Artificial Intelligence

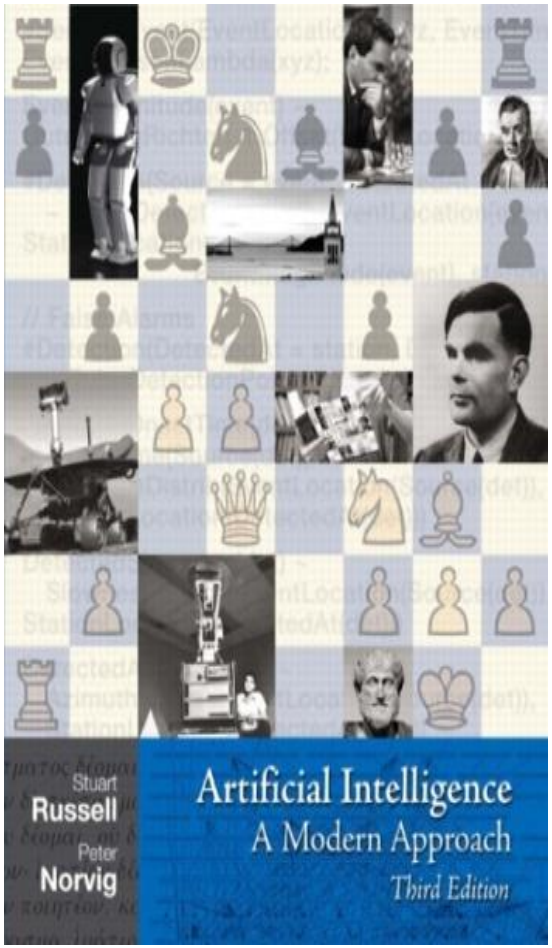
Course Learning Outcomes

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 AI techniques to develop more useful software for the comfort of humanity.
- Transferable Skills
  You should be able to solve problems and evaluate outcomes and alternatives

Textbook

Russell & Norvig, AI:
A Modern Approach, 3rd Ed.



Assessment Scheme

- Quizzes(Announced + Surprise): 10%
- Assignments:…… 10%
- Mid Terms-1:…… 15%
- Mid Term-2:…… 15%
- Final Exam:…….. 50%

Office Hours:

Tuesday & Thursday: 9-2 pm

HEC AI Syllabus

- Introduction to AI
- Problem Solving
- Probability in AI
- Probabilistic Inference
- Machine Learning (Supervised/Unsupervised)
- Representation with Logic
- Planning
- HMMs and Filters
- Game Theory
- Applications of AI in Computer Vision
- Robotics
- Natural Language Processing.

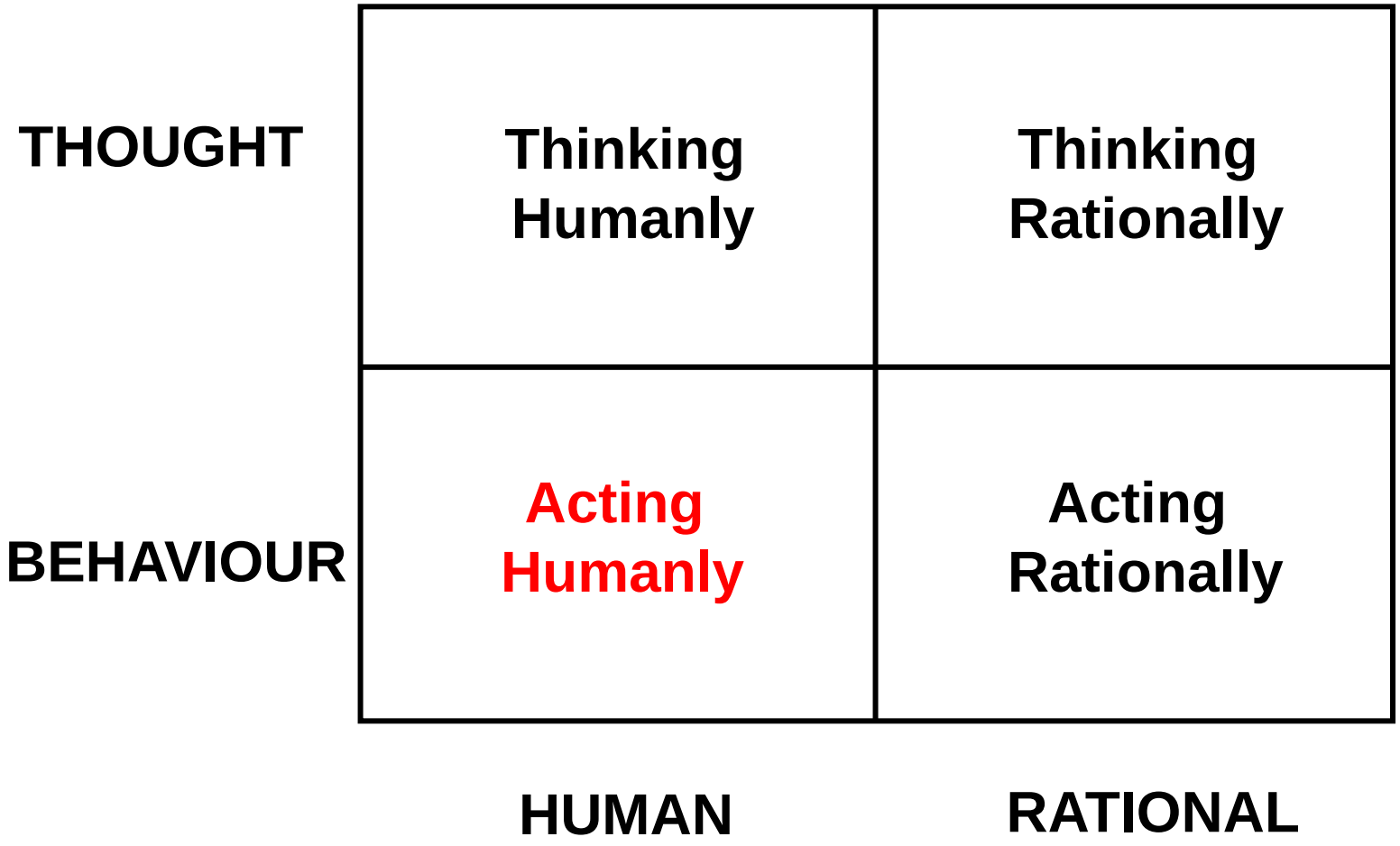
What is Artificial Intelligence ?

