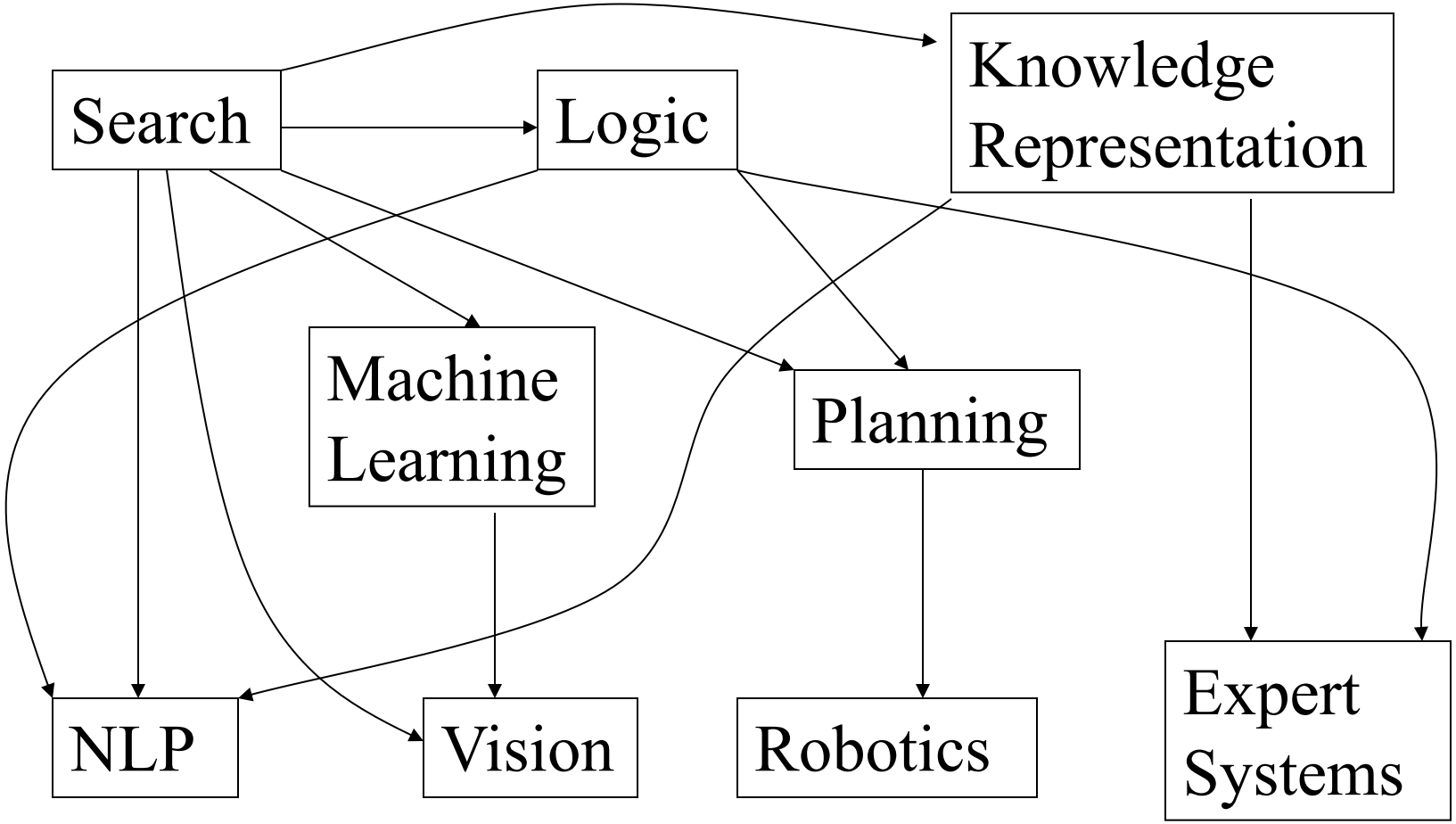
FOReSiGHT


SAPIENZA
UNIVERSITÀ DI ROMA

# Artificial Intelligence

# Areas of AI and Some Dependencies



# 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 ?

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

https://www.youtube.com/watch?v=Wy4EfdnMZ5g

# 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)

# Turing Test

- Human beings are intelligent
- To be called intelligent, a machine must produce responses that are indistinguishable from those of a human

