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# Overview of Artificial Intelligence

## What is AI?

- **A**rtificial Intelligence (AI) is a branch of *Science* which deals with helping machines find solutions to complex problems in a more human-like fashion.
- This generally involves borrowing characteristics from human intelligence, and applying them as algorithms in a computer friendly way.
- A more or less flexible or efficient approach can be taken depending on the requirements established, which influences how artificial the intelligent behavior appears
- Artificial intelligence can be viewed from a variety of perspectives.
- From the perspective of **intelligence**

artificial intelligence is making machines "intelligent" -- acting as we would expect people to act.

o The inability to distinguish computer responses from human responses is called the Turing test?

o Intelligence requires knowledge

o Expert problem solving - restricting domain to allow including significant relevant knowledge

- From a **business** perspective AI is a set of very powerful tools, and methodologies for using those tools to solve business problems.
- From a **programming** perspective, AI includes the study of symbolic programming, problem solving, and search.

o Typically AI programs focus on symbols rather than numeric processing.

o Problem solving - achieve goals.

o Search - seldom access a solution directly. Search may include a variety of techniques.

o AI programming languages include:

– LISP, developed in the 1950s, is the early programming language strongly associated with AI. LISP is a functional programming language with procedural extensions. LISP (LISt Processor) was specifically designed for processing heterogeneous lists -- typically a list of symbols. Features of LISP are run- time type checking, higher order functions (functions that have other functions as parameters), automatic memory management (garbage collection) and an interactive environment.

– The second language strongly associated with AI is PROLOG. PROLOG was developed in the 1970s. PROLOG is based on first order logic. PROLOG is declarative in nature and has facilities for explicitly limiting the search space.

– Object-oriented languages are a class of languages more recently used for AI programming. Important features of object-oriented languages include:

concepts of objects and messages, objects bundle data and methods for manipulating the data, sender specifies what is to be done receiver decides how to do it, inheritance (object hierarchy where objects inherit the attributes of the more general class of objects). Examples of object-oriented languages are Smalltalk, Objective C, C++. Object oriented extensions to LISP (CLOS - Common LISP Object System) and PROLOG (L&O - Logic & Objects) are also used.

- Artificial Intelligence is a new electronic machine that stores large amount of information and process it at very high speed
- The computer is interrogated by a human via a teletype It passes if the human cannot tell if there is a computer or human at the other end
- The ability to solve problems
- It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence

## Importance of AI

- **Game Playing**

You can buy machines that can play master level chess for a few hundred dollars. There is some AI in them, but they play well against people mainly through brute force computation--looking at hundreds of thousands of positions. To beat a world champion by brute force and known reliable heuristics requires being able to look at 200 million positions per second.

- **Speech Recognition**

In the 1990s, computer speech recognition reached a practical level for limited purposes. Thus United Airlines has replaced its keyboard tree for flight information by a system using speech recognition of flight numbers and city names. It is quite convenient. On the other hand, while it is possible to instruct some computers using speech, most users have gone back to the keyboard and the mouse as still more convenient.

- **Understanding Natural Language**

Just getting a sequence of words into a computer is not enough. Parsing sentences is not enough either. The computer has to be provided with an understanding of the domain the text is about, and this is presently possible only for very limited domains.

- **Computer Vision**

The world is composed of three-dimensional objects, but the inputs to the human eye and computers' TV cameras are two dimensional. Some useful programs can work solely in two dimensions, but full computer vision requires partial three-dimensional information that is not just a set of two-dimensional views. At present there are only limited ways of representing three-dimensional information directly, and they are not as good as what humans evidently use.

- **Expert Systems**

A ``knowledge engineer'' interviews experts in a certain domain and tries to embody their knowledge in a computer program for carrying out some task. How well this works depends on whether the intellectual mechanisms required for the task are within the present state of AI. When this turned out not to be so, there were many disappointing results. One of the first expert systems was MYCIN in 1974, which diagnosed bacterial infections of the blood and suggested treatments. It did better than medical students or practicing doctors, provided its limitations were observed. Namely, its ontology included bacteria, symptoms, and treatments and did not include patients, doctors, hospitals, death, recovery, and events occurring in time. Its interactions depended on a single patient being considered. Since the experts consulted by the knowledge engineers knew about patients, doctors, death, recovery, etc., it is clear that the knowledge engineers forced what the experts told them into a predetermined framework. The usefulness of current expert systems depends on their users having common sense.

- **Heuristic Classification**

One of the most feasible kinds of expert system given the present knowledge of AI is to put some information in one of a fixed set of categories using several sources of information. An example is advising whether to accept a proposed credit card purchase. Information is available about the owner of the credit card, his record of payment and also about the item he is buying and about the establishment from which he is buying it (e.g., about whether there have been previous credit card frauds at this establishment).

