CSE 366(3): Artificial Intelligence

Lecture-1: Introduction

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Topics of this lecture

- What is artificial intelligence?
- Related research fields
- A brief review of AI history
- Scope of this course

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

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 ? (!)

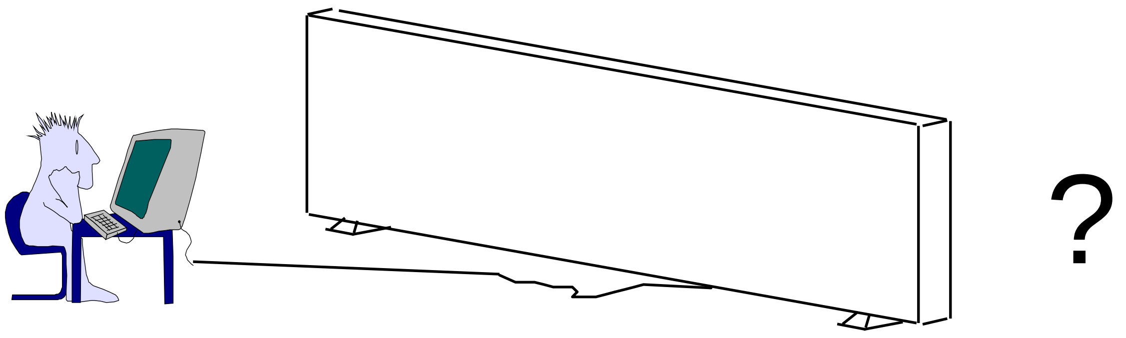
What is Artificial Intelligence ?

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

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)

What is Artificial Intelligence ?

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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

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

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

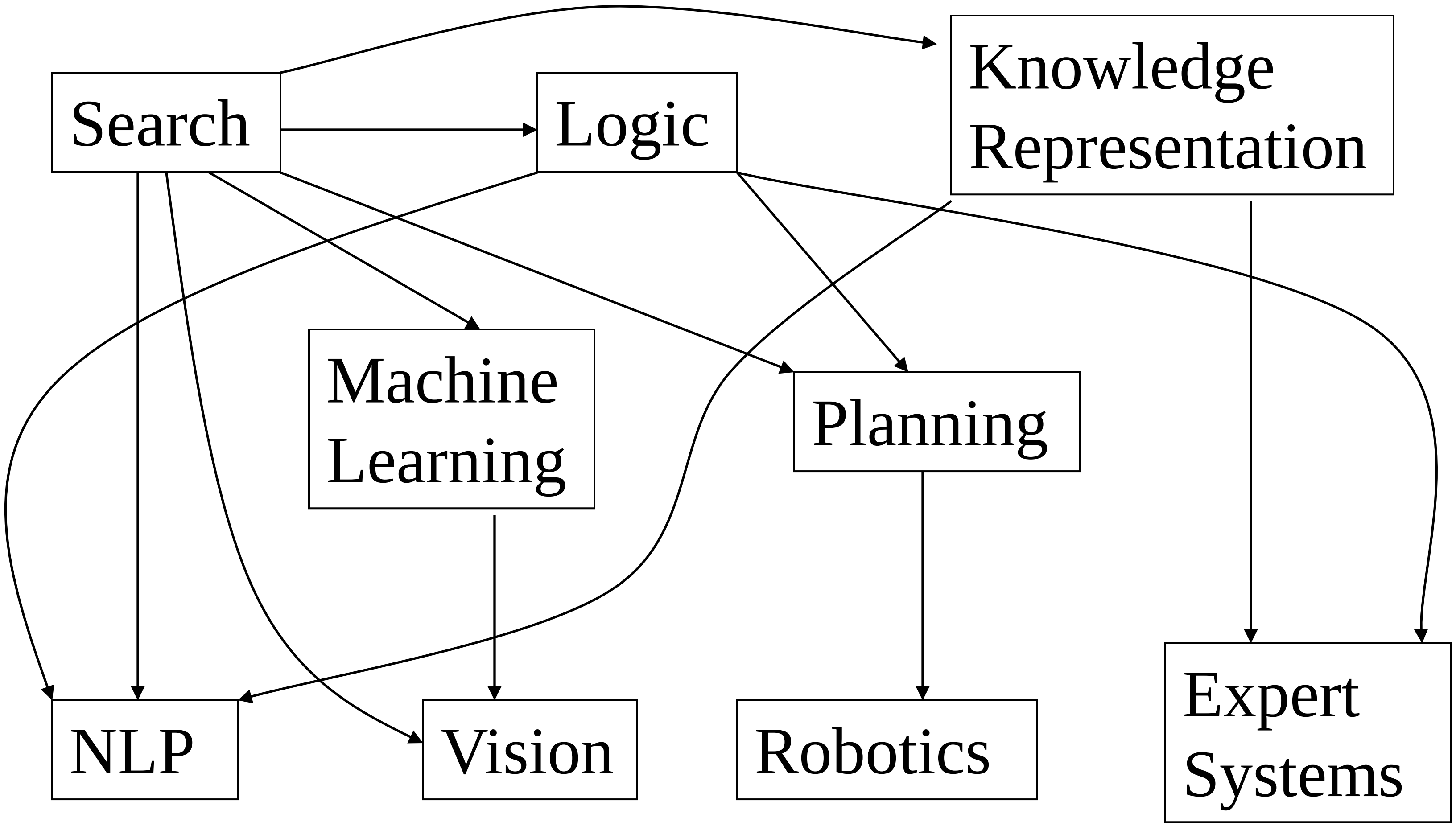
Systems that act rationally

- Study AI as rational agent –

2 advantages:

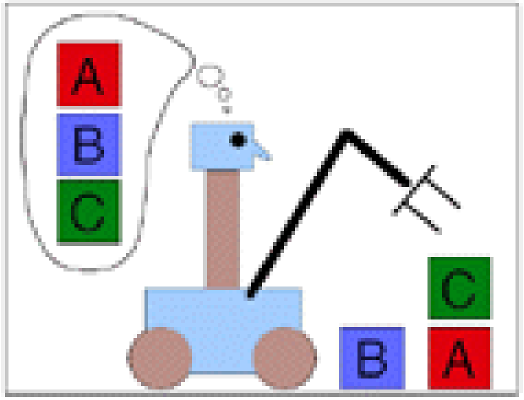
  - It is more general than using logic only
    - Because: LOGIC + Domain knowledge
  - It allows extension of the approach with more scientific methodologies