Alan Turing

https://www.youtube.com/watch?v=3wLqsRLvV-c

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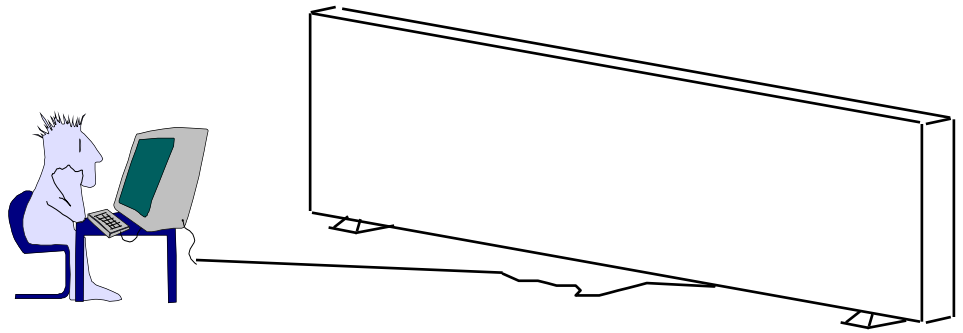
# Systems that act like humans



?

- 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)

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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)

# What is Artificial Intelligence ?

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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

https://www.youtube.com/watch?v=UjQ1AzSvCp8

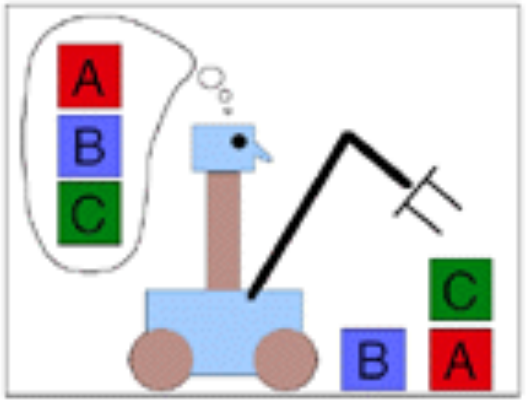
- Artificial
  - Produced by human art or effort, rather than originating naturally.
- Intelligence
- is the ability to acquire knowledge and use it" [Pigford and Baur]
- **So AI was defined as:**
  - AI is the study of ideas that enable computers to be intelligent.
  - AI is the part of computer science 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



# A rich history

- Philosophy
- Mathematics
- Economics
- Neuroscience
- Psychology
- Control Theory
- John McCarthy- coined the term- 1950’s

# 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

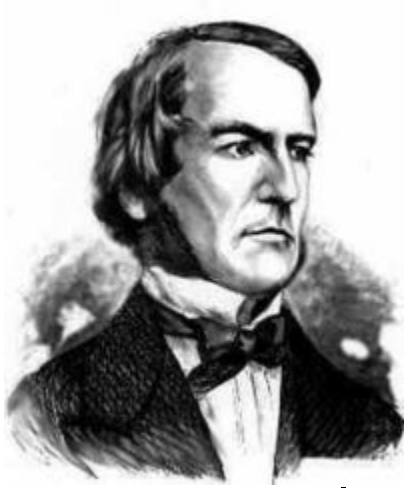
# Philosophy

- Dealt with questions like:
  - Can formal rules be used to draw valid conclusions?
  - Where does knowledge come from? How does it lead to action?
- David Hume proposed the principle of induction (later)
- Aristotle-
  - Given the end to achieve
  - Consider by what means to achieve it
  - Consider how the above will be achieved …till you reach the first cause
  - Last in the order of analysis = First in the order of action
  - If you reach an impossibility, abandon search

https://www.youtube.com/watch?v=8bin00oy6oE

# Mathematics

- Boolean Logic(mid 1800's)
- Intractability (1960's)
  - Polynomial Vs Exponential growth
  - Intelligent behaviour = tractable subproblems, not large intractable problems.
- Probability
  - Gerolamo Cardano(1500's) - probability in terms of outcomes of gambling events