- **The applications of AI are shown in Fig 1.1:**

- Consumer Marketing

o Have you ever used any kind of credit/ATM/store card while shopping?

o if so, you have very likely been "input" to an AI algorithm

o All of this information is recorded digitally

o Companies like Nielsen gather this information weekly and search for patterns

– general changes in consumer behavior

– tracking responses to new products

– identifying customer segments: targeted marketing, e.g., they find out that consumers with sports cars who buy textbooks respond well to offers of new credit cards.

o Algorithms ("data mining") search data for patterns based on mathematical theories of learning

- Identification Technologies

o ID cards e.g., ATM cards

o can be a nuisance and security risk: cards can be lost, stolen, passwords forgotten, etc

o Biometric Identification, walk up to a locked door

– Camera

– Fingerprint device

– Microphone

– Computer uses biometric signature for identification

– Face, eyes, fingerprints, voice pattern
– This works by comparing data from person at door with stored library
– Learning algorithms can learn the matching process by analyzing a large library database off-line, can improve its performance.

- Intrusion Detection

o Computer security - we each have specific patterns of computer use times of day, lengths of sessions, command used, sequence of commands, etc
– would like to learn the “signature” of each authorized user
– can identify non-authorized users
o How can the program automatically identify users?
– record user’s commands and time intervals
– characterize the patterns for each user
– model the variability in these patterns
– classify (online) any new user by similarity to stored patterns

- Machine Translation

o Language problems in international business
– e.g., at a meeting of Japanese, Korean, Vietnamese and Swedish investors, no common language
– If you are shipping your software manuals to 127 countries, the solution is ; hire translators to translate
– would be much cheaper if a machine could do this!
o How hard is automated translation
– very difficult!
– e.g., English to Russian
– not only must the words be translated, but their meaning also!
Fig: Application areas of AI

**Early work in AI**

- “Artificial Intelligence (AI) is the part of computer science concerned with designing intelligent computer systems, that is, systems that exhibit characteristics we associate with intelligence in human behavior – understanding language, learning, reasoning, solving problems, and so on.”

- Scientific Goal to determine which ideas about knowledge representation, learning, rule systems, search, and so on, explain various sorts of real intelligence.

- Engineering Goal to solve real world problems using AI techniques such as knowledge representation, learning, rule systems, search, and so on.

- Traditionally, computer scientists and engineers have been more interested in the engineering goal, while psychologists, philosophers and cognitive scientists have been more interested in the scientific goal.

- The Roots - Artificial Intelligence has identifiable roots in a number of older disciplines, particularly:

- Philosophy

- Logic/Mathematics
- Computation
- Psychology/Cognitive Science
- Biology/Neuroscience
- Evolution
- There is inevitably much overlap, e.g. between philosophy and logic, or between mathematics and computation. By looking at each of these in turn, we can gain a better understanding of their role in AI, and how these underlying disciplines have developed to play that role.
- Philosophy
- ~400 BC Socrates asks for an algorithm to distinguish piety from non-piety.
- ~350 BC Aristotle formulated different styles of deductive reasoning, which could mechanically generate conclusions from initial premises, e.g. Modus Ponens
If A ? B and A then B
If A implies B and A is true then B is true when it's raining you
get wet and it's raining then you get wet
- 1596 – 1650 Rene Descartes idea of mind-body dualism – part of the mind is exempt from physical laws.
- 1646 – 1716 Wilhelm Leibnitz was one of the first to take the materialist position which holds that the mind operates by ordinary physical processes – this has the implication that mental processes can potentially be carried out by machines.
- Logic/Mathematics
- Earl Stanhope's Logic Demonstrator was a machine that was able to solve syllogisms, numerical problems in a logical form, and elementary questions of probability.
- 1815 – 1864 George Boole introduced his formal language for making logical inference in 1847 – Boolean algebra.
- 1848 – 1925 Gottlob Frege produced a logic that is essentially the first-order logic that today forms the most basic knowledge representation system.
- 1906 – 1978 Kurt Gödel showed in 1931 that there are limits to what logic can do. His Incompleteness Theorem showed that in any formal logic powerful enough to describe the properties of natural numbers, there are true statements whose truth cannot be established by any algorithm.
- 1995 Roger Penrose tries to prove the human mind has non-computable capabilities.
- Computation
- 1869 William Jevon's Logic Machine could handle Boolean Algebra and Venn

Diagrams, and was able to solve logical problems faster than human beings.

