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New Artificial Intelligence

-Prakhar Swarup,1st Year (B.Tech) Electronics And Communication Engineering

Indian School Of Mines Dhanbad

1. ABSTRACT

Artificial intelligence (AI) is the intelligence of machines and the branch of computer science that aims to create it. It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the task of using computers to understand human intelligence, but AI does not confine itself to methods that are biologically observable.

While there are many different definitions, AI textbooks define the field as "the study and design of intelligent agents" where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success. John McCarthy, who coined the term in 1956, defines it as "the science and engineering of making intelligent machines."

The field was founded on the claim that a central property of humans, intelligence—the sapience of Homo sapiens—can be so precisely described that it can be simulated by a machine. This raises philosophical issues about the nature of the mind and the ethics of creating artificial beings, issues which have been addressed by myth, fiction and philosophy since antiquity. Artificial intelligence has been the subject of optimism, but has also suffered setbacks and, today, has become an essential part of the technology industry, providing the heavy lifting for many of the most difficult problems in computer science.

Keywords: Combinatorial Explosion, Sub-Symbolic, Cybernetics, Scruffy, Heuristics, Bayesian Networks, Neural Network, The Support Vector Machine, K-Nearest Neighbor Algorithm, Gaussian Mixture Model, Naive Bayes Classifier.

2. INTELLIGENCE

Intelligence can be defined as the computational part of the ability to achieve goals in the world. Varying kinds and degrees of intelligence occur in people, many animals and some machines. A

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common question that arises related to intelligence is that 'Isn't there a solid definition of intelligence which does not relate it to human intelligence?' .The answer is not yet because we cannot characterize in general what kind of computational procedures we want to call intelligent. We understand some forms of intelligence and not others. Intelligence involves mechanisms, and AI research has discovered how to make computers carry out some of them and not others. If doing a task requires only mechanisms that are well understood today, computer programs can give very impressive performances on these tasks. Such programs should be considered ``somewhat intelligent''.

Artificial intelligence is not always about simulating human intelligence. Most work in AI involves studying the problems the world presents to intelligence rather than studying people or animals. AI researchers are free to use methods that are not observed in people or that involve much more computing than people can do.

Another important fact about artificial intelligence is that computer programs have no IQ (Intelligence Quotient). This is because IQ is based on the rates at which intelligence develops in children. It is the ratio of the age at which a child normally makes a certain score to the child's age. The scale is extended to adults in a suitable way. IQ correlates well with various measures of success or failure in life, but making computers that can score high on IQ tests would be weakly correlated with their usefulness. For example, the ability of a child to repeat back a long sequence of digits correlates well with other intellectual abilities, perhaps because it measures how much information the child can compute with at once. However, ``digit span'' is trivial for even extremely limited computers.

3. HISTORY OF ARTIFICIAL INTELLIGENCE

Evidence of Artificial Intelligence folklore can be traced back to ancient Egypt, but with the development of the electronic computer in 1941, the technology finally became available to create machine intelligence. The term artificial intelligence was first coined in 1956, at the Dartmouth conference, and since then Artificial Intelligence has expanded because of the theories and principles developed by its dedicated researchers.

3.1 THE ERA OF THE COMPUTER

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In 1941 an invention revolutionized every aspect of the storage and processing of information. That invention was the electronic computer. The first computers required large, separate air-conditioned rooms, and were a programmer's nightmare, involving the separate configuration of thousands of wires to even get a program running. The 1949 innovation, the stored program computer, made the job of entering a program easier, and advancements in computer theory lead to computer science, and eventually Artificial intelligence. With the invention of an electronic means of processing data, came a medium that made AI possible.

3.2 THE BEGINNINGS OF AI

Although the computer provided the technology necessary for AI, it was not until the early 1950's that the link between human intelligence and machines was really observed. The first observations were made on the principle of feedback theory. The most familiar example of feedback theory is the thermostat. It controls the temperature of an environment by gathering the actual temperature of the house, comparing it to the desired temperature, and responding by turning the heat up or down. What was so important about this research into feedback loops was that it theorized that all intelligent behavior was the result of feedback mechanisms. This discovery influenced much of the early development of AI.