- 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 ? (!)

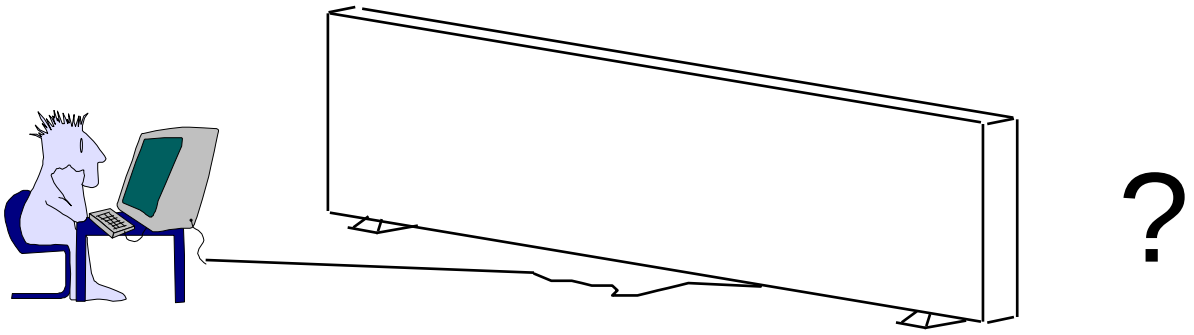
Artificial Intelligence Approaches



Acting Humanly: The Turing Test Approach

- “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)

Acting Humanly: The Turing Test Approach



- 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.

Acting Humanly: The Turing Test Approach

- 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

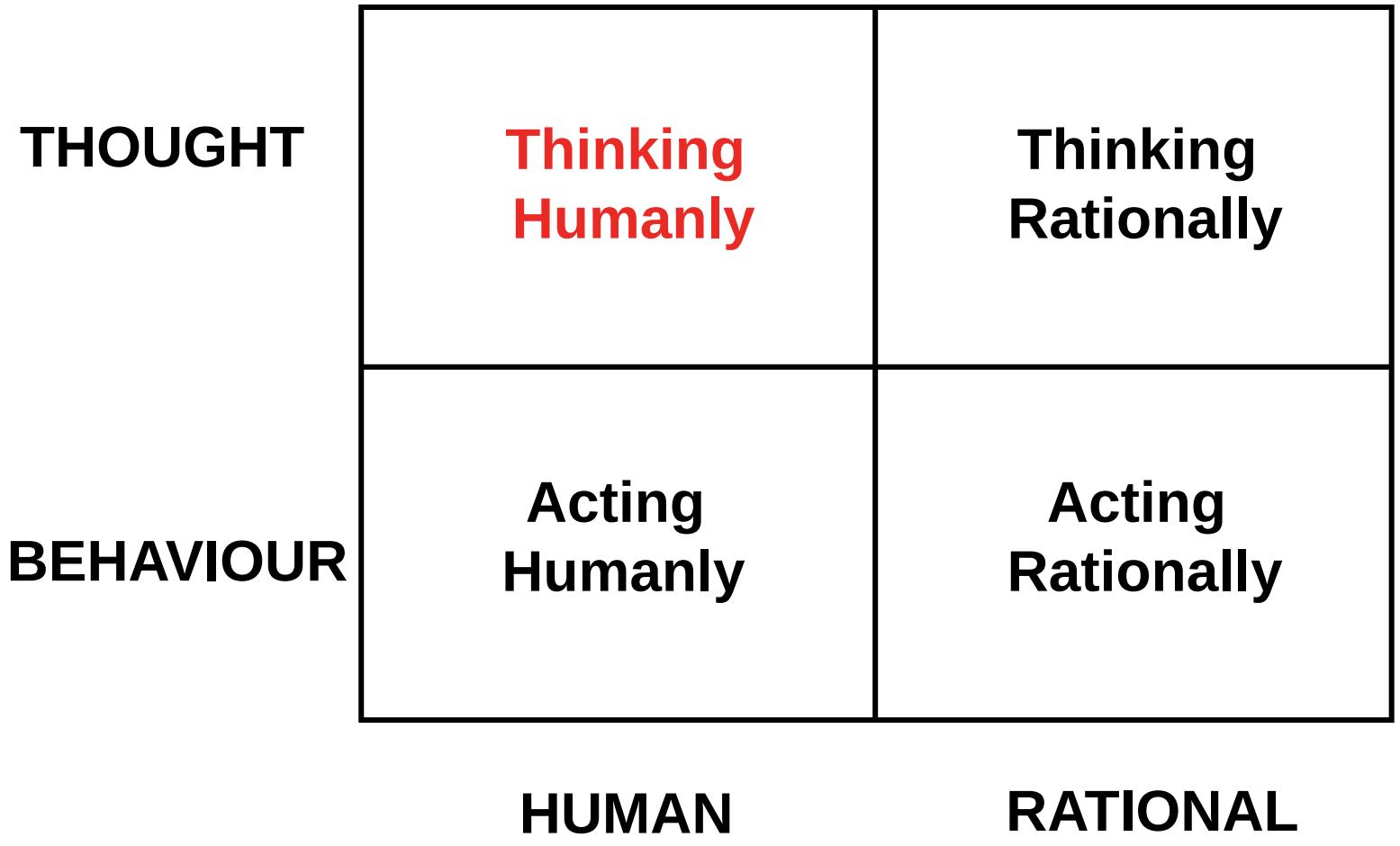
Acting Humanly: The Turing Test Approach

- The skills required to pass Turing Test are:
  - *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)