Areas of AI and Some Dependencies



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

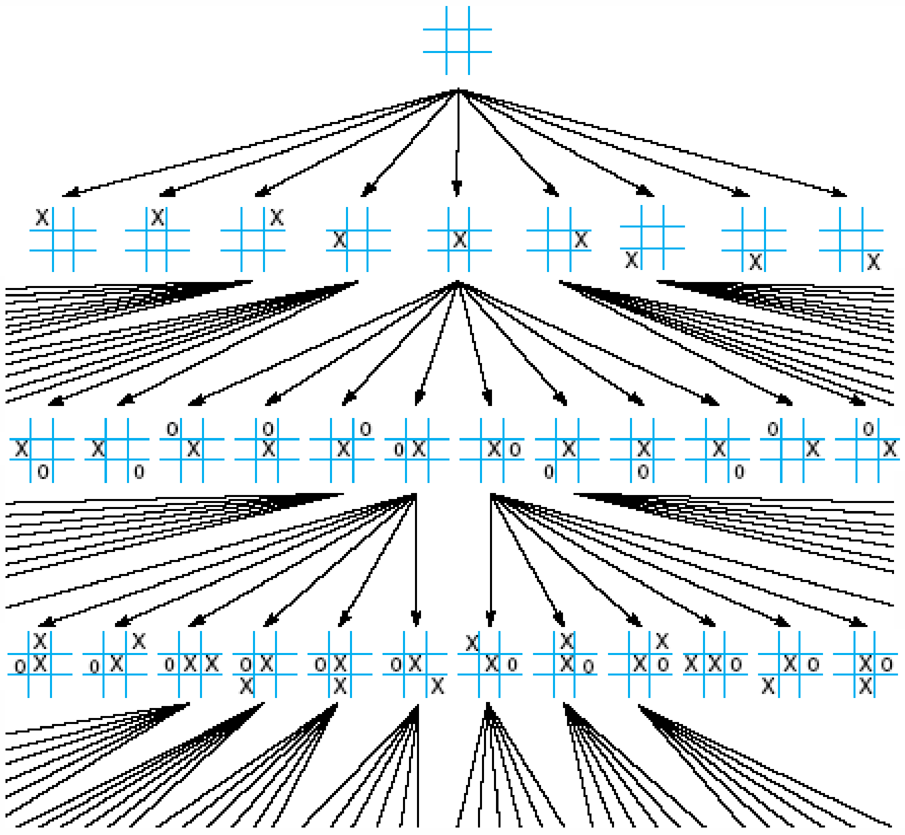
- increased costs
- difficulty with software development - slow and expensive
- few experienced programmers
- few practical products have reached the market as yet.

Scope of this course

- Search
  - Problem formulation and basic search algorithms
- Expert system-based reasoning
  - Production system, semantic network, and frame
- Logic based-reasoning
  - Propositional logic and predicate logic
- Soft computing based reasoning
  - Fuzzy logic and multilayer neural network

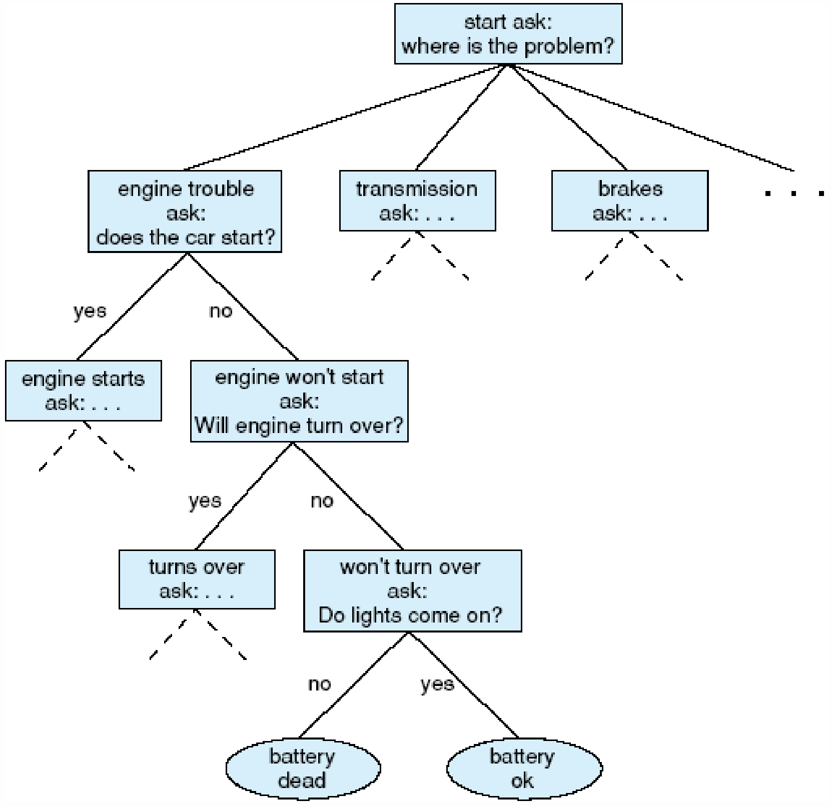
What is Search?