In late 1955 *The Logic Theorist,* was developed considered by many to be the first AI program. The program, representing each problem as a tree model, would attempt to solve it by selecting the branch that would most likely result in the correct conclusion. The impact that it made on both the public and the field of AI has made it a crucial stepping stone in developing the AI field.

In 1956 John McCarthy regarded as the father of AI, organized a conference to draw the talent and expertise of others interested in machine intelligence for a month of brainstorming. He invited them to Vermont for "The Dartmouth summer research project on artificial intelligence." From that point on, because of McCarthy, the field would be known as Artificial intelligence. Although not a huge success, the Dartmouth conference did bring together the founders in AI, and served to lay the groundwork for the future of AI research.

4. PROBLEMS RELATED TO ARTIFICIAL INTELLIGENCE

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"Can a machine act intelligently?" is still an open problem. Taking "A machine can act intelligently" as a working hypothesis, many researchers have attempted to build such a machine.

The general problem of simulating (or creating) intelligence has been broken down into a number of specific sub-problems. These consist of particular traits or capabilities that researchers would like an intelligent system to display. Some of the most important traits are described below:

4.1 DEDUCTION, REASONING AND PROBLEM SOLVING

Early AI researchers developed algorithms that imitated the step-by-step reasoning that humans use when they solve puzzles or make logical deductions. By the late 1980s and '90s, AI research had also developed highly successful methods for dealing with uncertain or incomplete information, employing concepts from probability and economics.

For difficult problems, most of these algorithms can require enormous computational resources — most experience a "combinatorial explosion": the amount of memory or computer time required becomes astronomical when the problem goes beyond a certain size. The search for more efficient problem-solving algorithms is a high priority for AI research.

Human beings solve most of their problems using fast, intuitive judgments rather than the conscious, step-by-step deduction that early AI research was able to model. AI has made some progress at imitating this kind of "sub-symbolic" problem solving: embodied agent approaches emphasize the importance of sensorimotor skills to higher reasoning; neural net research attempts to simulate the structures inside human and animal brains that give rise to this skill.

4.2 KNOWLEDGE REPRESENTATION

Knowledge representation and knowledge engineering are central to AI research. Many of the problems machines are expected to solve will require extensive knowledge about the world. Among the things that AI needs to represent are: objects, properties, categories and relations

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between objects, situations, events, states and time; causes and effects; knowledge about knowledge (what we know about what other people know); and many other, less well researched domains.

Among the most difficult problems in knowledge representations are:

- Default reasoning and the qualification problem-
  Many of the things people know take the form of "working assumptions." For example, if a bird comes up in conversation, people typically picture an animal that is fist sized, sings, and flies. None of these things are true about all birds. John McCarthy identified this problem in 1969 as the qualification problem: for any commonsense rule that AI researchers care to represent, there tend to be a huge number of exceptions. Almost nothing is simply true or false in the way that abstract logic requires.
- The sub-symbolic form of some commonsense knowledge-
  Much of what people know is not represented as "facts" or "statements" that they could express verbally. For example, a chess master will avoid a particular chess position because it "feels too exposed" or an art critic can take one look at a statue and instantly realize that it is a fake. These are intuitions or tendencies that are represented in the brain non-consciously and sub-symbolically. Knowledge like this supports and provides a context for symbolic, conscious knowledge. As with the related problem of sub-symbolic reasoning, it is hoped that situated AI or computational intelligence will provide ways to represent this kind of knowledge.

4.3 PLANNING

Intelligent agents must be able to set goals and achieve them. They need a way to visualize the future (they must have a representation of the state of the world and be able to make predictions about how their actions will change it) and be able to make choices that maximize the utility of the available choices.

4.4 LEARNING

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Machine learning has been central to AI research from the beginning. In 1956, at the original Dartmouth AI summer conference, a report was written on unsupervised probabilistic machine learning: "An Inductive Inference Machine". Unsupervised learning is the ability to find patterns in a stream of input. Supervised learning includes both classification and numerical regression. Classification is used to determine what category something belongs in, after seeing a number of examples of things from several categories. Regression is the attempt to produce a function that describes the relationship between inputs and outputs and predicts how the outputs should change as the inputs change.