Artificial Intelligence Approaches



Thinking Humanly: The Cognitive Modeling Approach

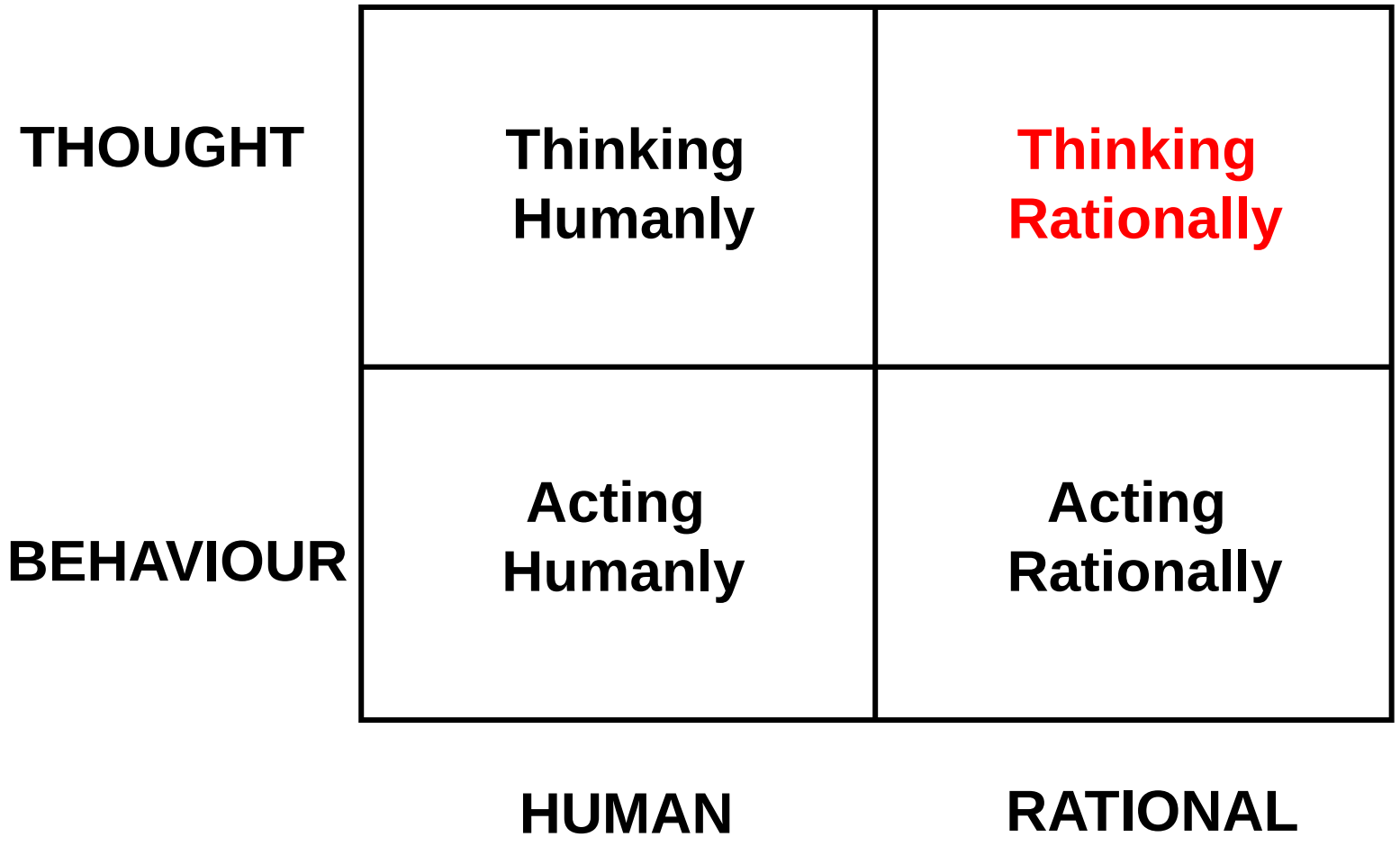
A difficult approach as we need to get inside human mind when in action. There are three ways:

- Introspection: try to catch own thoughts as they go by
- Psychological experiments: Observing a person in action
- Brain Imaging: Observing brain in action

Once we have a precise theory it can be programed. Input-Output should match human behavior.

Cognitive Science = Computer Model from AI + Experiment Techniques from Psychology

Artificial Intelligence Approaches



Thinking Rationally “The laws of thought approach”

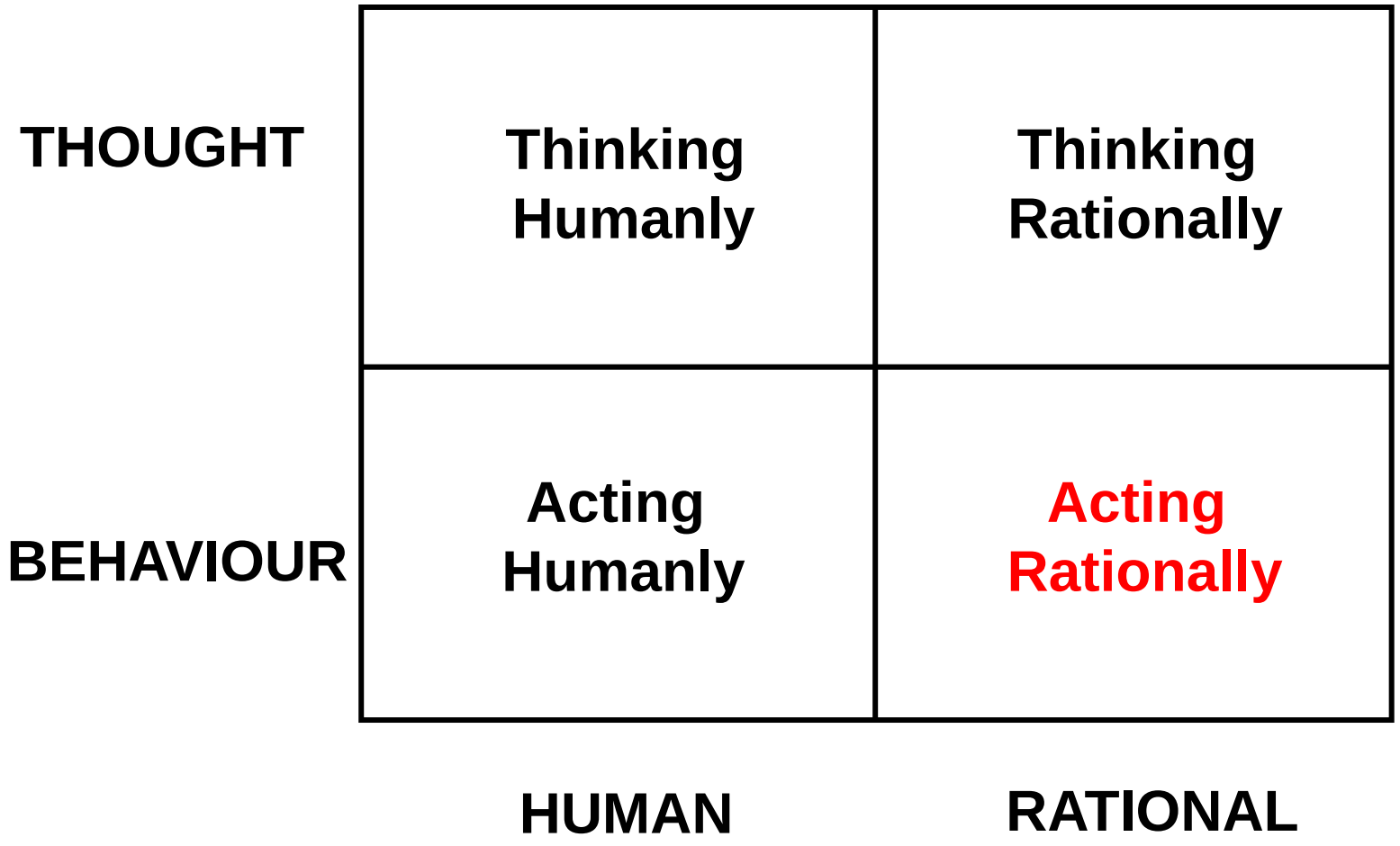
- “The study of mental faculties through the use of computational models” (Charniak and McDermott)
- “The study of the computations that make it possible to perceive, reason, and act” (Winston)
- Irrefutable reasoning process: Logic: Precise notations+ established rules for deduction, inference etc.