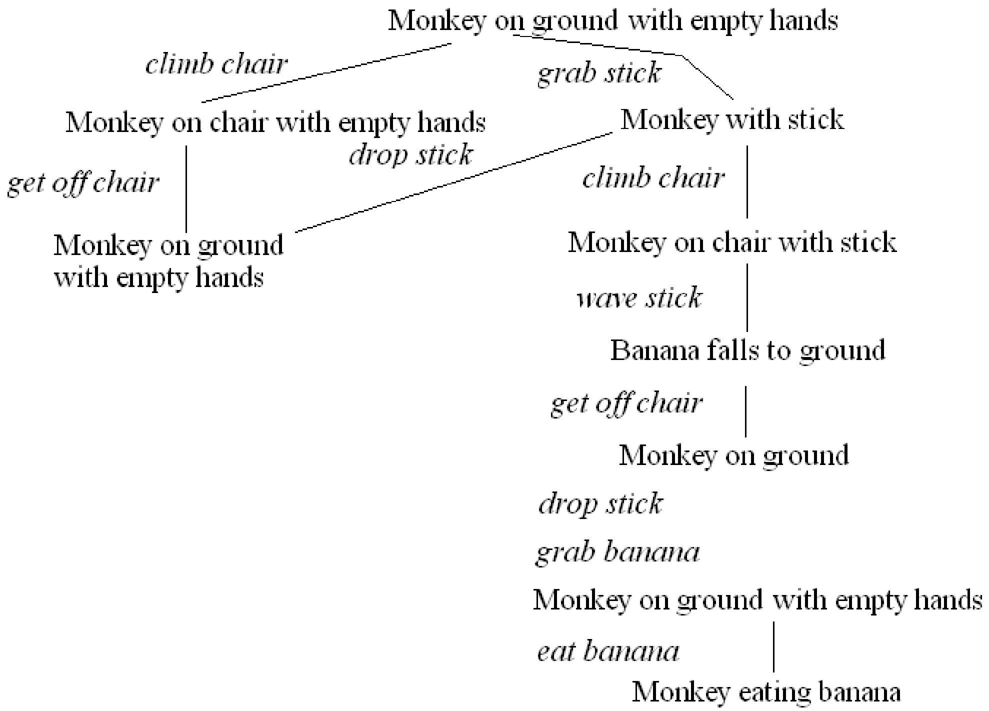
- We define the state of the problem being solved as the values of the active variables
  - this will include any partial solutions, previous conclusions, user answers to questions, etc
  - while humans are often able to make intuitive leaps, or recall solutions with little thought, the computer must search through various combinations to find a solution
- To the right is a search space for a tic-tac-toe game

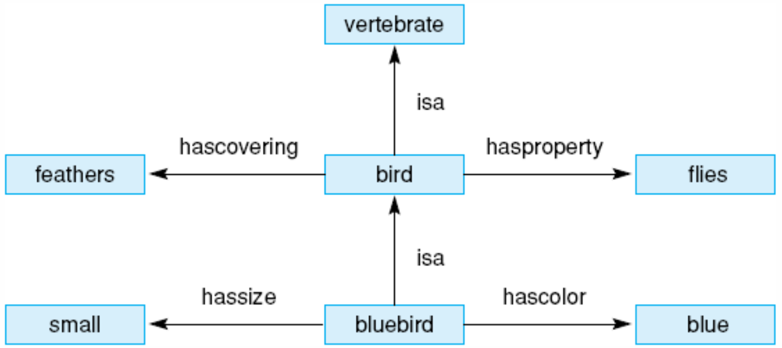


Search Spaces and Types of Search

- The search space consists of all possible states of the problem as it is being solved
  - A search space is often viewed as a tree and can very well consist of an exponential number of nodes making the search process intractable
  - Search spaces might be pre-enumerated or generated during the search process
  - Some search algorithms may search the entire space until a solution is found, others will only search parts of the space, possibly selecting where to search through a heuristic
- Search spaces include
  - Game trees like the tic-tac-toe game
  - Decision trees (see next slides)
  - Combinations of rules to select in a production system
  - Networks of various forms (see next slides)
  - Other types of spaces


start ask:
where is the problem?
engine trouble
ask:
does the car start?
transmission
ask: . . .
brakes
ask: . . .
. . .
yes
no
engine starts
ask: . . .
engine won't start
ask:
Will engine turn over?
yes
no
turns over
ask: . . .
won't turn over
ask:
Do lights come on?
no
yes
battery
dead
battery
ok


Monkey on ground with empty hands
climb chair
grab stick
Monkey on chair with empty hands
Monkey with stick
drop stick
get off chair
climb chair
Monkey on ground
with empty hands
Monkey on chair with stick
wave stick
Banana falls to ground
get off chair
Monkey on ground
drop stick
grab banana
Monkey on ground with empty hands
eat banana
Monkey eating banana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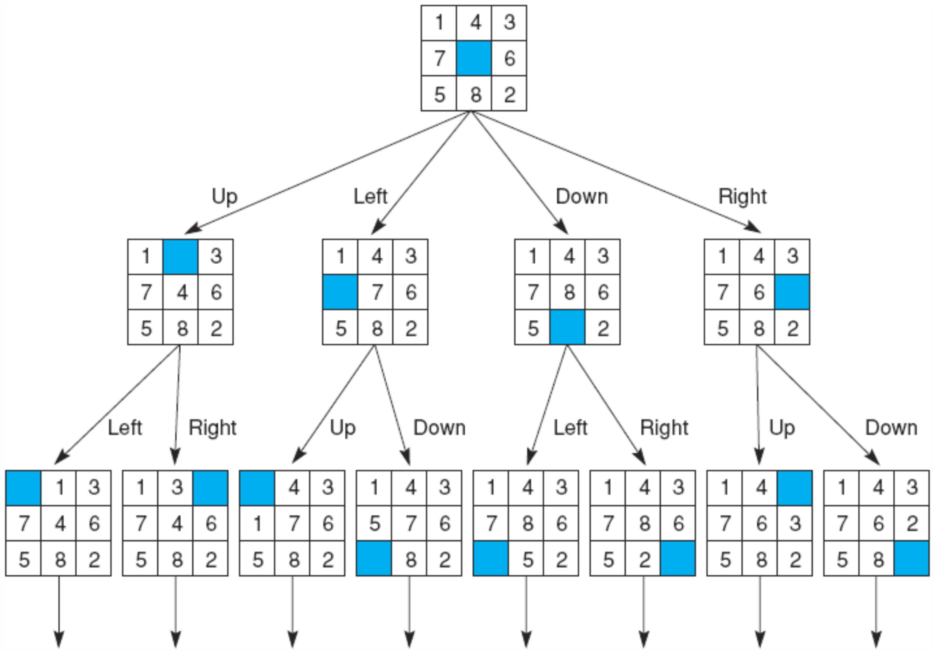
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5 8 2
1 4 3
7 6 2
5 8