4.5 NATURAL LANGUAGE PROCESSING

Natural language processing gives machines the ability to read and understand the languages that humans speak. A sufficiently powerful natural language processing system would enable the acquisition of knowledge directly from human-written sources, such as Internet texts. Some straightforward applications of natural language processing include information retrieval and machine translation.

5. APPROACHES TOWARDS ARTIFICIAL INTELLIGENCE

There is no established unifying theory or paradigm that guides AI research. Researchers disagree about many issues. A few of the longest standing questions that have remained unanswered are these: Should artificial intelligence simulate natural intelligence by studying psychology or neurology? Or is human biology as irrelevant to AI research as bird biology is to aeronautical engineering? Can intelligent behavior be described using simple, elegant principles such as logic or optimization? Or does it necessarily require solving a large number of completely unrelated problems? Can intelligence be reproduced using high-level symbols, similar to words and ideas? Or does it require "sub-symbolic" processing? No single algorithm can answer all these questions .However there are some widely accepted approaches which are listed below:

5.1 CYBERNETICS AND BRAIN SIMULATION

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There is currently no consensus on how closely the brain should be simulated.

In the 1940s and 1950s, a number of researchers explored the connection between neurology, information theory, and cybernetics. Some of them built machines that used electronic networks to exhibit rudimentary intelligence, such as W. Grey Walter's turtles and the Johns Hopkins Beast. Many of these researchers gathered for meetings of the Teleological Society at Princeton University and the Ratio Club in England. By 1960, this approach was largely abandoned, although elements of it were revived in the 1980s.

5.2 SYMBOLIC

When access to digital computers became possible in the middle 1950s, AI research began to explore the possibility that human intelligence could be reduced to symbol manipulation. The research was centered in three institutions: CMU, Stanford and MIT, and each one developed its own style of research. John Haugeland named these approaches to AI "good old fashioned AI" or "GOFAI".

5.3 COGNITIVE SIMULATION

Researchers and economists studied human problem-solving skills and attempted to formalize them, and their work laid the foundations of the field of artificial intelligence, as well as cognitive science. The results of psychological experiments were used to develop programs that simulated the techniques that people use to solve problems.

5.4 LOGIC-BASED

Unlike other researchers, John McCarthy felt that machines did not need to simulate human thought, but should instead try to find the essence of abstract reasoning and problem solving, regardless of whether people used the same algorithms. His laboratory at Stanford focused on using formal logic to solve a wide variety of problems, including knowledge representation, planning and learning. Logic was also focus of the work at the University of

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Edinburgh and elsewhere in Europe which led to the development of the programming language Prolog and the science of logic programming.

5.5 "ANTI-LOGIC" OR "SCRUFFY"

Researchers at MIT found that solving difficult problems in vision and natural language processing required ad-hoc solutions – they argued that there was no simple and general principle that would capture all the aspects of intelligent behavior. This logic was described as "anti-logic" or "scruffy" (as opposed to the "neat" paradigms at CMU and Stanford). Commonsense knowledge bases are an example of "scruffy" AI, since they must be built by hand, one complicated concept at a time.

5.6 KNOWLEDGE-BASED

When computers with large memories became available around 1970, researchers from all three traditions began to build knowledge into AI applications. This "knowledge revolution" led to the development and deployment of expert systems, the first truly successful form of AI software. The knowledge revolution was also driven by the realization that enormous amounts of knowledge would be required by many simple AI applications.

5.7 SUB-SYMBOLIC

During the 1960s, symbolic approaches had achieved great success at simulating high-level thinking in small demonstration programs. By the 1980s, however, progress in symbolic AI seemed to stall and many believed that symbolic systems would never be able to imitate all the processes of human cognition, especially perception, robotics, learning and pattern recognition. A number of researchers began to look into "sub-symbolic" approaches to specific AI problems.

Researchers from the related field of robotics rejected symbolic AI and focused on the basic engineering problems that would allow robots to move and survive. Their work revived the non-symbolic viewpoint of the early researchers of the 50s and reintroduced the use of control theory in AI.