Thinking Rationally: The “laws of thought“ Approach

Problems:

- 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’)
- Stating Informal (imprecise, uncertain) Knowledge into formal terms
- Problems with just few hundred facts can exhaust the computational resources quickly

Artificial Intelligence Approaches



Acting Rationally: The "Rational agent" Approach

- 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

- Study AI as rational agent –

Advantages:

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

Acting Rationally “The Rational agent approach”

Agent: Acts on someone behalf

Computer Agent: Operates autonomously, perceive their environment, persists over prolonged time period, adapt to change, create and pursue goals.

A rational agent is one that acts so as to achieve the best outcome.

Correct inference is sometime part of being rational.

Advantages:

Correct inference is one of the several possible mechanism for rationality

Rationality can be mathematically defined and it is very general; Also notion of partial rationality when constraint with time and space

Rational Decisions

We'll use the term **rational** in a very specific, technical way:

- Rational: maximally achieving pre-defined goals
- Rationality only concerns what decisions are made (not the thought process behind them)
- Goals are expressed in terms of the **utility** of outcomes
- Being rational means **maximizing your expected utility**

A better title for this course would be:

Computational Rationality

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:

$$[f: P^* \rightarrow A]$$

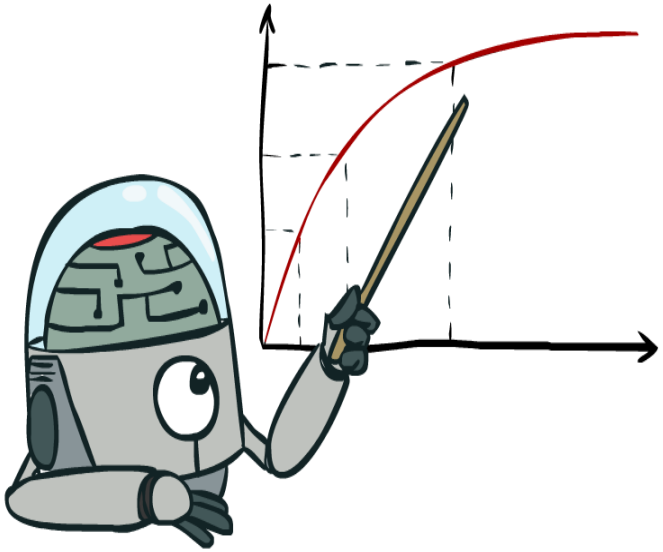
- For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- Caveat: computational limitations make perfect rationality unachievable
  - → design best program for given machine resources

- 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:

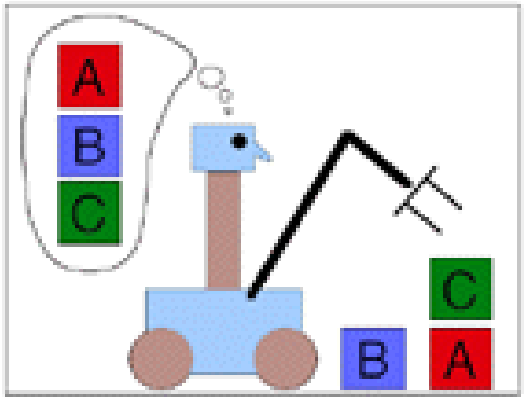
- Study the intelligent part concerned with humans.
- Represent those actions using computers.

Maximize Your Expected Utility



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: Where Knowledge come from? How knowledge lead to action? How mind arises from physical Brain etc.
- Mathematics: What are rules to draw valid conclusions? What can be computed? How do we reason with imprecise & uncertainty?
- Economics: How to make decision to maximize profit? How do we do this when others may not go along? How do we do this when pay off may be far in the future?
- Neuroscience: How do brain process information?

The Foundation of AI

- Psychology: How do humans and animals think and act?
- Computer Engineering: How can we build an efficient computer?
- Control Theory and Cybernetics (Study of controls and communication) concepts of cybernetics include Learning, cognition, adaptation, social control etc. : How can artifacts operate under their own control?
- Linguistics: How does language relate to thought?

What About the Brain?