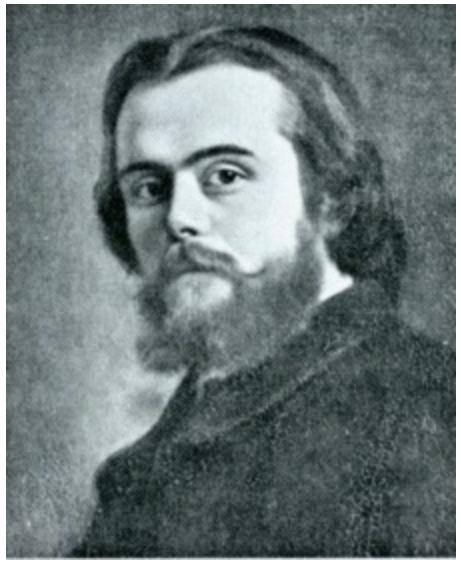


George Boole

Cardano

# Economics

- How do we make decisions so as to maximize payoff?
- How do we do this when the payoff may be far in the future?
- Concept of utility (early 1900's)
- Game Theory (mid 1900's)



Leon Walras

# Neuroscience

- Study of the nervous system, esp. brain
- A collection of simple cells can lead to thought and action
- Cycle time: Human brain- microseconds

  Computers- nanoseconds

❑The brain is still 100,000 times faster

# The Foundation of AI

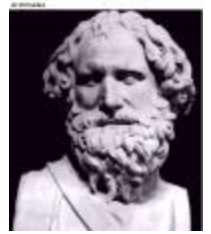
- Psychology
  - How do humans think and act?
  - The study of human reasoning and acting
  - Provides reasoning models for AI
  - Strengthen the ideas
    - humans and other animals can be considered as information processing machines

# Psychology

- Behaviourism- stimulus leads to response
- Cognitive science
  - Computer models can be used to understand the psychology of memory, language and thinking
  - The brain is now thought of in terms of computer science constructs like I/O units, and processing center

# Control Theory

- Ctesibius of Alexandria- water clock with a regulator
- Purposeful behaviour as arising from a regulatory mechanism to minimize the difference between goal state and current state (“error”)



# 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

- 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

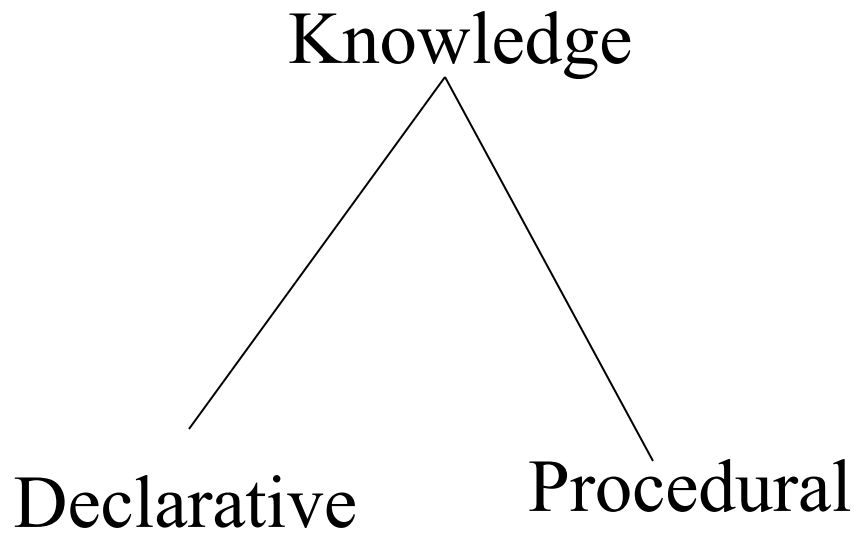
- increased costs
- difficulty with software development - slow and expensive
- few experienced programmers
- few practical products have reached the market as yet.