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5.8 STATISTICAL

In the 1990s, AI researchers developed sophisticated mathematical tools to solve specific problems. These tools were truly scientific, in the sense that their results were both measurable and verifiable. Also they have been responsible for many of AI's recent successes. The shared mathematical language has also permitted a high level of collaboration with more established fields (like mathematics, economics or operations research). This movement is described as nothing less than a "revolution" and "the victory of the neats." Critics argue that these techniques are too focused on particular problems and have failed to address the long term goal of general intelligence.

6. INTEGRATING THE APPROACHES

An intelligent agent is a system that perceives its environment and takes actions which maximize its chances of success. The simplest intelligent agents are programs that solve specific problems. More complicated agents include human beings and organizations of human beings (such as firms). The paradigm gives researchers license to study isolated problems and find solutions that are both verifiable and useful, without agreeing on one single approach. An agent that solves a specific problem can use any approach that works — some agents are symbolic and logical, some are sub-symbolic neural networks and others may use new approaches. The paradigm also gives researchers a common language to communicate with other fields—such as decision theory and economics—that also use concepts of abstract agents.

7. TOOLS USED IN ARTIFICIAL INTELLIGENCE

In the course of 50 years of research, AI has developed a large number of tools to solve the most difficult problems in computer science. A few of the most general of these methods are discussed below.

7.1 SEARCH AND OPTIMIZATION

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Many problems in AI can be solved in theory by intelligently searching through many possible solutions that is reasoning can be reduced to performing a search. For example, logical proof can be viewed as searching for a path that leads from premises to conclusions, where each step is the application of an inference rule. Planning algorithms search through trees of goals and sub goals, attempting to find a path to a target goal, a process called means-ends analysis. Robotics algorithms for moving limbs and grasping objects use local searches in configuration space. Many learning algorithms use search algorithms based on optimization.

Simple exhaustive searches are rarely sufficient for most real world problems: the search space (the number of places to search) quickly grows to astronomical numbers. The result is a search that is too slow or never completes. The solution, for many problems, is to use "heuristics" or "rules of thumb" that eliminate choices that are unlikely to lead to the goal (called "pruning the search tree"). Heuristics supply the program with a "best guess" for the path on which the solution lies.

A very different kind of search came to prominence in the 1990s, based on the mathematical theory of optimization. For many problems, it is possible to begin the search with some form of a guess and then refine the guess incrementally until no more refinements can be made. These algorithms can be visualized as blind hill climbing: we begin the search at a random point on the landscape, and then, by jumps or steps, we keep moving our guess uphill, until we reach the top.

Evolutionary computation uses a form of optimization search. For example, they may begin with a population of organisms (the guesses) and then allow them to mutate and recombine, selecting only the fittest to survive each generation (refining the guesses). Forms of evolutionary computation include swarm intelligence algorithms (such as ant colony or particle swarm optimization) and evolutionary algorithms (such as genetic algorithms and genetic programming).

7.2 LOGIC

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Logic is used for knowledge representation and problem solving, but it can be applied to other problems as well. Several different forms of logic are used in AI research. Propositional or sentential logic is the logic of statements which can be true or false. First-order logic also allows the use of quantifiers and predicates, and can express facts about objects, their properties, and their relations with each other. Fuzzy logic is a version of first-order logic which allows the truth of a statement to be represented as a value between 0 and 1, rather than simply true (1) or false (0). Fuzzy systems can be used for uncertain reasoning and have been widely used in modern industrial and consumer product control systems. Subjective logic models uncertainty in a different and more explicit manner than fuzzy-logic: a given binomial opinion satisfies belief + disbelief + uncertainty = 1 within a Beta distribution. By this method, ignorance can be distinguished from probabilistic statements that an agent makes with high confidence.

Default logics, non-monotonic logics and circumscription are forms of logic designed to help with default reasoning and the qualification problem. Several extensions of logic have been designed to handle specific domains of knowledge, such as description logics, situation calculus, event calculus and fluent calculus (for representing events and time), causal calculus; belief calculus, and modal logics.