- 1912 – 1954 Alan Turing tried to characterize exactly which functions are capable of being computed. Unfortunately, it is difficult to give the notion of computation a formal definition. However, the Church-Turing thesis, which states that a Turing machine is capable of computing any computable function, is generally accepted as providing a sufficient definition. Turing also showed that there were some functions which no Turing machine can compute (e.g. Halting Problem).
- 1903 – 1957 John von Neumann proposed the von Neuman architecture which allows a description of computation that is independent of the particular realization of the computer.
- 1960s Two important concepts emerged: Intractability (when solution time grows at least exponentially) and Reduction (to 'easier' problems).
- Psychology / Cognitive Science
- Modern Psychology / Cognitive Psychology / Cognitive Science is the science which studies how the mind operates, how we behave, and how our brains process information.
- Language is an important part of human intelligence. Much of the early work on knowledge representation was tied to language and informed by research into linguistics.
- It is natural for us to try to use our understanding of how human (and other animal) brains lead to intelligent behavior in our quest to build artificial intelligent systems. Conversely, it makes sense to explore the properties of artificial systems (computer models/simulations) to test our hypotheses concerning human systems.
- Many sub-fields of AI are simultaneously building models of how the human system operates, and artificial systems for solving real world problems, and are allowing useful ideas to transfer between them.
- Biology / Neuroscience
- Our brains (which give rise to our intelligence) are made up of tens of billions of neurons, each connected to hundreds or thousands of other neurons.
- Each neuron is a simple processing device (e.g. just firing or not firing depending on the total amount of activity feeding into it). However, large networks of neurons are extremely powerful computational devices that can learn how best to operate.
- The field of Connectionism or Neural Networks attempts to build artificial systems based on simplified networks of simplified artificial neurons.
- The aim is to build powerful AI systems, as well as models of various human abilities.
- Neural networks work at a sub-symbolic level, whereas much of conscious human

reasoning appears to operate at a symbolic level.

- Artificial neural networks perform well at many simple tasks, and provide good models of many human abilities. However, there are many tasks that they are not so good at, and other approaches seem more promising in those areas.
- Evolution
- One advantage humans have over current machines/computers is that they have a long evolutionary history.
- Charles Darwin (1809 – 1882) is famous for his work on evolution by natural selection. The idea is that fitter individuals will naturally tend to live longer and produce more children, and hence after many generations a population will automatically emerge with good innate properties.
- This has resulted in brains that have much structure, or even knowledge, built in at birth.
- This gives them at the advantage over simple artificial neural network systems that have to learn everything.
- Computers are finally becoming powerful enough that we can simulate evolution and evolve good AI systems.
- We can now even evolve systems (e.g. neural networks) so that they are good at learning.
- A related field called genetic programming has had some success in evolving programs, rather than programming them by hand.
- Sub-fields of Artificial Intelligence
- Neural Networks – e.g. brain modelling, time series prediction, classification
- Evolutionary Computation – e.g. genetic algorithms, genetic programming
- Vision – e.g. object recognition, image understanding
- Robotics – e.g. intelligent control, autonomous exploration
- Expert Systems – e.g. decision support systems, teaching systems
- Speech Processing– e.g. speech recognition and production
- Natural Language Processing – e.g. machine translation
- Planning – e.g. scheduling, game playing
- Machine Learning – e.g. decision tree learning, version space learning
- Speech Processing
- As well as trying to understand human systems, there are also numerous real world applications: speech recognition for dictation systems and voice activated control; speech production for automated announcements and computer interfaces.

- How do we get from sound waves to text streams and vice-versa?
- Natural Language Processing
- For example, machine understanding and translation of simple sentences:
- Planning
- Planning refers to the process of choosing/computing the correct sequence of steps to solve a given problem.
- To do this we need some convenient representation of the problem domain. We can define states in some formal language, such as a subset of predicate logic, or a series of rules.
- A plan can then be seen as a sequence of operations that transform the initial state into the goal state, i.e. the problem solution. Typically we will use some kind of search algorithm to find a good plan.
- Common Techniques
- Even apparently radically different AI systems (such as rule based expert systems and neural networks) have many common techniques.
- Four important ones are:

o Knowledge Representation: Knowledge needs to be represented somehow – perhaps as a series of if-then rules, as a frame based system, as a semantic network, or in the connection weights of an artificial neural network.

o Learning: Automatically building up knowledge from the environment – such as acquiring the rules for a rule based expert system, or determining the appropriate connection weights in an artificial neural network.

o Rule Systems: These could be explicitly built into an expert system by a knowledge engineer, or implicit in the connection weights learnt by a neural network.

o Search: This can take many forms – perhaps searching for a sequence of states that leads quickly to a problem solution, or searching for a good set of connection weights for a neural network by minimizing a fitness function.

## AI and related fields

- **Logical AI**

What a program knows about the world in general the facts of the specific situation in which it must act, and its goals are all represented by sentences of some mathematical logical language. The program decides what to do by inferring that certain actions are appropriate for achieving its goals.