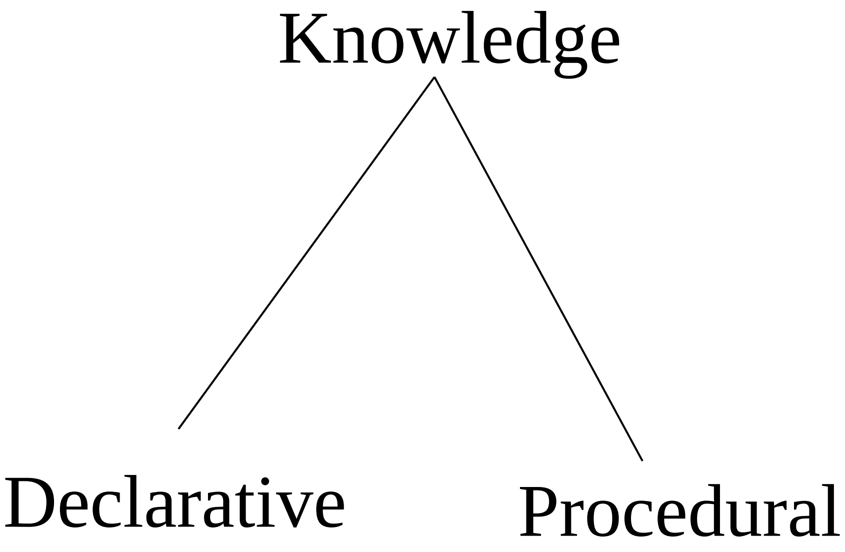
Search Algorithms and Representations

- Breadth-first
- Depth-first
- Best-first (Heuristic Search)
- A*
- Hill Climbing
- Limiting the number of Plies
- Minimax
- Alpha-Beta Pruning
- Adding Constraints
- Genetic Algorithms
- Forward vs Backward Chaining

- We will study various forms of representation and uncertainty handling in the next class period
- Knowledge needs to be represented
  - Production systems of some form are very common
    - If-then rules
    - Predicate calculus rules
    - Operators
  - Other general forms include semantic networks, frames, scripts
  - Knowledge groups
  - Models, cases
  - Agents
  - Ontologies

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

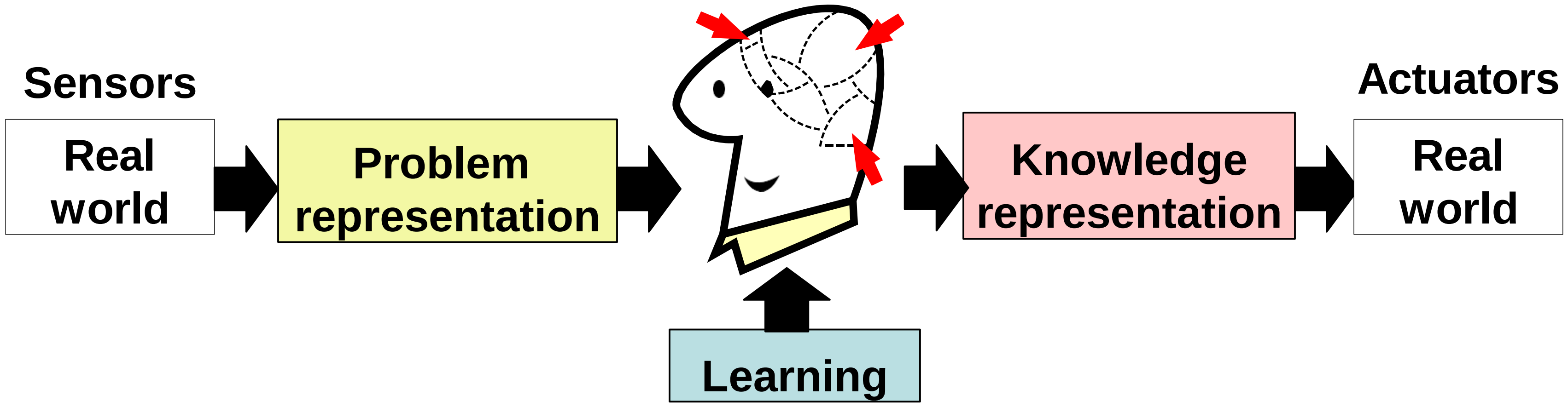
- In order to enable intelligent behaviour, we will have to interact with our environment.
- Properly intelligent systems may be expected to:
  - accept sensory input
    - vision, sound, …
  - interact with humans
    - understand language, recognise speech,
      generate text, speech and graphics,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

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.

Three MAPs for knowledge acquisition

- What is the input?
  - Map from real world to the mind model
- What is the output?
  - Map from the mind model to the real world
- What is the relation between the input and the output?
  - Abstracted knowledge about the real world



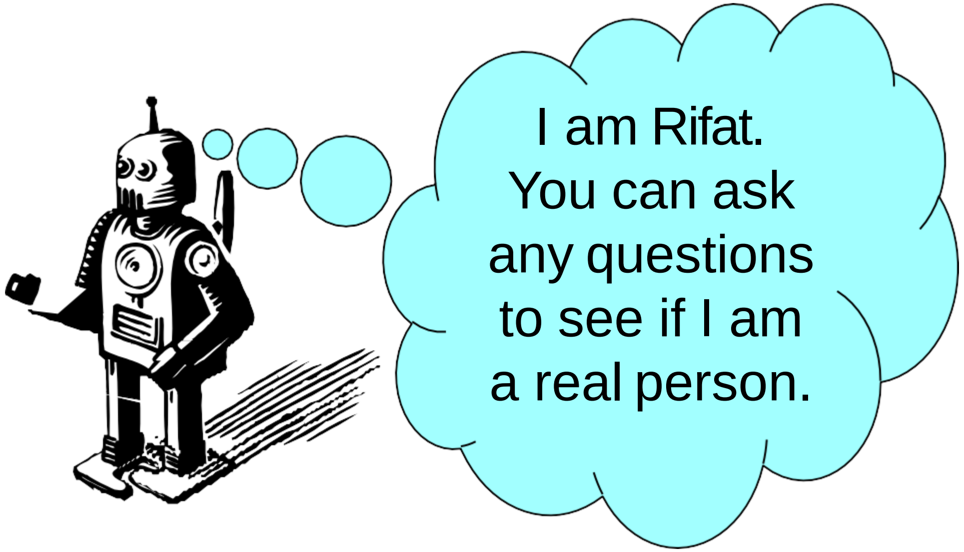
Early work (Around 1900)

- Representatives
  - George Boole
  - Alfred North Whitehead
  - Bertrand A. W. Russell
- Main contributions
  - Boolean algebra
  - Principia Mathematica

- **PM was an attempt to describe a set of axioms and inference rules in symbolic logic from which all mathematical truths could in principle be proven.**
- **However, in 1931, Gödel's incompleteness theorem proved that PM could never achieve this lofty goal.**

(from Wikipedia)

Early work (1930～)



- Representatives
  - Alan Turing
  - Claude Shannon
  - John von Neumann
- Main contributions
  - Theory of computation, Turing Machine
  - Turing test (to distinguish machine from human)
  - Information theory, application of Boolean algebra
  - von Neumann model of computing machines