# 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 ?

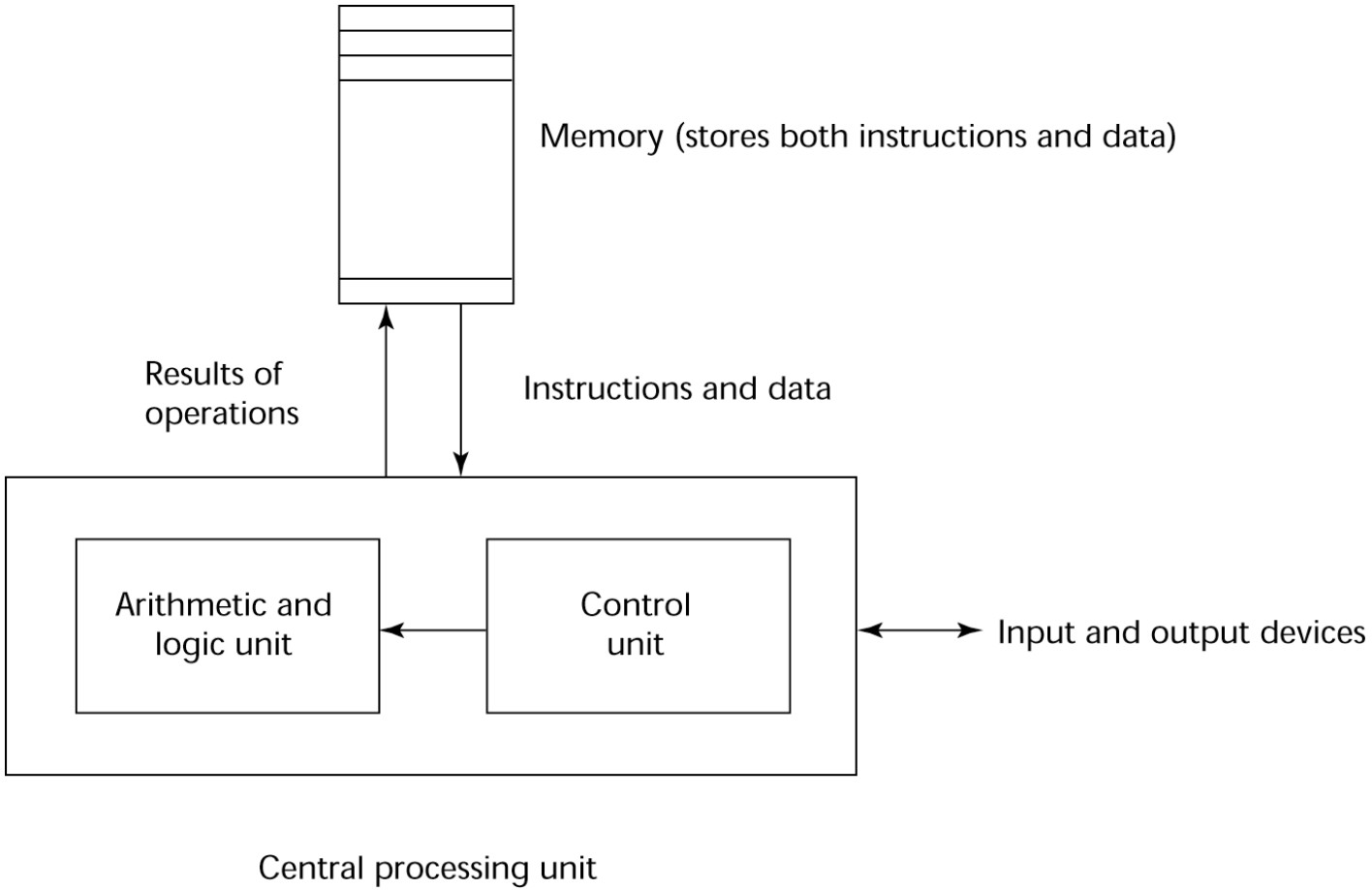
# Interacting with the Environment

- 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 Khowarazmi
    - Leonardo da Vinci
    - David Hume
    - George Boole
    - Charles Babbage
    - John von Neuman
    - Alan Turing
  - 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 McCorckindale

# 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

- ? 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.

