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# Artificial Intelligence (AI) - Concerned with Building Smart Machines

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**ABSTRACT:** Artificial intelligence (AI) is intelligence—perceiving, synthesizing, and inferring information—demonstrated by machines, as opposed to intelligence displayed by non-human animals and humans. Example tasks in which this is done include speech recognition, computer vision, translation between (natural) languages, as well as other mappings of inputs. AI applications include advanced web search engines (e.g., Google Search), recommendation systems (used by YouTube, Amazon, and Netflix), understanding human speech (such as Siri and Alexa), self-driving cars (e.g., Waymo), generative or creative tools (ChatGPT and AI art), automated decision-making, and competing at the highest level in strategic game systems (such as chess and Go).<sup>[1]</sup> As machines become increasingly capable, tasks considered to require "intelligence" are often removed from the definition of AI, a phenomenon known as the AI effect.<sup>[2]</sup> For instance, optical character recognition is frequently excluded from things considered to be AI,<sup>[3]</sup> having become a routine technology.<sup>[4]</sup>

**KEYWORDS:** Artificial Intelligence, machines, applications, web, internet, computer, smart, optical, search

## I. INTRODUCTION

Artificial intelligence was founded as an academic discipline in 1956, and in the years since it has experienced several waves of optimism,<sup>[5][6]</sup> followed by disappointment and the loss of funding (known as an "AI winter"),<sup>[7][8]</sup> followed by new approaches, success, and renewed funding.<sup>[6][9]</sup> AI research has tried and discarded many different approaches, including simulating the brain, modeling human problem solving, formal logic, large databases of knowledge, and imitating animal behavior. In the first decades of the 21st century, highly mathematical and statistical machine learning has dominated the field, and this technique has proved highly successful, helping to solve many challenging problems throughout industry and academia.<sup>[9][10]</sup>

The various sub-fields of AI research are centered around particular goals and the use of particular tools. The traditional goals of AI research include reasoning, knowledge representation, planning, learning, natural language processing, perception, and the ability to move and manipulate objects.<sup>[a]</sup> General intelligence (the ability to solve an arbitrary problem) is among the field's long-term goals.<sup>[11]</sup> To solve these problems, AI researchers have adapted and integrated a wide range of problem-solving techniques, including search and mathematical optimization, formal logic, artificial neural networks, and methods based on statistics, probability, and economics. AI also draws upon computer science, psychology, linguistics, philosophy, and many other fields. The field was founded on the assumption that human intelligence "can be so precisely described that a machine can be made to simulate it".<sup>[b]</sup> This raised philosophical arguments about the mind and the ethical consequences of creating artificial beings endowed with human-like intelligence; these issues have previously been explored by myth, fiction, and philosophy since antiquity.<sup>[13]</sup> Computer scientists and philosophers have since suggested that AI may become an existential risk to humanity if its rational capacities are not steered towards beneficial goals.<sup>[c]</sup> The term artificial intelligence has also been criticized for overhyping AI's true technological capabilities.

The general problem of simulating (or creating) intelligence has been broken down into sub-problems. These consist of particular traits or capabilities that researchers expect an intelligent system to display. The traits described below have received the most attention.<sup>[a]</sup>

### Reasoning, problem-solving

Early researchers developed algorithms that imitated step-by-step reasoning that humans use when they solve puzzles or make logical deductions.<sup>[47]</sup> By the late 1980s and 1990s, AI research had developed methods for dealing with uncertain or incomplete information, employing concepts from probability and economics.<sup>[48]</sup>

Many of these algorithms proved to be insufficient for solving large reasoning problems because they experienced a "combinatorial explosion": they became exponentially slower as the problems grew larger.<sup>[49]</sup> Even humans rarely use

the step-by-step deduction that early AI research could model. They solve most of their problems using fast, intuitive judgments.<sup>[50]</sup>

### Knowledge representation

Knowledge representation and knowledge engineering<sup>[51]</sup> allow AI programs to answer questions intelligently and make deductions about real-world facts.

