CS60045 Artificial Intelligence Autumn 2023

Introduction

What is Artificial? What is Intelligence?

- Artificial = Machine
- Computation and computers are reasonably understood (Turing machines)

- But what is intelligence?
- Are we intelligent?
- Are humans the only intelligent species?
- Do we include all living beings as intelligent?

- There do not exist standard and mathematically precise definitions of intelligence.
- Let us be happy with only an intuitive notion.

Not everything is intelligent

- Number crunching is not considered intelligent.

- My laptop computes 12^{34567} in less than one ms. My mobile phone computes it in 4 seconds.

- This is a 37,305-digit number.

- A human would take a lifetime to compute this manually, and come up with a faulty answer.

- So this computation cannot be intelligent.

- We have a notion of complexities.

- Some computational problems are easy, some are difficult, some are apparently difficult.

- Some computational problems are even unsolvable.

- You studied many of these problems in various algorithms and automata courses.

- These problems, in general, are traditionally not considered intelligent.

Only a few things are intelligent

- We are *naturally* good at certain things.
  - Pattern recognition.
  - Languages and speech.
  - Reasoning.
  - Planning.
  - Learning.
  - Exploring.
  - …
- Electromechanical machines are apparently way behind us in replicating our performance.
- That should not be the case, because our machines are already formidable enough, and are growing faster and more complex day by day.
- Still, some of the natural human tasks are difficult for these machines.
- AI deals with algorithms/techniques/methods/… to make machines more like humans.

A Japanese android and its creator Professor Hiroshi Ishiguro in *Hyper Evolution: Rise of the Robots* (BBC) [Source: YouTube]

The end justifies the means

The areas where AI has already has some achievements include the following

- Automated driving
- Legged locomotion
- Autonomous planning and scheduling
- Understanding and translating natural languages
- Speech recognition
- Recommendations
- Game playing
- Image understanding
- Clinical diagnosis
- Climate prediction
- Human computer interaction

Intersections with other branches of CS

- The study of AI has developed many new tools and techniques.

- If nothing else works, imitate nature (human brains, natural selection, …)

- AI also uses algorithms developed in other branches of CS.

- For example, graph and string algorithms are often used in AI.

- Tools and techniques developed for AI problems are useful elsewhere too.

- For example, deep learning techniques are used in breaking cryptographic ciphers.

- This course is an introduction to the basic problems AI deals with, and the tools used to solve these problems.

A brief history of AI

Inception (1943–1956)

- McCulloch and Piits (1943): Model of artificial neurons
- Hebb (1949): Updating connection strengths between neurons (Hebbian learning)
- Minsky and Edmonds (1950): First neural networks

Great expectations (1952–1969)

- Automated problem solvers (Newell and Simon) and theorem provers (Rochester, Gelernter)
- Game playing and learning to play better (Samuel, birth of reinforcement learning)
- McCarthy (1959): LISP (programming language for AI)
- Rosenblatt (1962): Perceptrons
- Friedberg et al. (1958,1959): Machine evolution (Genetic algorithms)

A brief history of AI

Expert Systems (1969-1986)

Return of neural networks (1986–present): back-propagation learning

Probabilistic reasoning and machine learning (1987–present): Hidden Markov models, Bayesian networks

Big Data (2001–present)

Deep learning (2011–present): convoluted neural networks

Search techniques

To search in a space starting from the start position. The goal is

- To arrive at one desired position (there may be one or more such positions)
- To reach a good or a best position
- To discover that the goal is unreachable

The search space may have several issues

- Very large (possibly infinite)
- Insufficiently/probabilistically specified
- Partially observable
- May have adversaries
- May offer domain-specific information

Search techniques

Uninformed search

- Adaptations of graph traversal algorithms

Informed search

- Application of domain-specific heuristics to reduce search complexity (A* algorithm), iterative deepening

Local search

- Hill climbing
- Simulated annealing
- Evolutionary algorithms

Adversarial search

- Two-player games
- Alpha-beta pruning

Constraint Satisfaction Problems

Knowledge representation and reasoning

Propositional logic

Predicate logic

Inferencing

Planning

- Partial Order Planning
- Graph Planning
- SAT Planning
- Hierarchical Planning

Reasoning under uncertainty

Quantifying uncertainty

- Joint distribution
- Independence
- Bayes rule

Probabilistic reasoning

- Knowledge representation
- Bayesian network
- Conditional independence and D-separation

Machine learning

Humans learn

- How to walk
- How to understand, speak, read, and write languages
- How to get good grades in courses
- How to swim, how to play guitar, how to draw, …
- How to devise new ideas (research)

Machines may also learn

- It is often impossible to program a machine beforehand to tackle every possible situation
- It is often unknown a priori what algorithm works for certain problems
- Machines must improve their performance with time from experience (interaction with the environment)

Machine learning

Supervised learning: Learning based on a set of (input, output) specifications

Unsupervised learning: Learning without the help of any feedback

Reinforcement learning: Learning from rewards and punishments

Classical learning techniques

- Decision trees
- Linear regression

Machine learning

Deep learning

- Neural networks (back propagation)
- Convolution networks
- Recurrent networks

Reinforcement learning

- Model-based learning
- Model-free learning

State of the art

- **Beat world chess champions**   [Of course]
- **Drive safely from Manali to Leh**   [Will give it a good try]
- **Drive safely on Scholar's Avenue at 1:05pm**   [Banned in IIT]
- **Buy a week's grocery from Amazon**   [Why not?]
- **Buy a week's grocery from Tech Market**   [Which Boudi?]
- **Discover and prove a new mathematical theorem**   [Really?]
- **Give competent legal advice in a specialized area of law**   [Oh, yeah]
- **Converse successfully with another person for an hour**   [You dumb!!!]
- **Perform a complex surgical operation**   [May be]
- **Translate spoken Chinese to spoken English in real time**   [Yep]
- **Write an intentional funny story**   [What is fun?]