# Does AI have applications?

- Autonomous planning and scheduling of tasks aboard a spacecraft
- Beating Gary Kasparov in a chess match
- Steering a driver-less car
- Understanding language
- Robotic assistants in surgery
- Monitoring trade in the stock market to see if insider trading is going on

# Does AI meet EE?

- Robotics- the science and technology of robots, their design, manufacture, and application.

- Liar! (1941)

Isaac Asimov

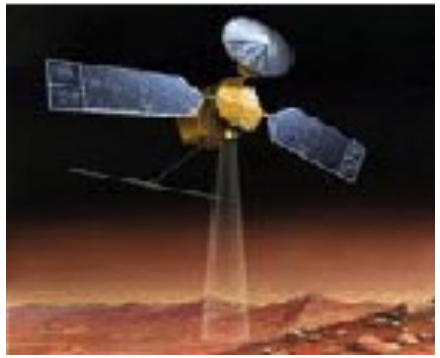
- Mechatronics- mechanics, electronics and computing which, combined, make possible the generation of simpler, more economical, reliable and versatile systems.

Norbert Wiener

Cybernetics- the study of communication and control, typically involving regulatory feedback, in living organisms, in machines, and in combinations of the two.

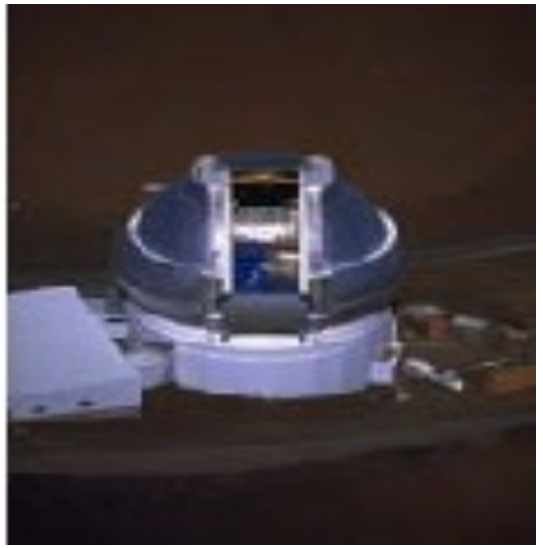
# AI Applications

- Autonomous Planning & Scheduling:
  - Autonomous rovers.



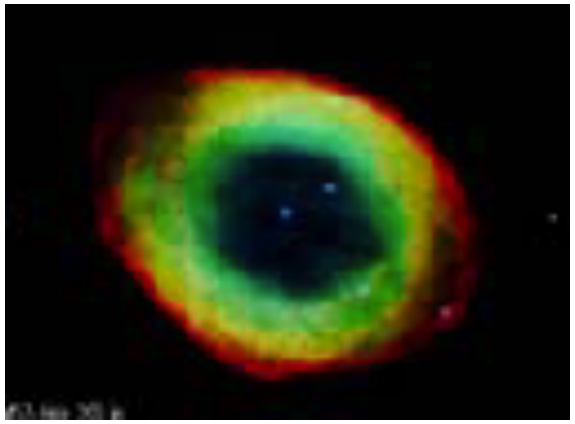
# AI Applications

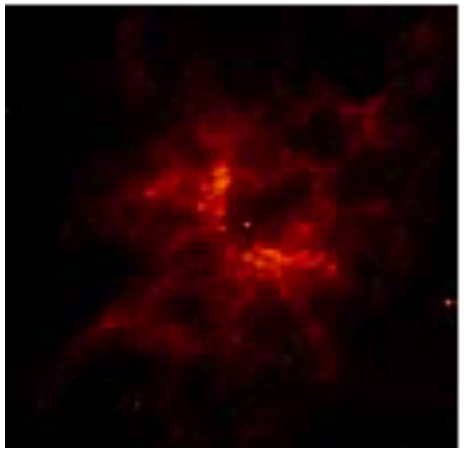
- Autonomous Planning & Scheduling:
  - Telescope scheduling