A representation of "what exists" is an ontology: the set of objects, relations, concepts, and properties formally described so that software agents can interpret them.<sup>[52]</sup> The most general ontologies are called upper ontologies, which attempt to provide a foundation for all other knowledge and act as mediators between domain ontologies that cover specific knowledge about a particular knowledge domain (field of interest or area of concern). A truly intelligent program would also need access to commonsense knowledge; the set of facts that an average person knows. The semantics of an ontology is typically represented in description logic, such as the Web Ontology Language.<sup>[53]</sup>

AI research has developed tools to represent specific domains, such as objects, properties, categories and relations between objects;<sup>[53]</sup> situations, events, states and time;<sup>[54]</sup> causes and effects;<sup>[55]</sup> knowledge about knowledge (what we know about what other people know);<sup>[56]</sup> default reasoning (things that humans assume are true until they are told differently and will remain true even when other facts are changing);<sup>[57]</sup> as well as other domains. Among the most difficult problems in AI are: the breadth of commonsense knowledge (the number of atomic facts that the average person knows is enormous);<sup>[58]</sup> and the sub-symbolic form of most commonsense knowledge (much of what people know is not represented as "facts" or "statements" that they could express verbally).<sup>[50]</sup>

Formal knowledge representations are used in content-based indexing and retrieval,<sup>[59]</sup> scene interpretation,<sup>[60]</sup> clinical decision support,<sup>[61]</sup> knowledge discovery (mining "interesting" and actionable inferences from large databases),<sup>[62]</sup> and other areas.<sup>[63]</sup>

### Learning

Machine learning (ML), a fundamental concept of AI research since the field's inception,<sup>[j]</sup> is the study of computer algorithms that improve automatically through experience.<sup>[k]</sup>

Unsupervised learning finds patterns in a stream of input.

Supervised learning requires a human to label the input data first, and comes in two main varieties: classification and numerical regression. Classification is used to determine what category something belongs in – the program sees a number of examples of things from several categories and will learn to classify new inputs. 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. Both classifiers and regression learners can be viewed as "function approximators" trying to learn an unknown (possibly implicit) function; for example, a spam classifier can be viewed as learning a function that maps from the text of an email to one of two categories, "spam" or "not spam".<sup>[67]</sup>

In reinforcement learning the agent is rewarded for good responses and punished for bad ones. The agent classifies its responses to form a strategy for operating in its problem space.<sup>[68]</sup>

Transfer learning is when the knowledge gained from one problem is applied to a new problem.<sup>[69]</sup>

Computational learning theory can assess learners by computational complexity, by sample complexity (how much data is required), or by other notions of optimization.<sup>[70]</sup>

### Natural language processing

Natural language processing (NLP)<sup>[71]</sup> allows machines to read and understand human language. A sufficiently powerful natural language processing system would enable natural-language user interfaces and the acquisition of knowledge directly from human-written sources, such as newswire texts. Some straightforward applications of NLP include information retrieval, question answering and machine translation.<sup>[72]</sup>

Symbolic AI used formal syntax to translate the deep structure of sentences into logic. This failed to produce useful applications, due to the intractability of logic<sup>[49]</sup> and the breadth of commonsense knowledge.<sup>[58]</sup> Modern statistical techniques include co-occurrence frequencies (how often one word appears near another), "Keyword spotting" (searching for a particular word to retrieve information), transformer-based deep learning (which finds patterns in text),



and others.<sup>[73]</sup> They have achieved acceptable accuracy at the page or paragraph level, and, by 2019, could generate coherent text.<sup>[74]</sup>

### Perception

Machine perception<sup>[75]</sup> is the ability to use input from sensors (such as cameras, microphones, wireless signals, and active lidar, sonar, radar, and tactile sensors) to deduce aspects of the world. Applications include speech recognition,<sup>[76]</sup> facial recognition, and object recognition.<sup>[77]</sup> Computer vision is the ability to analyze visual input.<sup>[78]</sup>

### Social intelligence

Affective computing is an interdisciplinary umbrella that comprises systems that recognize, interpret, process or simulate human feeling, emotion and mood.<sup>[80]</sup> For example, some virtual assistants are programmed to speak conversationally or even to banter humorously; it makes them appear more sensitive to the emotional dynamics of human interaction, or to otherwise facilitate human–computer interaction. However, this tends to give naive users an unrealistic conception of how intelligent existing computer agents actually are.<sup>[81]</sup> Moderate successes related to affective computing include textual sentiment analysis and, more recently, multimodal sentiment analysis), wherein AI classifies the affects displayed by a videotaped subject.<sup>[82]</sup>

### General intelligence

A machine with general intelligence can solve a wide variety of problems with breadth and versatility similar to human intelligence. There are several competing ideas about how to develop artificial general intelligence. Hans Moravec and Marvin Minsky argue that work in different individual domains can be incorporated into an advanced multi-agent system or cognitive architecture with general intelligence.<sup>[83]</sup> Pedro Domingos hopes that there is a conceptually straightforward, but mathematically difficult, "master algorithm" that could lead to AGI.<sup>[84]</sup> Others believe that anthropomorphic features like an artificial brain<sup>[85]</sup> or simulated child development<sup>[1]</sup> will someday reach a critical point where general intelligence emerges.