- Brains (human minds) are very good at making rational decisions, but not perfect
- Brains aren't as modular as software, so hard to reverse engineer!
- "Brains are to intelligence as wings are to flight"
- Lessons learned from the brain: memory and simulation are key to decision making

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

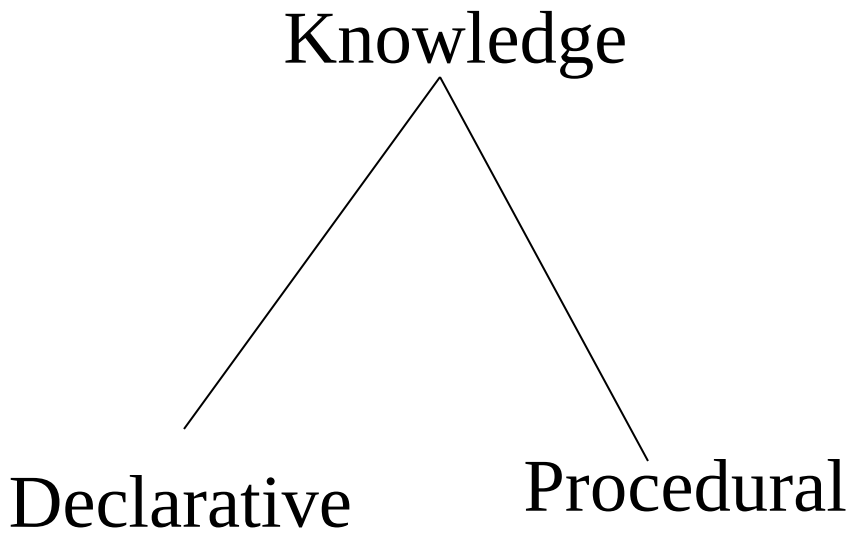
- increased costs
- difficulty with software development - slow and expensive
- few experienced programmers
- few practical products have reached the market as yet.

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?

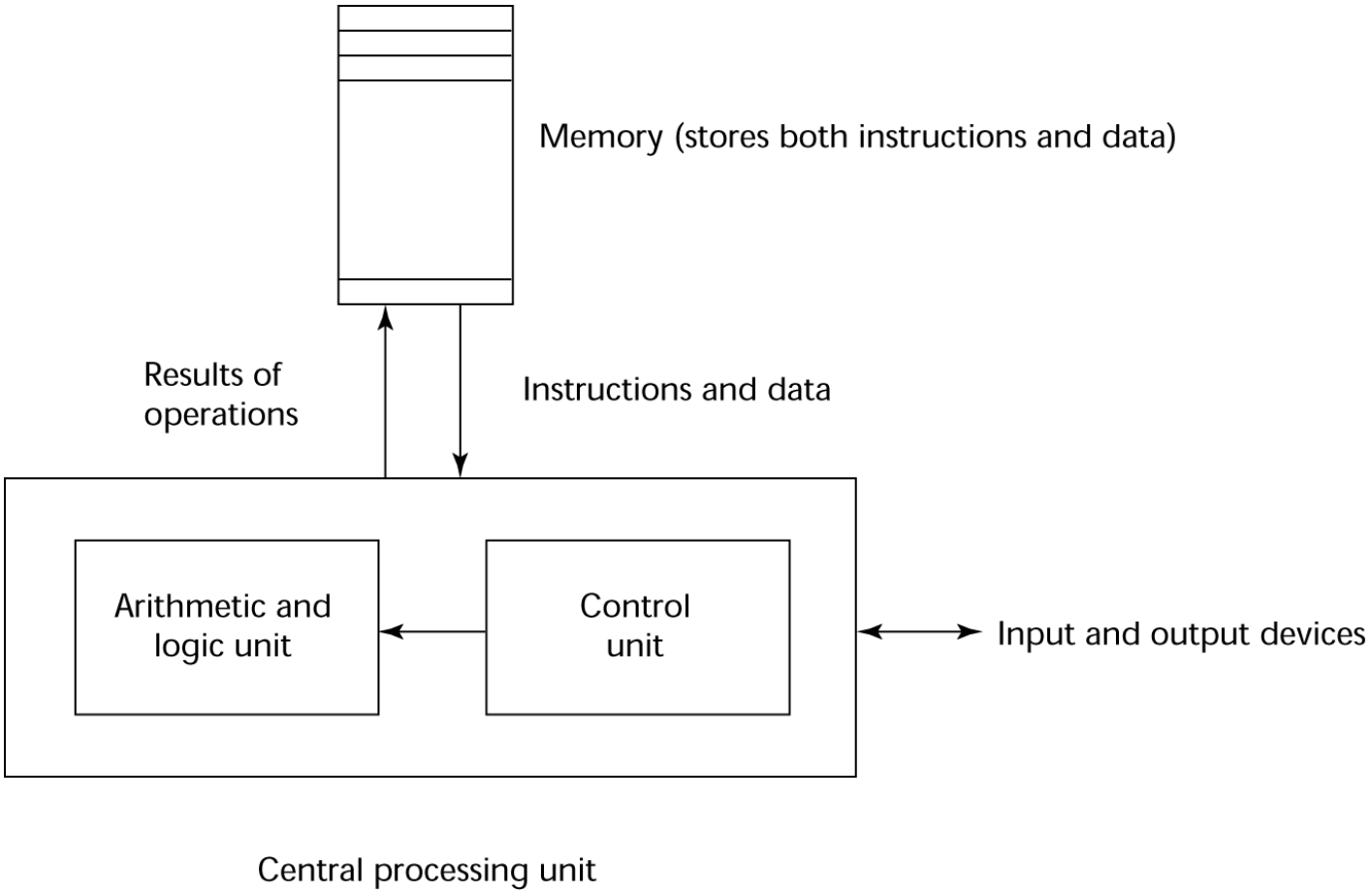
Learning

- 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

The ‘von Neuman’ Architecture



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
  - As old as electronic computers themselves

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

A (Short) History of AI

- 1940-1950: Early days
  - 1943: McCulloch & Pitts: Boolean circuit model of brain
  - 1950: Turing's “Computing Machinery and Intelligence”
- 1950—70: Excitement: Look, Ma, no hands!
  - 1950s: Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
  - 1956: Dartmouth meeting: “Artificial Intelligence” adopted
  - Allen Newell and Herbert Simon (LT) then GPS
  - 1965: Robinson's complete algorithm for logical reasoning

Proposal for Dartmouth Conference

We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely de- scribed that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer.