# AI Applications

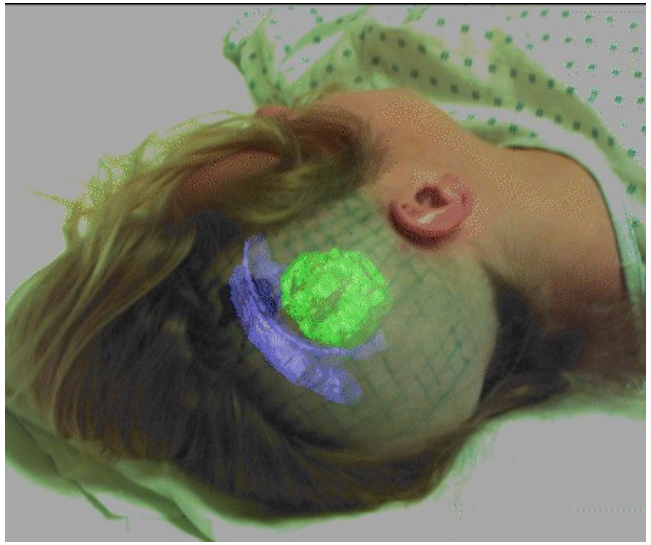
- Autonomous Planning & Scheduling:
  - Analysis of data:

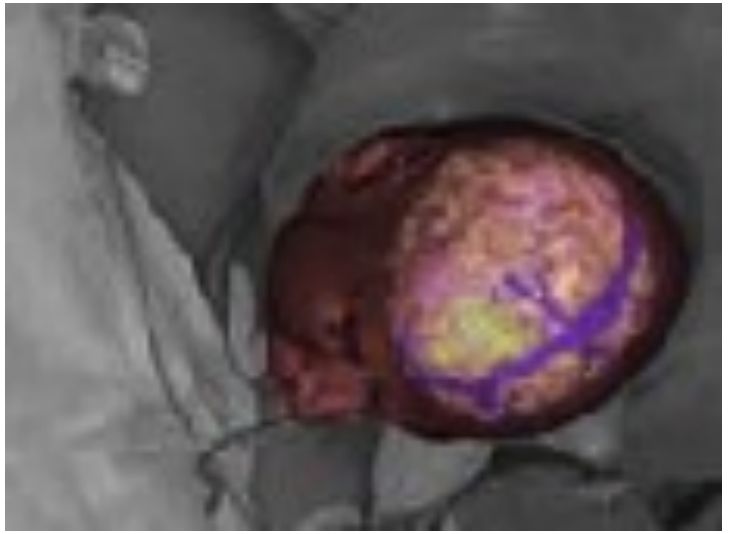




# AI Applications

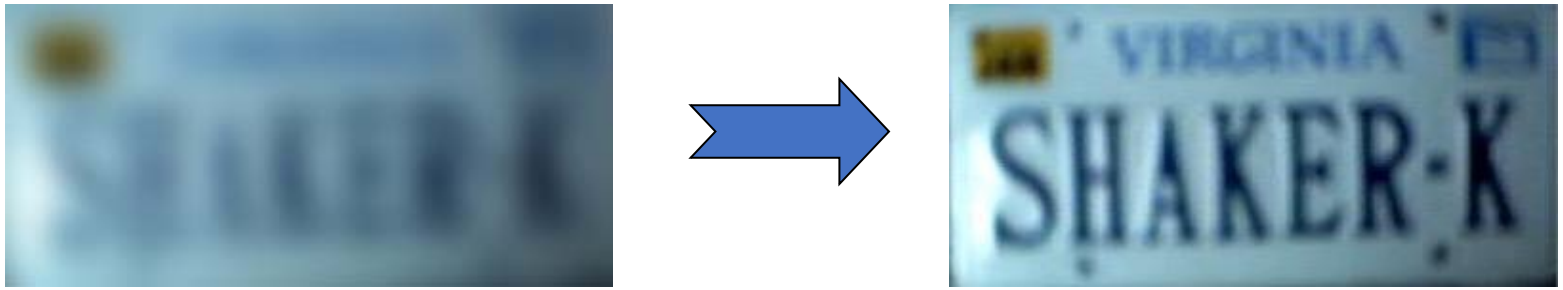
- **Medicine**:
  - Image guided surgery