- **Search**

AI programs often examine large numbers of possibilities, e.g. moves in a chess game or inferences by a theorem proving program. Discoveries are continually made about how to do this more efficiently in various domains.

- **Pattern Recognition**

When a program makes observations of some kind, it is often programmed to compare what it sees with a pattern. For example, a vision program may try to match a pattern of eyes and a nose in a scene in order to find a face. More complex patterns, e.g. in a natural language text, in a chess position, or in the history of some event are also studied.

- **Representation**

Facts about the world have to be represented in some way. Usually languages of mathematical logic are used.

- **Inference**

From some facts, others can be inferred. Mathematical logical deduction is adequate for some purposes, but new methods of *non-monotonic* inference have been added to logic since the 1970s. The simplest kind of non-monotonic reasoning is default reasoning in which a conclusion is to be inferred by default, but the conclusion can be withdrawn if there is evidence to the contrary. For example, when we hear of a bird, we man infer that it can fly, but this conclusion can be reversed when we hear that it is a penguin. It is the possibility that a conclusion may have to be withdrawn that constitutes the non-monotonic character of the reasoning. Ordinary logical reasoning is monotonic in that the set of conclusions that can the drawn from a set of premises is a monotonic increasing function of the premises.

- **Common sense knowledge and reasoning**

This is the area in which AI is farthest from human-level, in spite of the fact that it has been an active research area since the 1950s. While there has been considerable progress, e.g. in developing systems of *non-monotonic reasoning* and theories of action, yet more new ideas are needed.

- **Learning from experience**

Programs do that. The approaches to AI based on *connectionism* and *neural nets* specialize in that. There is also learning of laws expressed in logic. Programs can only learn what facts or behaviors their formalisms can represent, and unfortunately learning systems are almost all based on very limited abilities to represent information.

- **Planning**

Planning programs start with general facts about the world (especially facts about the effects of actions), facts about the particular situation and a statement of a goal. From these, they generate a strategy for achieving the goal. In the most common cases, the strategy is just a sequence of actions.

- **Epistemology**

This is a study of the kinds of knowledge that are required for solving problems in the world.

- **Ontology**

Ontology is the study of the kinds of things that exist. In AI, the programs and sentences deal with various kinds of objects, and we study what these kinds are and what their basic properties are. Emphasis on ontology begins in the 1990s.

- **Heuristics**

A heuristic is a way of trying to discover something or an idea imbedded in a program. The term is used variously in AI. *Heuristic functions* are used in some approaches to search to measure how far a node in a search tree seems to be from a goal. *Heuristic predicates* that compare two nodes in a search tree to see if one is better than the other, i.e. constitutes an advance toward the goal, may be more useful.

- **Genetic Programming**

Genetic programming is a technique for getting programs to solve a task by mating random Lisp programs and selecting fittest in millions of generations.

**Search and Control Strategies:**

Problem solving is an important aspect of Artificial Intelligence. A problem can be considered to consist of a goal and a set of actions that can be taken to lead to the goal. At any given time, we consider the state of the search space to represent where we have reached as a result of the actions we have applied so far. For example, consider the problem of looking for a contact lens on a football field. The initial state is how we start out, which is to say we know that the lens is somewhere on the field, but we don't know where. If we use the representation where we examine the field in units of one square foot, then our first action might be to examine the square in the top-left corner of the field. If we do not find the lens there, we could consider the state now to be that we have examined the top-left square and have not found the lens. After a number of actions, the state might be that we have examined 500 squares, and we have now just found the lens in the last square we examined. This is a goal state because it satisfies the goal that we had of finding a contact lens.
Search is a method that can be used by computers to examine a problem space like this in order to find a goal. Often, we want to find the goal as quickly as possible or without using too many resources. A problem space can also be considered to be a search space because in order to solve the problem, we will search the space for a goal state.We will continue to use the term search space to describe this concept. In this chapter, we will look at a number of methods for examining a search space. These methods are called search methods.

- The Importance of Search in AI

- It has already become clear that many of the tasks underlying AI can be phrased in terms of a search for the solution to the problem at hand.

- Many goal based agents are essentially problem solving agents which must decide what to do by searching for a sequence of actions that lead to their solutions.

- For production systems, we have seen the need to search for a sequence of rule applications that lead to the required fact or action.

- For neural network systems, we need to search for the set of connection weights that will result in the required input to output mapping.

- Which search algorithm one should use will generally depend on the problem domain? There are four important factors to consider:

- Completeness – Is a solution guaranteed to be found if at least one solution exists?
- Optimality – Is the solution found guaranteed to be the best (or lowest cost) solution if there exists more than one solution?
- Time Complexity – The upper bound on the time required to find a solution, as a function of the complexity of the problem.
- Space Complexity – The upper bound on the storage space (memory) required at any point during the search, as a function of the complexity of the problem.