The 1st wave of AI (1950～)

- Representatives
  - John McCarthy
  - Marvin Lee Minsky
  - Herbert Alexander Simon
  - Allen Newell
  - Edward Albert Feigenbaum
- Main contributions
  - LISP
  - Semantic network and frame
  - General problem solver and Expert systems

The term AI was proposed by these persons in the well-known Dartmouth Artificial Intelligence conference (1956)

The 2nd wave of AI (1980～)

- Representatives
  - David Rumelhart
  - Lotfi Zdeh
  - John Holland
  - Lawrence Forgel
  - Ingo Rechenberg
  - John Koza
- Main contributions
  - Learning of MLP
  - Fuzzy logic
  - Genetic algorithms
  - Evolutionary programming
  - Evolution strategy
  - Genetic programming

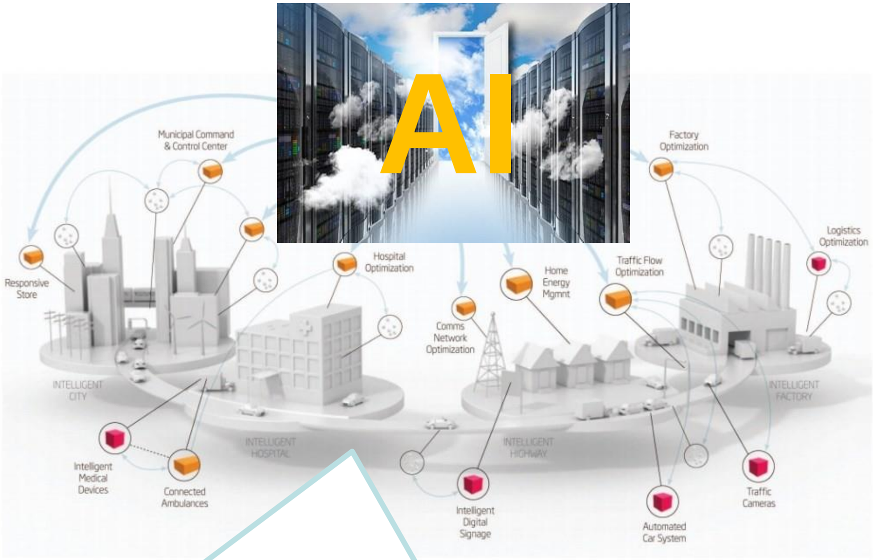
Soft computing
Human like computing and natural computing

The 3rd wave of AI (2000～)

- Representative technologies
  - Internet: Tim Berners-Lee, WWW inventor, 1989
  - Internet of things: Kevin Ashton, MIT Auto-ID Center, 1999
  - Cloud computing
    - Main frame (1950s)
    - Virtual machine (1970s)
    - Cloud (1990s)
  - Big data: John R. Masey, SGI, 1998
  - Deep learning: Geoffrey Hinton, UoT, 2006

A brief summary

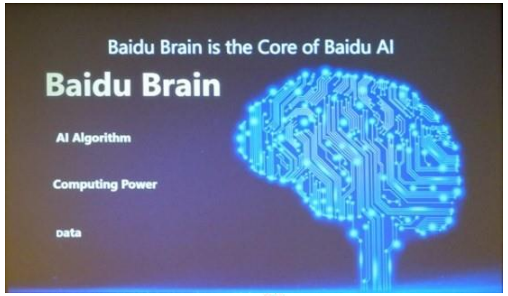
- Early work
  - Theoretic foundations
- 1st wave:
  - Reasoning with given knowledge
- 2nd wave
  - Acquire knowledge from data / experiences
- 3rd wave
  - Learn in the cyber-space



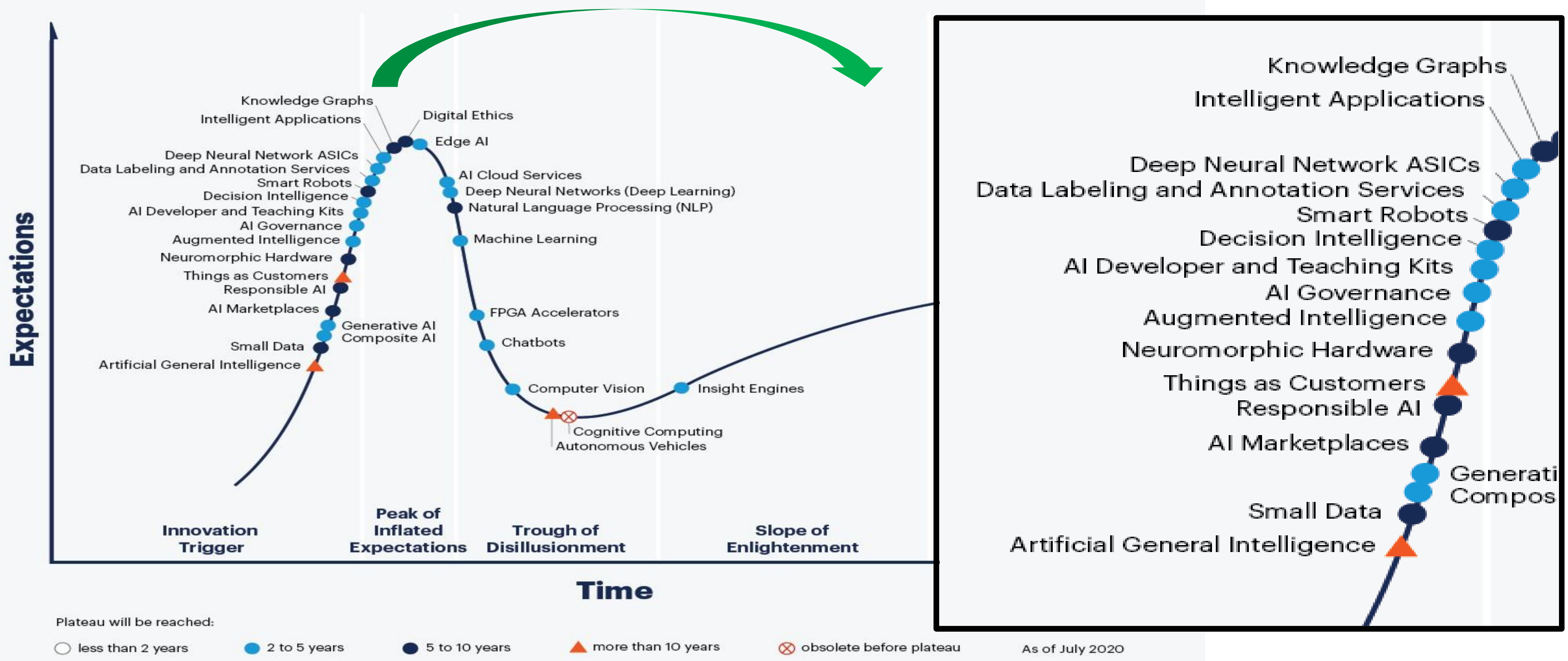
The same as learning inside the brain. Each brain has a "natural intelligence" that can learn using the sensor data captured by different parts of the body.