McCarthy+Minsky+Shannon+Rochester

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

Trends 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

Trends in AI Contd.

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.

THE STATE OF THE ART

What can AI do today? Here we sample a few applications:

- **Robotic vehicles**: A driverless robotic car named STANLEY sped through the rough terrain of the Mojave dessert at 22 mph, finishing the 132-mile course first to win the 2005 DARPA Grand Challenge. STANLEY is a Volkswagen Touareg outfitted with cameras, radar, and laser rangefinders to sense the environment and onboard software to command the steering, braking, and acceleration (Thrun, 2006). The following year CMU's BOSS won the Urban Challenge, safely driving in traffic through the streets of a closed Air Force base, obeying traffic rules and avoiding pedestrians and other vehicles.

THE STATE OF THE ART

- **Speech recognition**: A traveler calling United Airlines to book a flight can have the entire conversation guided by an automated speech recognition and dialog management system.
- **Autonomous planning and scheduling**: A hundred million miles from Earth, NASA's Remote Agent program became the first on-board autonomous planning program to control the scheduling of operations for a spacecraft (Jonsson *et al.*, 2000). REMOTE AGENT generated plans from high-level goals specified from the ground and monitored the execution of those plans; detecting, diagnosing, and recovering from problems as they occurred. Successor program MAPGEN (Al-Chang *et al.*, 2004) plans the daily operations for NASA's Mars Exploration Rovers, and MEXAR2 (Cesta *et al.*, 2007) did mission planning—both logistics and science planning—for the European Space Agency's Mars Express mission in 2008.

THE STATE OF THE ART

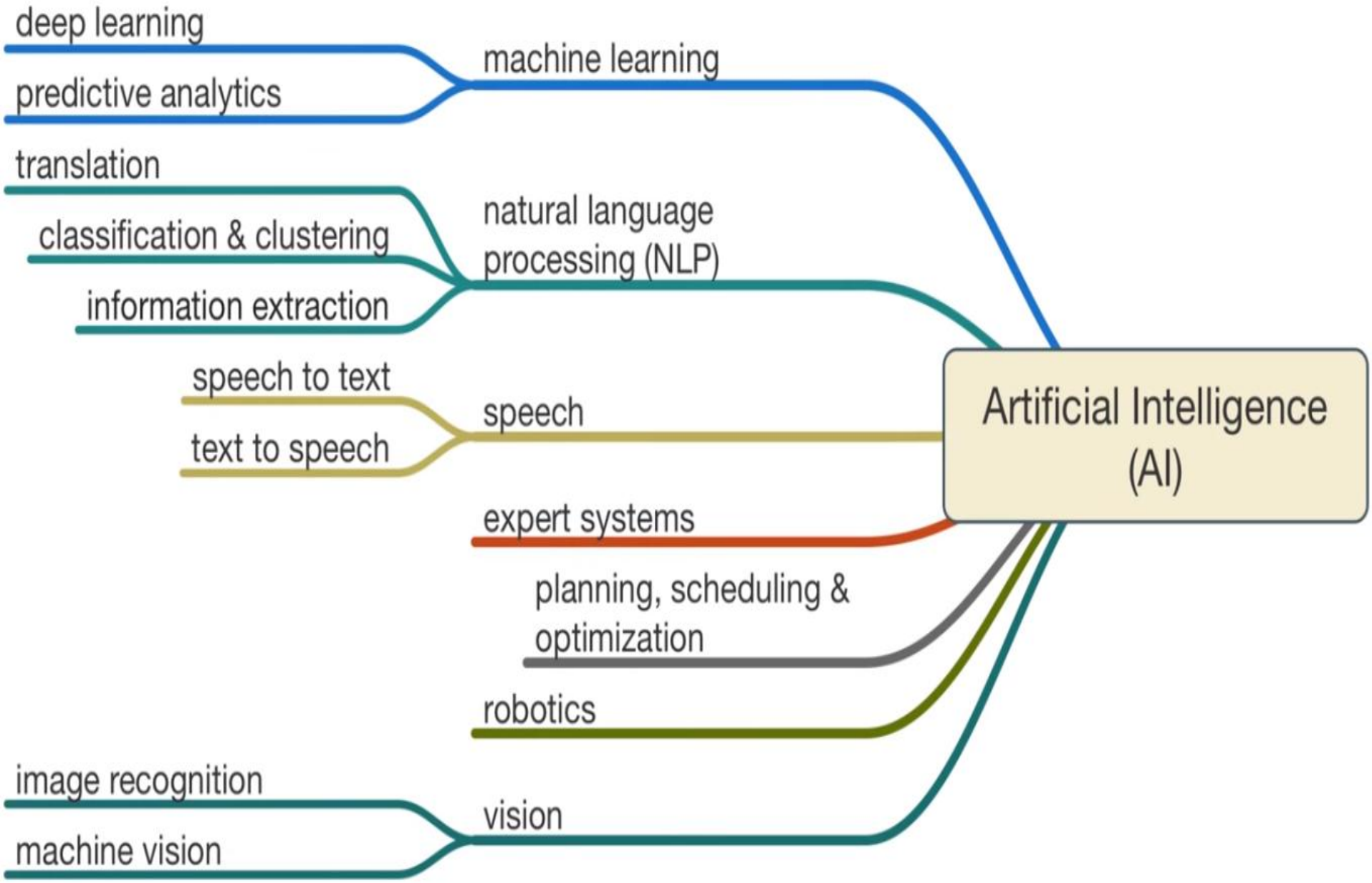
- **Game playing**: IBM's DEEP BLUE became the first computer program to defeat the world champion in a chess match when it bested Garry Kasparov by a score of 3.5 to 2.5 in an exhibition match (Goodman and Keene, 1997). Kasparov said that he felt a "new kind of intelligence" across the board from him. *Newsweek* magazine described the match as "The brain's last stand." The value of IBM's stock increased by $18 billion. Human champions studied Kasparov's loss and were able to draw a few matches in subsequent years, but the most recent human-computer matches have been won convincingly by the computer.