## II. DISCUSSION

AI can solve many problems by intelligently searching through many possible solutions.<sup>[86]</sup> 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.<sup>[87]</sup> Planning algorithms search through trees of goals and subgoals, attempting to find a path to a target goal, a process called means-ends analysis.<sup>[88]</sup> Robotics algorithms for moving limbs and grasping objects use local searches in configuration space.<sup>[89]</sup>

Simple exhaustive searches<sup>[90]</sup> 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 prioritize choices in favor of those more likely to reach a goal and to do so in a shorter number of steps. In some search methodologies, heuristics can also serve to eliminate some choices unlikely to lead to a goal (called "pruning the search tree"). Heuristics supply the program with a "best guess" for the path on which the solution lies.<sup>[91]</sup> Heuristics limit the search for solutions into a smaller sample size.<sup>[92]</sup> 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. Other related optimization algorithms include random optimization, beam search and metaheuristics like simulated annealing.<sup>[93]</sup> 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). Classic evolutionary algorithms include genetic algorithms, gene expression programming, and genetic programming.<sup>[94]</sup> Alternatively, distributed search processes can coordinate via swarm intelligence algorithms. Two popular swarm algorithms used in search are particle swarm optimization (inspired by bird flocking) and ant colony optimization (inspired by ant trails).<sup>[95]</sup>

## Logic

Logic<sup>[96]</sup> is used for knowledge representation and problem-solving, but it can be applied to other problems as well. For example, the satplan algorithm uses logic for planning<sup>[97]</sup> and inductive logic programming is a method for learning.<sup>[98]</sup>

Several different forms of logic are used in AI research. Propositional logic<sup>[99]</sup> involves truth functions such as "or" and "not". First-order logic<sup>[100]</sup> adds quantifiers and predicates and can express facts about objects, their properties, and their relations with each other. Fuzzy logic assigns a "degree of truth" (between 0 and 1) to vague statements such as "Alice is old" (or rich, or tall, or hungry), that are too linguistically imprecise to be completely true or false.<sup>[101]</sup> Default logics, non-monotonic logics and circumscription are forms of logic designed to help with default reasoning and the qualification problem.<sup>[57]</sup> Several extensions of logic have been designed to handle specific domains of knowledge, such as description logics;<sup>[53]</sup> situation calculus, event calculus and fluent calculus (for representing events and time);<sup>[54]</sup> causal calculus;<sup>[55]</sup> belief calculus (belief revision); and modal logics.<sup>[56]</sup> Logics to model contradictory or inconsistent statements arising in multi-agent systems have also been designed, such as paraconsistent logics.<sup>[102]</sup>

## Probabilistic methods for uncertain reasoning

Many problems in AI (including in reasoning, planning, learning, perception, and robotics) require the agent to operate with incomplete or uncertain information. AI researchers have devised a number of tools to solve these problems using methods from probability theory and economics.<sup>[103]</sup> Bayesian networks<sup>[104]</sup> are a very general tool that can be used for various problems, including reasoning (using the Bayesian inference algorithm),<sup>[m][106]</sup> learning (using the expectation-maximization algorithm),<sup>[n][108]</sup> planning (using decision networks)<sup>[109]</sup> and perception (using dynamic Bayesian networks).<sup>[110]</sup> 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 (e.g., hidden Markov models or Kalman filters).<sup>[110]</sup>

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,<sup>[111]</sup> and information value theory.<sup>[112]</sup> These tools include models such as Markov decision processes,<sup>[113]</sup> dynamic decision networks,<sup>[110]</sup> game theory and mechanism design.<sup>[114]</sup>

## Classifiers and statistical learning methods

The simplest AI applications can be divided into two types: classifiers ("if shiny then diamond") and controllers ("if diamond 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 the 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 is 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.<sup>[115]</sup>

A classifier can be trained in various ways; there are many statistical and machine learning approaches. The decision tree is the simplest and most widely used symbolic machine learning algorithm.<sup>[116]</sup> K-nearest neighbor algorithm was the most widely used analogical AI until the mid-1990s.<sup>[117]</sup> Kernel methods such as the support vector machine (SVM) displaced k-nearest neighbor in the 1990s.<sup>[118]</sup> The naive Bayes classifier is reportedly the "most widely used learner"<sup>[119]</sup> at Google, due in part to its scalability.<sup>[120]</sup> Neural networks are also used for classification.<sup>[121]</sup>