Current status of AI

- In March 2016, Alpha-Go of DeepMind defeated Lee Sedol, who was the strongest human GO player at that time.
- This is a big news that may have profound meaning in the human history.



Hype Cycle for Artificial Intelligence, 2020



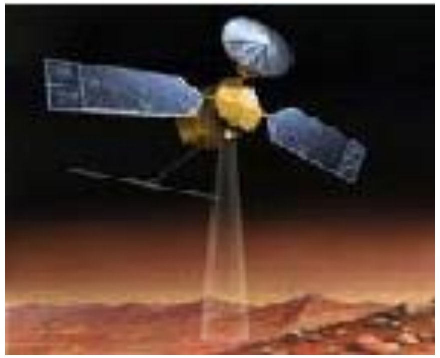
gartner.com/SmarterWithGartner

Source: Gartner

Gartner

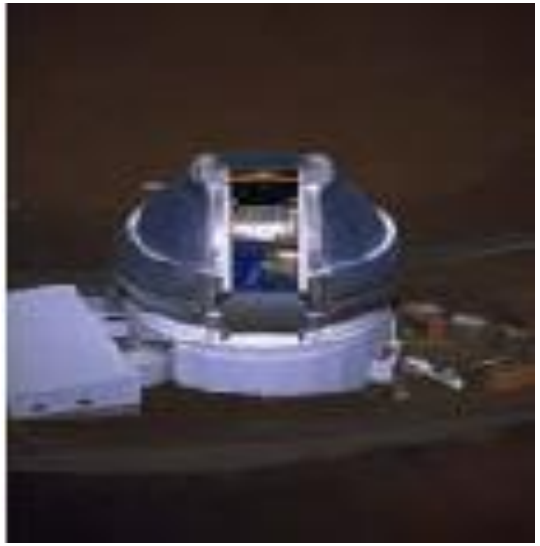
AI Applications

- Autonomous Planning & Scheduling:
  - Autonomous rovers.



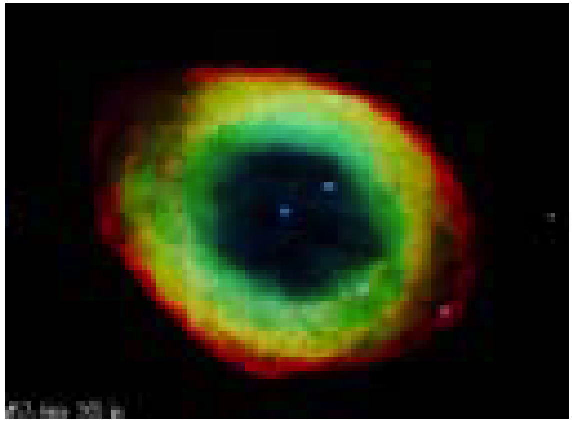
AI Applications

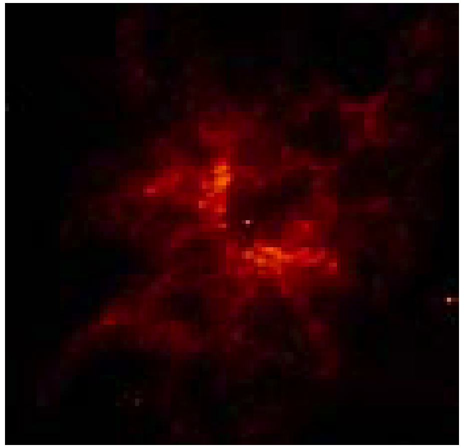
- Autonomous Planning & Scheduling:
  - Telescope scheduling



AI Applications

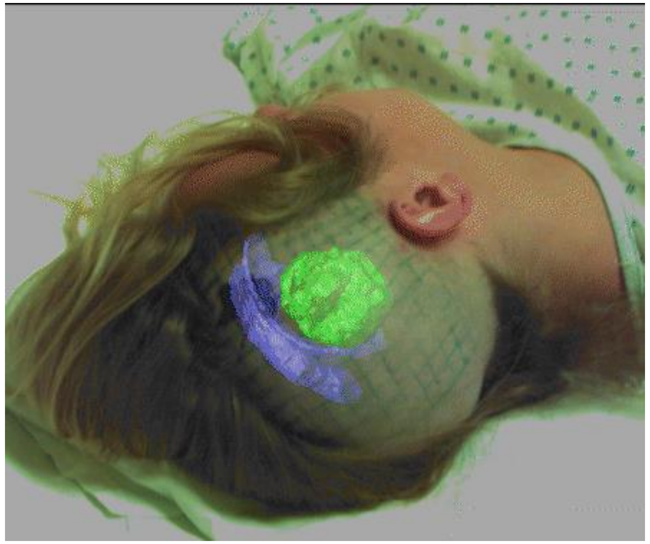
- Autonomous Planning & Scheduling:
  - Analysis of data:

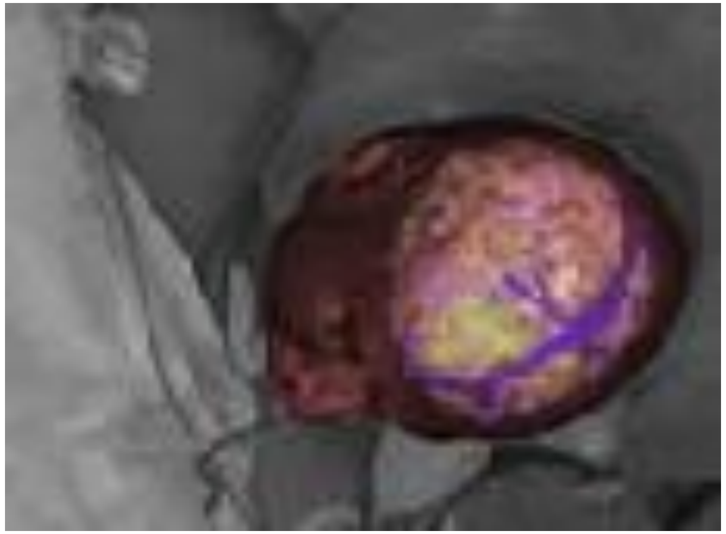




AI Applications

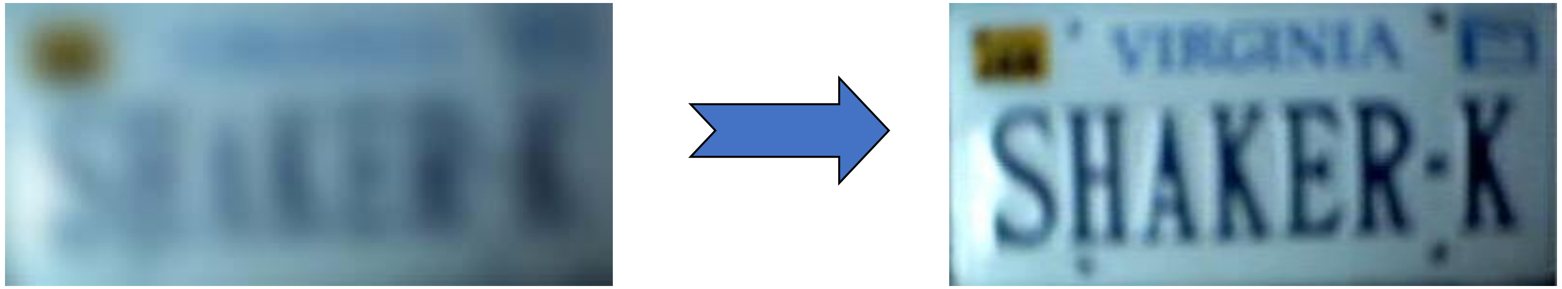
- **Medicine**:
  - Image guided surgery

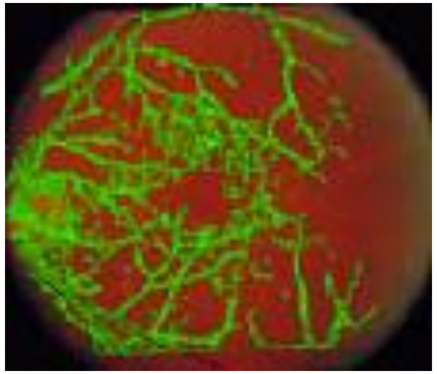


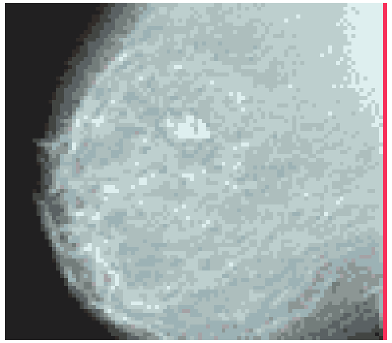


AI Applications

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







AI Applications

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

AI Applications

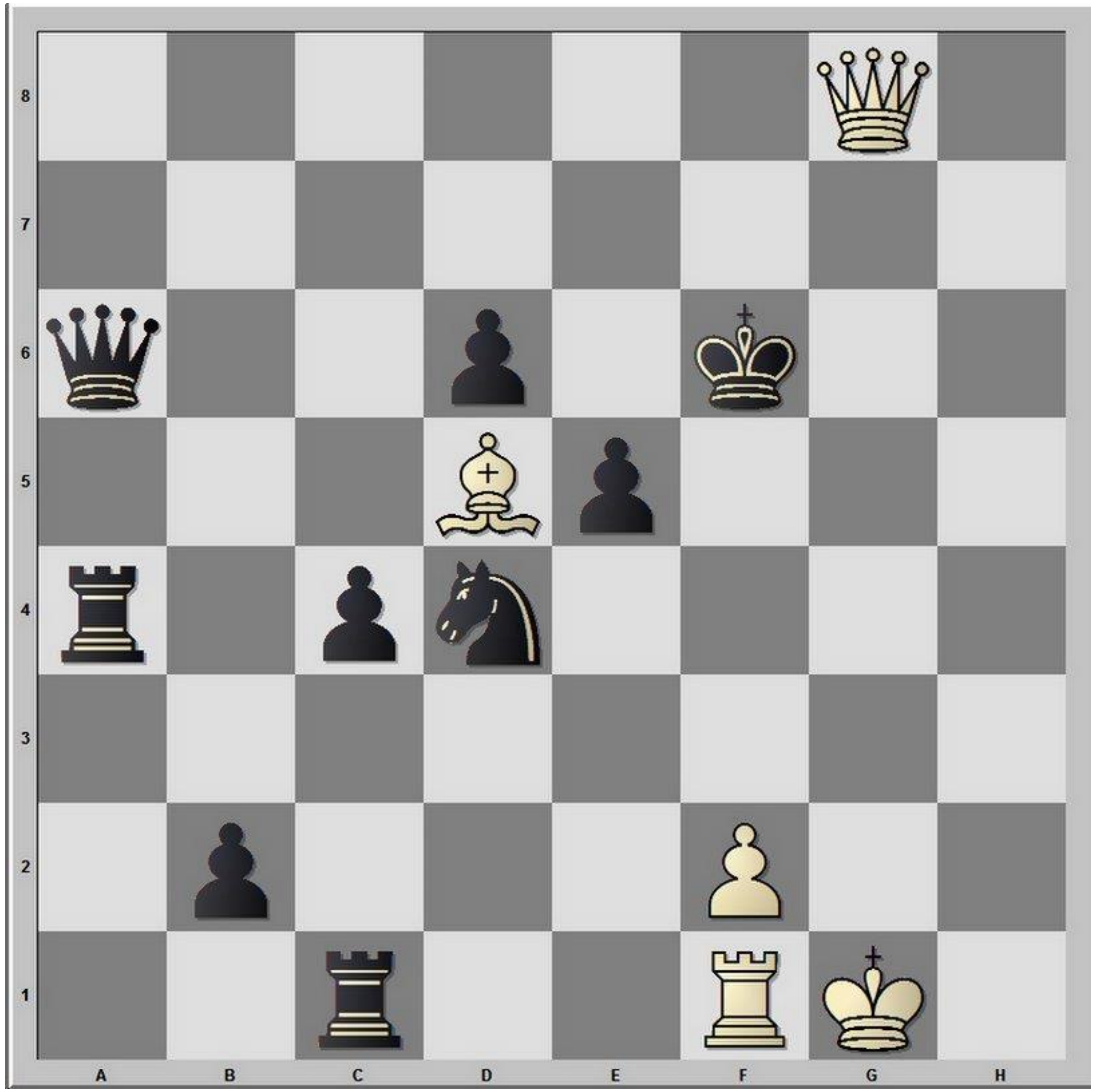
- **Transportation**:
  - **Pedestrian detection:**