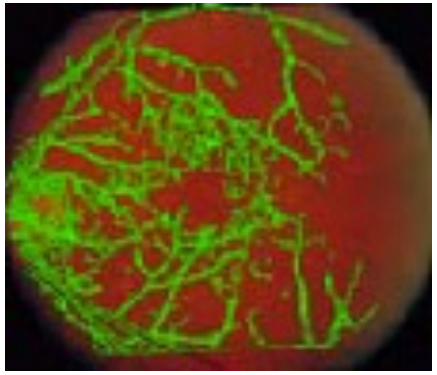


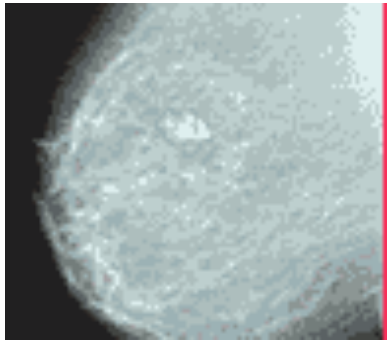


# AI Applications

- **Medicine**:
  - Image analysis and enhancement





# AI Applications

- **Transportation**:
  - **Autonomous vehicle control:**

# AI Applications

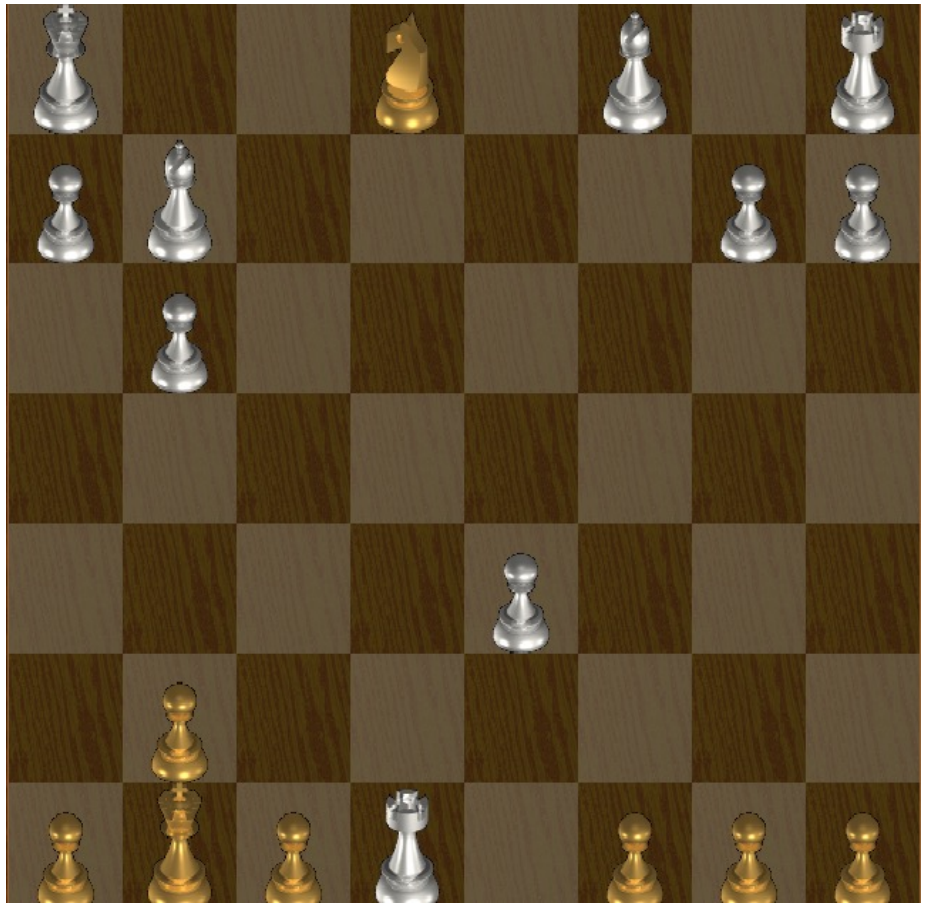
- **Transportation**:
  - **Pedestrian detection:**

# 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** 
- 

# Unknown unknowns

“Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns - the ones we don't know we don't know. And if one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones”

Donald Rumsfeld, United States Secretary of Defense, 2002