7.3 PROBABILISTIC METHODS FOR UNCERTAIN REASONING

Many problems in AI (in reasoning, planning, learning, perception and robotics) require the agent to operate with incomplete or uncertain information. AI researchers have devised a number of powerful tools to solve these problems using methods from probability theory and economics.

Bayesian networks are a very general tool that can be used for a large number of problems: reasoning (using the Bayesian inference algorithm), learning (using the expectation-maximization algorithm), planning (using decision networks) and perception (using dynamic Bayesian networks). Probabilistic algorithms can also be used for filtering, prediction, smoothing and finding explanations for streams of data, helping perception systems to analyze processes that occur over time.

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A key concept from the science of economics is "utility": a measure of how valuable something is to an intelligent agent. Precise mathematical tools have been developed that analyze how an agent can make choices and plan, using decision theory, decision analysis, information value theory. These tools include models such as dynamic decision networks, game theory and mechanism design.

7.4 CLASSIFIERS AND STATISTICAL LEARNING METHODS

The simplest AI applications can be divided into two types: classifiers ("if shiny then diamond") and controllers ("if shiny then pick up"). Controllers do however also classify conditions before inferring actions, and therefore classification forms a central part of many AI systems. Classifiers are functions that use pattern matching to determine a closest match. They can be tuned according to examples, making them very attractive for use in AI. These examples are known as observations or patterns. In supervised learning, each pattern belongs to a certain predefined class. A class can be seen as a decision that has to be made. All the observations combined with their class labels are known as a data set. When a new observation is received, that observation is classified based on previous experience.

A classifier can be trained in various ways; there are many statistical and machine learning approaches. The most widely used classifiers are the neural network, kernel methods such as the support vector machine ,k-nearest neighbor algorithm, Gaussian mixture model, naive Bayes classifier, and decision tree. The performance of these classifiers have been compared over a wide range of tasks. Classifier performance depends greatly on the characteristics of the data to be classified. There is no single classifier that works best on all given problems. This is also referred to as the "no free lunch" theorem. Determining a suitable classifier for a given problem is still more an art than science.

7.5 NEURAL NETWORKS

A neural network is an interconnected group of nodes, akin to the vast network of neurons in the human brain. The study of artificial neural networks began in the decade before the field AI research was founded, in the work of Walter Pitts and Warren McCullough. Other important

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early researchers were Frank Rosenblatt, who invented the perceptron and Paul Werbos who developed the backpropagation algorithm.

The main categories of neural networks are acyclic or feedforward neural networks (where the signal passes in only one direction) and recurrent neural networks (which allow feedback). Among the most popular feedforward networks are perceptrons, multi-layer perceptrons and radial basis networks. Among recurrent networks, the most famous is the Hopfield net, a form of attractor network, which was first described by John Hopfield in 1982. Neural networks can be applied to the problem of intelligent control (for robotics) or learning, using such techniques as competitive learning.

8. BRANCHES OF ARTIFICIAL INTELLIGENCE

Some of the branches of artificial intelligence are briefly described below. These are not the complete number of branches because some of the branches have not been studied yet. Also some of these may be regarded as concepts rather than full branches.

8.1 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. The first article proposing this was [McC59]. [McC89], [McC96b], [Sha97] are more recent texts which list some of the concepts involved in logical AI.

8.2 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.

8.3 PATTERN RECOGNITION

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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. These more complex patterns require quite different methods than do the simple patterns that have been studied the most.

8.4 REPRESENTATION

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

8.5 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 can 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 be drawn from a set of premises is a monotonic increasing function of the premises. Circumscription is another form of non-monotonic reasoning.

8.6 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. For example the Cyc system contains a large but spotty collection of common sense facts.

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8.7 LEARNING FROM EXPERIENCE

Computer programs can learn from experience and practice. The approaches to AI based on connectionism and neural nets specialize in this. There is also learning of laws expressed in logic. [Mit97] is a comprehensive undergraduate text on machine learning. 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.

8.8 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.

8.9 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 compares two nodes in a search tree to see if one is better than the other, i.e. constitutes an advance toward the goal.

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