes
  - makes the same decisions as humans
  - uses purely logical reasoning

### Systems that act rationally

- Logic → only *part* of a rational agent, not *all* of rationality
  - Sometimes logic cannot reason a correct conclusion
  - At that time, some *specific (in domain) human knowledge* or information is used
- Thus, it covers more generally different situations of problems
  - Compensate the incorrectly reasoned conclusion

### Systems that act rationally

- Study AI as rational agent – 2 advantages:
  - It is more general than using logic only
    - Because: LOGIC + Domain knowledge
  - It allows extension of the approach with more scientific methodologies

### Rational agents

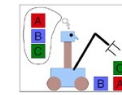
- An **agent** is an entity that perceives and acts
- This course is about designing rational agents
- Abstractly, an agent is a function from percept histories to actions:
 
$$[f: P^* \rightarrow A]$$
- For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- Caveat: computational limitations make perfect rationality unachievable
  - → design best program for given machine resources

- Artificial
  - Produced by human art or effort, rather than originating naturally.
- Intelligence
- is the ability to acquire knowledge and use it" [Pigford and Baur]
- **So AI was defined as:**
  - AI is the study of ideas that enable computers to be intelligent.
  - AI is the part of computer science concerned with design of computer systems that exhibit human intelligence (From the Concise Oxford Dictionary)

- From the above two definitions, we can see that AI has two major roles:
- Study the intelligent part concerned with humans.
  - Represent those actions using computers.

### Goals of AI

- To make computers more useful by letting them take over dangerous or tedious tasks from human
- Understand principles of human intelligence



### The Foundation of AI

- **Philosophy**
  - At that time, the study of human intelligence began with no formal expression
  - Initiate the idea of mind as a machine and its internal operations

### The Foundation of AI

- Mathematics formalizes the three main area of AI: *computation, logic, and probability*
  - Computation leads to analysis of the problems that can be computed
    - *complexity theory*
  - Probability contributes the "degree of belief" to handle *uncertainty* in AI
  - *Decision theory* combines *probability theory* and *utility theory* (bias)

### The Foundation of AI

- Psychology
  - How do humans think and act?
  - The study of human reasoning and acting
  - Provides reasoning models for AI
  - Strengthen the ideas
    - humans and other animals can be considered as information processing machines

## The Foundation of AI

- Computer Engineering
  - How to build an efficient computer?
  - Provides the artifact that makes AI application possible
- The power of computer makes computation of large and difficult problems more easily
- AI has also contributed its own work to computer science, including: time-sharing, the linked list data type, OOP, etc.

## The Foundation of AI

- **Control theory and Cybernetics**
  - How can artifacts operate under their own control?
  - The artifacts adjust their actions
    - To do better for the environment over time
    - Based on an objective function and feedback from the environment
  - Not limited only to linear systems but also other problems
    - as language, vision, and planning, etc.

## The Foundation of AI

- Linguistics
  - For understanding natural languages
    - different approaches has been adopted from the linguistic work
  - Formal languages
  - Syntactic and semantic analysis
- Knowledge representation

## The main topics in AI

Artificial intelligence can be considered under a number of headings:

- Search (includes Game Playing).
- Representing Knowledge and Reasoning with it.
- Planning
- Learning
- Natural language processing
- Expert Systems.
- Interacting with the Environment  
(e.g Vision, Speech recognition, Robotics)

*We won't have time in this course to consider all of these.*

## Some Advantages of Artificial Intelligence

- more powerful and more useful computers
- new and improved interfaces
- solving new problems
- better handling of information
- relieves information overload
- conversion of information into knowledge

## The Disadvantages

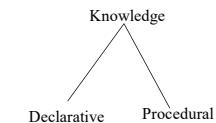
- increased costs
- difficulty with software development - slow and expensive
- few experienced programmers
- few practical products have reached the market as yet.

## Search

- Search is the **fundamental** technique of AI.
  - Possible answers, decisions or courses of action are structured into an abstract space, which we then search.
- Search is either "blind" or "uninformed":
  - blind
    - we move through the space without worrying about what is coming next, but recognising the answer if we see it
  - informed
    - we guess what is ahead, and use that information to decide where to look next.
- We may want to search for the first answer that satisfies our goal, or we may want to keep searching until we find the best answer.

## Knowledge Representation & Reasoning

- The second most important concept in AI
- If we are going to act rationally in our environment, then we must have some way of describing that environment and drawing inferences from that representation.
  - how do we describe what we know about the world?
  - how do we describe it *concisely*?
  - how do we describe it so that we can get hold of the right piece of knowledge when we need it?
  - how do we generate new pieces of knowledge?
  - how do we deal with *uncertain* knowledge?



- Declarative knowledge deals with factoid questions (what is the capital of India? Etc.)
- Procedural knowledge deals with "How"
- Procedural knowledge can be embedded in declarative knowledge

## Planning

Given a set of goals, construct a sequence of actions that achieves those goals:

- often very large search space
- but most parts of the world are independent of most other parts
- often start with goals and connect them to actions
- no necessary connection between order of planning and order of execution
- what happens if the world changes as we execute the plan and/or our actions don't produce the expected results?