The main areas of AI research

Artificial intelligence can be considered under a number of headings:

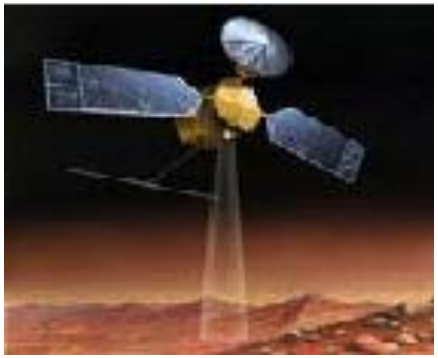
- Machine Learning.
- Natural language processing.
- Speech
- Expert Systems.
- Problem Solving (includes Game Playing).
- Robotics
- Vision
- Representing Knowledge and Reasoning with it.
- Planning.

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


deep learning
predictive analytics
machine learning
translation
classification & clustering
information extraction
natural language processing (NLP)
speech to text
text to speech
speech
Artificial Intelligence (AI)
expert systems
planning, scheduling & optimization
robotics
image recognition
machine vision
vision

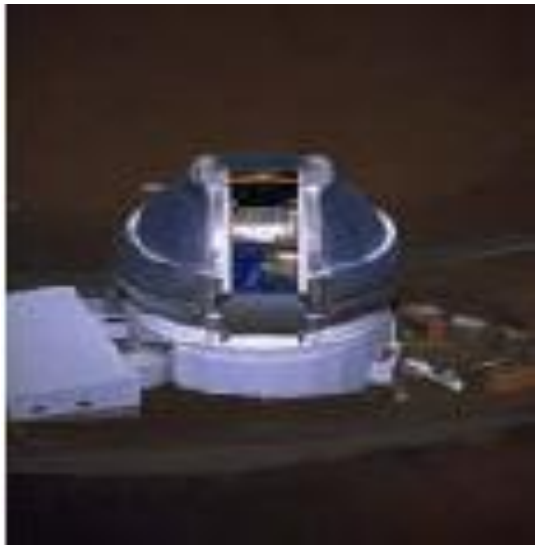
AI Applications

- Autonomous Planning & Scheduling:
  - Autonomous rovers.



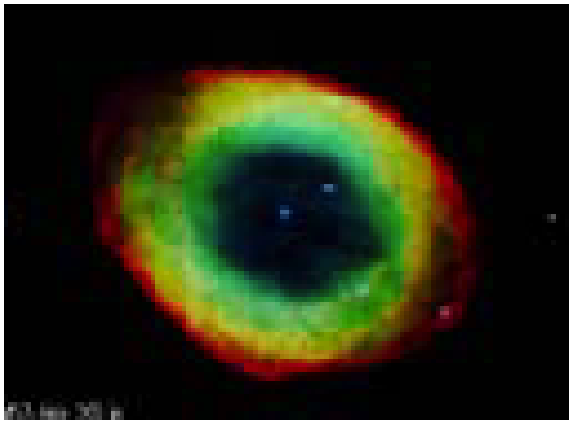
AI Applications

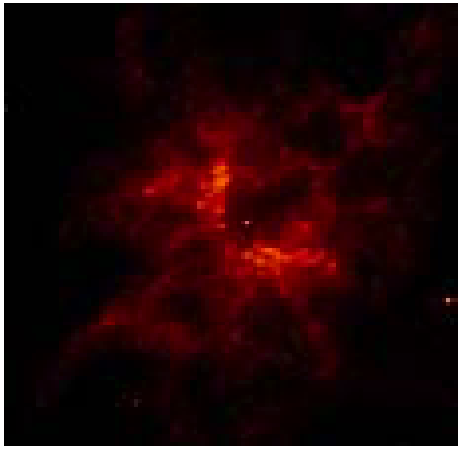
- Autonomous Planning & Scheduling:
  - Telescope scheduling



AI Applications

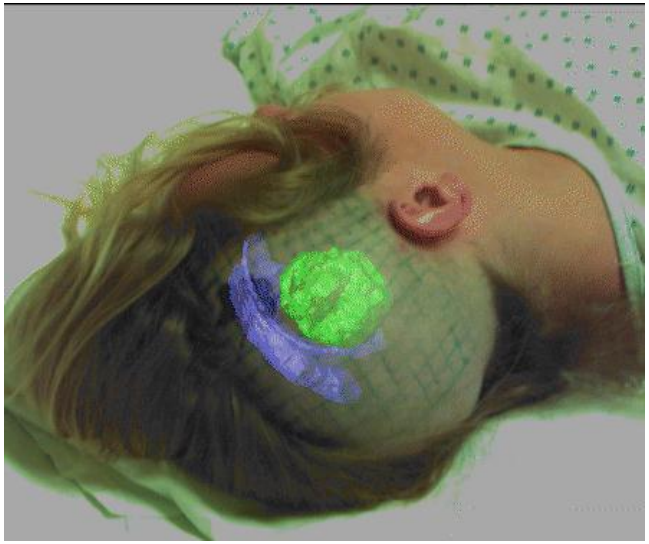
- Autonomous Planning & Scheduling:
  - Analysis of data:

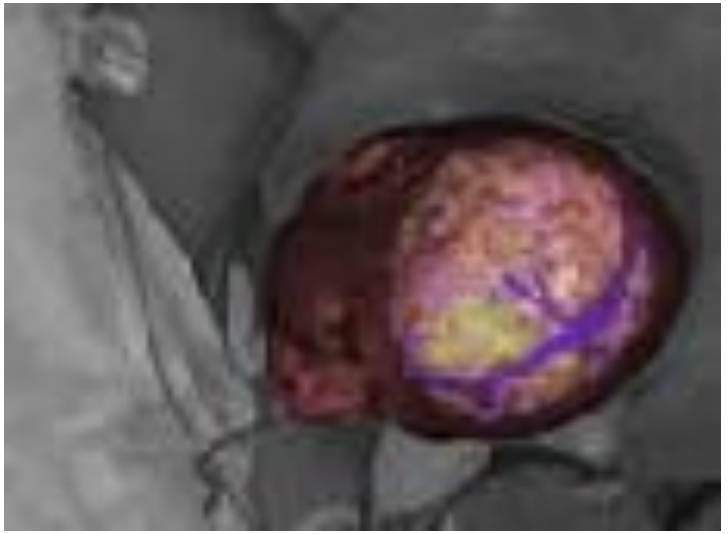




AI Applications

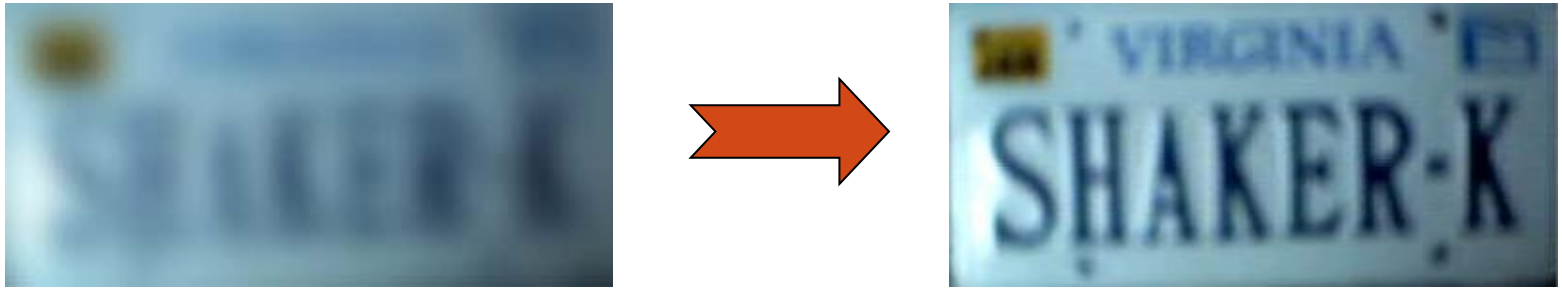
- **Medicine**:
  - Image guided surgery

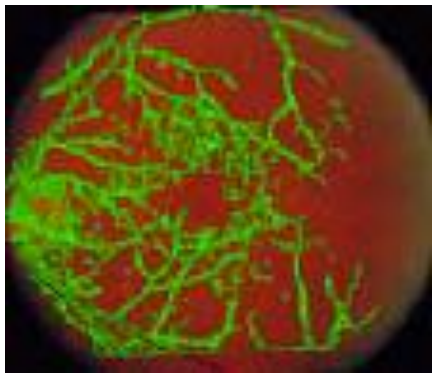


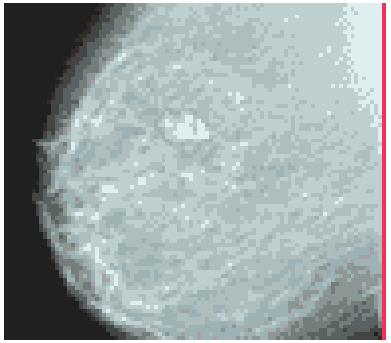


AI Applications

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







AI Applications

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

AI Applications

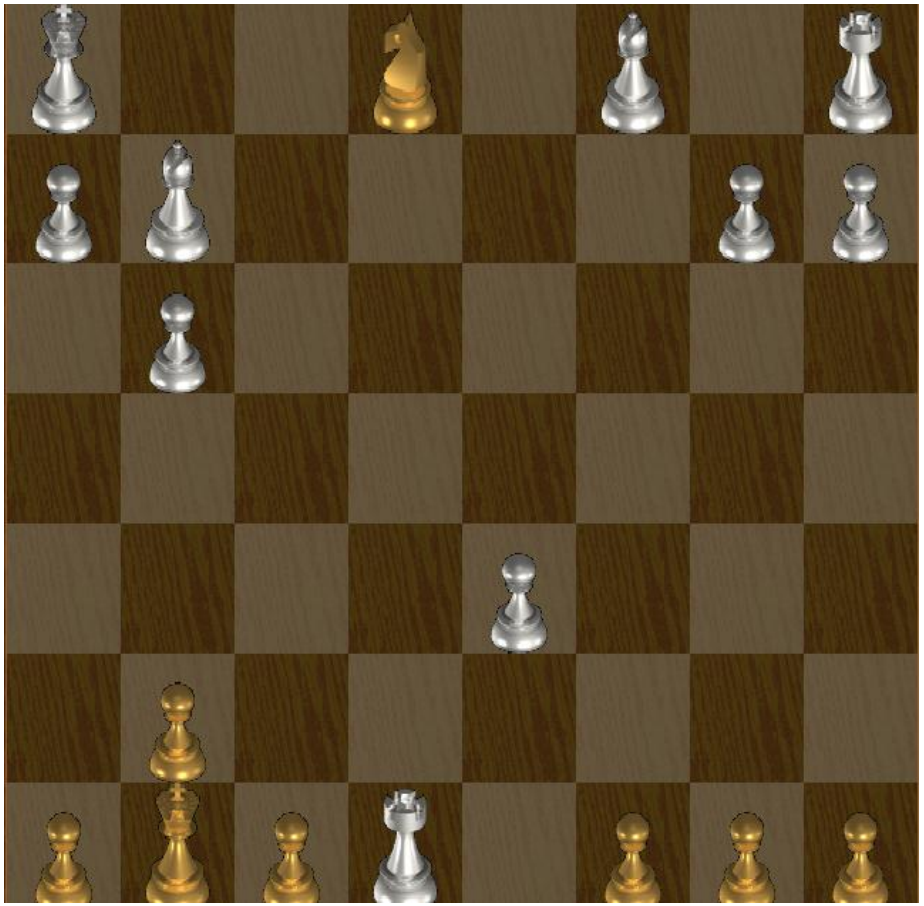
- **Transportation**:
  - **Pedestrian detection:**

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 sortin**g:
  - Web pages, e-mails
  - Articles in the news
- **Video, image classification**
- **Music composition, picture drawing**
- **Natural Language Processing** .
- **Perception.**

What AI Can do today

- a. Playing a decent game of table tennis (Ping-Pong).
- b. Driving in the center of Cairo, Egypt.
- c. Driving in Victorville, California.
- d. Buying a week's worth of groceries at the market.
- e. Buying a week's worth of groceries on the Web.
- f. Playing a decent game of bridge at a competitive level.
- g. Discovering and proving new mathematical theorems.
- h. Writing an intentionally funny story.
- i. Giving competent legal advice in a specialized area of law.
- j. Translating spoken English into spoken Swedish in real time.
- k. Performing a complex surgical operation.