AI Applications

Games:

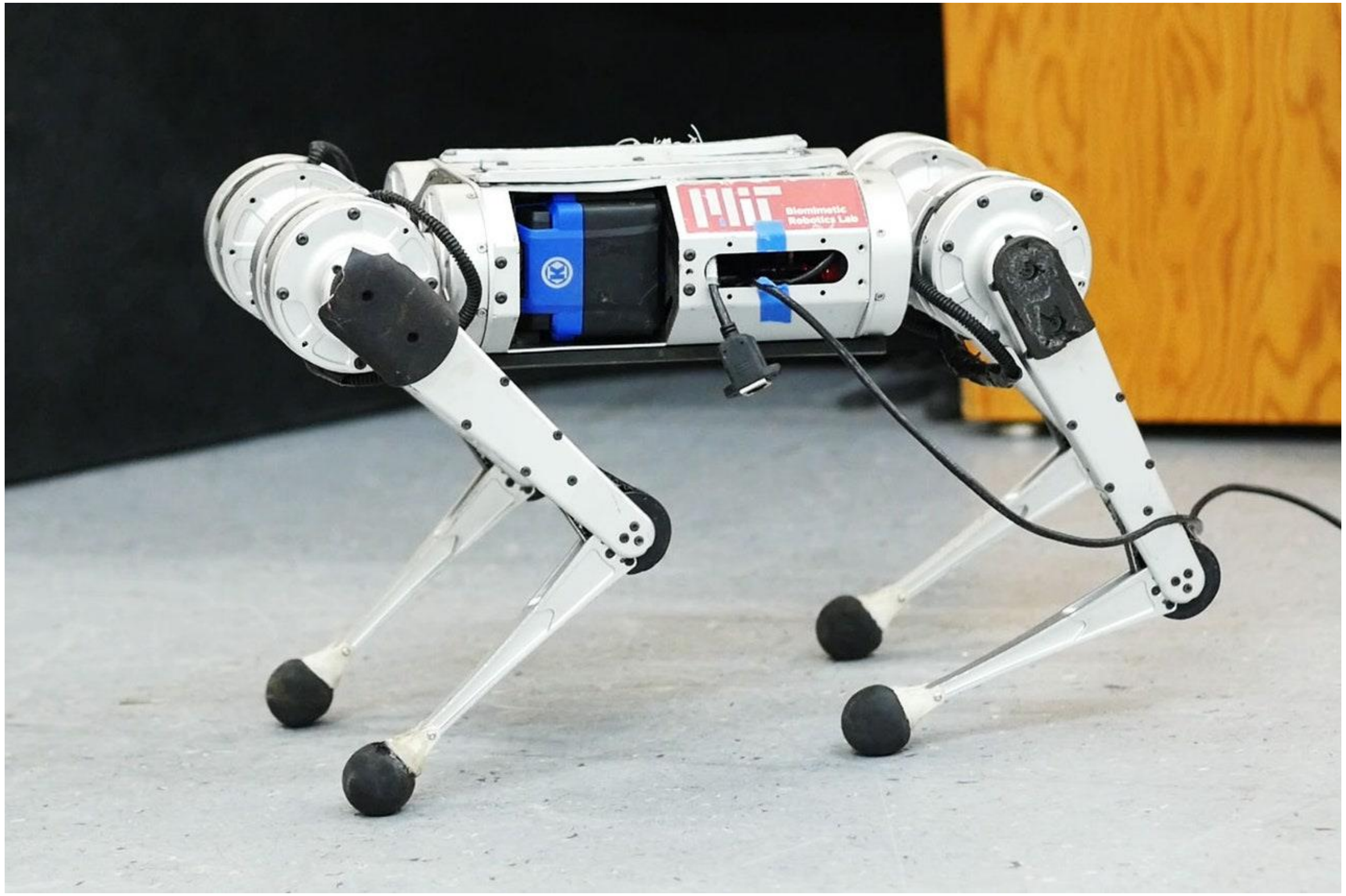
AI Applications

- **Games**:



AI Applications

- **Robotics**:



Today: AI Applications

- Look around, who is doing AI research?
- By their own admission, AI researchers are not doing “AI”, they are doing
  - Intelligent agents, multi-agent systems/collaboration
  - Ontologies
  - Machine learning and data mining
  - Adaptive and perceptual systems
  - Robotics, path planning
  - Search engines, filtering, recommendation systems
- Areas of current research interest:
  - NLU/Information Retrieval, Speech Recognition
  - Planning/Design, Diagnosis/Interpretation
  - Sensor Interpretation, Perception, Visual Understanding
  - Robotics
- Approaches
  - Knowledge-based
  - Ontologies
  - Probabilistic (HMM, Bayesian Nets)
  - Neural Networks, Fuzzy Logic, Genetic Algorithms

So What Does AI Do?

- Most AI research has fallen into one of two categories
  - Select a specific problem to solve
    - study the problem (perhaps how humans solve it)
    - come up with the proper representation for any knowledge needed to solve the problem
    - acquire and codify that knowledge
    - build a problem solving system
  - Select a category of problem or cognitive activity (e.g., learning, natural language understanding)
    - theorize a way to solve the given problem
    - build systems based on the model behind your theory as experiments
    - modify as needed
- Both approaches require
  - one or more representational forms for the knowledge
  - some way to select proper knowledge, that is, search

Representation methods

- Representation of the problem
  - State space representation
  - Vector representation
- Representation of knowledge
  - Production (decision) rules
  - Semantic network and ontology
  - Predicate logic
  - Fuzzy logic
  - Neural network (for tacit knowledge)

Purpose of this course

- Learn how to use the basic search methods;
- Understand the basic methods for problem formulation and knowledge representation;
- Understand the basic idea of automatic reasoning;
- Know some basic concepts related to pattern recognition and machine learning.

Be able to learn more by yourself to follow the newest trends!