## Learning

- If a system is going to act truly appropriately, then it must be able to change its actions in the light of experience:
  - how do we generate new facts from old ?
  - how do we generate new concepts ?
  - how do we learn to distinguish different situations in new environments ?

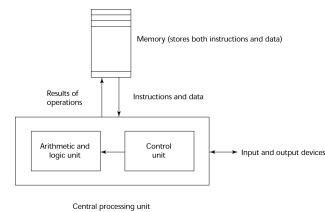
## Interacting with the Environment

- In order to enable intelligent behaviour, we will have to interact with our environment.
- Properly intelligent systems may be expected to:
  - accept sensory input
    - vision, sound, ...
  - interact with humans
    - understand language, recognise speech, generate text, speech and graphics, ...
  - modify the environment
    - robotics

## History of AI

- AI has a long history
  - Ancient Greece
    - Aristotle
  - Historical Figures Contributed
    - Ramon Lull
    - Al Khwarazmi
    - Leonardo da Vinci
    - David Hume
    - George Boole
    - Charles Babbage
    - John von Neuman
  - As old as electronic computers themselves (c1940)

## The 'von Neuman' Architecture



## History of AI

- Origins
  - The Dartmouth conference: 1956
    - John McCarthy (Stanford)
    - Marvin Minsky (MIT)
    - Herbert Simon (CMU)
    - Allen Newell (CMU)
    - Arthur Samuel (IBM)
  - The Turing Test (1950)
  - "Machines who Think"
    - By Pamela McCordkindale

## Periods in AI

- Early period - 1950's & 60's
  - Game playing
    - brute force (calculate your way out)
  - Theorem proving
    - symbol manipulation
  - Biological models
    - neural nets
- Symbolic application period - 70's
  - Early expert systems, use of knowledge
- Commercial period - 80's
  - boom in knowledge/ rule bases

## Periods in AI cont'd

- ? period - 90's and New Millenium
- Real-world applications, modelling, better evidence, use of theory, .....?
- Topics: data mining, formal models, GA's, fuzzy logic, agents, neural nets, autonomous systems
- Applications
  - visual recognition of traffic
  - medical diagnosis
  - directory enquiries
  - power plant control
  - automatic cars

## Fashions in AI

Progress goes in stages, following funding booms and crises: Some examples:

1. Machine translation of languages
  - 1950's to 1966 - Syntactic translators
  - 1966 - all US funding cancelled
  - 1980 - commercial translators available
2. Neural Networks
  - 1943 - first AI work by McCulloch & Pitts
  - 1950's & 60's - Minsky's book on "Perceptrons" stops nearly all work on nets
  - 1986 - rediscovery of solutions leads to massive growth in neural nets research

The UK had its own funding freeze in 1973 when the Lighthill report reduced AI work severely - Lesson: Don't claim too much for your discipline!!!!  
Look for similar stop/go effects in fields like genetic algorithms and evolutionary computing. This is a very active modern area dating back to the work of Friedberg in 1958.

## Symbolic and Sub-symbolic AI

- Symbolic AI is concerned with describing and manipulating our knowledge of the world as explicit symbols, where these symbols have clear relationships to entities in the real world.
- Sub-symbolic AI (e.g. neural-nets) is more concerned with obtaining the correct response to an input stimulus without 'looking inside the box' to see if parts of the mechanism can be associated with discrete real world objects.
- This course is concerned with symbolic AI.

## AI Applications

- Autonomous Planning & Scheduling:
  - Autonomous rovers.



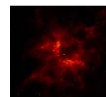
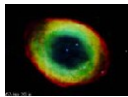
## AI Applications

- Autonomous Planning & Scheduling:
  - Telescope scheduling



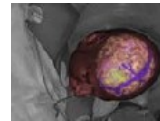
## AI Applications

- Autonomous Planning & Scheduling:
  - Analysis of data:



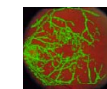
## AI Applications

- Medicine:
  - Image guided surgery



## AI Applications

- Medicine:
  - Image analysis and enhancement



## AI Applications

- Transportation:
  - Autonomous vehicle control:



## AI Applications

- Transportation:
  - Pedestrian detection:



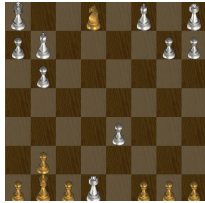
## AI Applications

### Games:



### AI Applications

- **Games:**



### AI Applications

- **Robotic toys:**



### AI Applications

- **Other application areas:**

- **Bioinformatics:**
  - Gene expression data analysis
  - Prediction of protein structure
- **Text classification, document sorting:**
  - Web pages, e-mails
  - Articles in the news
- **Video, image classification**
- **Music composition, picture drawing**
- **Natural Language Processing**
- **Perception.**

## Homework

Read Pg (1 – 31) From the book