Classifier performance depends greatly on the characteristics of the data to be classified, such as the dataset size, distribution of samples across classes, dimensionality, and the level of noise. Model-based classifiers perform well if the assumed model is an extremely good fit for the actual data. Otherwise, if no matching model is available, and if accuracy (rather than speed or scalability) is the sole concern, conventional wisdom is that discriminative classifiers (especially SVM) tend to be more accurate than model-based classifiers such as "naive Bayes" on most practical data sets.<sup>[122]</sup>

## Artificial neural networks

Neural networks<sup>[121]</sup> were inspired by the architecture of neurons in the human brain. A simple "neuron" N accepts input from other neurons, each of which, when activated (or "fired"), casts a weighted "vote" for or against whether neuron N should itself activate. Learning requires an algorithm to adjust these weights based on the training data; one simple algorithm (dubbed "fire together, wire together") is to increase the weight between two connected neurons when

the activation of one triggers the successful activation of another. Neurons have a continuous spectrum of activation; in addition, neurons can process inputs in a nonlinear way rather than weighing straightforward votes.

Modern neural networks model complex relationships between inputs and outputs and find patterns in data. They can learn continuous functions and even digital logical operations. Neural networks can be viewed as a type of mathematical optimization – they perform gradient descent on a multi-dimensional topology that was created by training the network. The most common training technique is the backpropagation algorithm.<sup>[123]</sup> Other learning techniques for neural networks are Hebbian learning ("fire together, wire together"), GMDH or competitive learning.<sup>[124]</sup>

The main categories of networks are acyclic or feedforward neural networks (where the signal passes in only one direction) and recurrent neural networks (which allow feedback and short-term memories of previous input events). Among the most popular feedforward networks are perceptrons, multi-layer perceptrons and radial basis networks.<sup>[125]</sup>

### Deep learning

Deep learning<sup>[127]</sup> uses several layers of neurons between the network's inputs and outputs. The multiple layers can progressively extract higher-level features from the raw input. For example, in image processing, lower layers may identify edges, while higher layers may identify the concepts relevant to a human such as digits or letters or faces.<sup>[128]</sup> Deep learning has drastically improved the performance of programs in many important subfields of artificial intelligence, including computer vision, speech recognition, image classification<sup>[129]</sup> and others.

Deep learning often uses convolutional neural networks for many or all of its layers. In a convolutional layer, each neuron receives input from only a restricted area of the previous layer called the neuron's receptive field. This can substantially reduce the number of weighted connections between neurons,<sup>[130]</sup> and creates a hierarchy similar to the organization of the animal visual cortex.<sup>[131]</sup>

In a recurrent neural network (RNN) the signal will propagate through a layer more than once;<sup>[132]</sup> thus, an RNN is an example of deep learning.<sup>[133]</sup> RNNs can be trained by gradient descent,<sup>[134]</sup> however long-term gradients which are back-propagated can "vanish" (that is, they can tend to zero) or "explode" (that is, they can tend to infinity), known as the vanishing gradient problem.<sup>[135]</sup> The long short term memory (LSTM) technique can prevent this in most cases.<sup>[136]</sup>

### Specialized languages and hardware

Specialized languages for artificial intelligence have been developed, such as Lisp, Prolog, TensorFlow and many others. Hardware developed for AI includes AI accelerators and neuromorphic computing.

## III. RESULTS

### Applications

AI is relevant to any intellectual task.<sup>[137]</sup> Modern artificial intelligence techniques are pervasive and are too numerous to list here.<sup>[138]</sup> Frequently, when a technique reaches mainstream use, it is no longer considered artificial intelligence; this phenomenon is described as the AI effect.<sup>[139]</sup>

In the 2010s, AI applications were at the heart of the most commercially successful areas of computing, and have become a ubiquitous feature of daily life. AI is used in search engines (such as Google Search), targeting online advertisements,<sup>[140]</sup> recommendation systems (offered by Netflix, YouTube or Amazon), driving internet traffic,<sup>[141][142]</sup> targeted advertising (AdSense, Facebook), virtual assistants (such as Siri or Alexa),<sup>[143]</sup> autonomous vehicles (including drones, ADAS and self-driving cars), automatic language translation (Microsoft Translator, Google Translate), facial recognition (Apple's Face ID or Microsoft's DeepFace), image labeling (used by Facebook, Apple's iPhoto and TikTok), spam filtering and chatbots (such as Chat GPT).

There are also thousands of successful AI applications used to solve problems for specific industries or institutions. A few examples are energy storage,<sup>[144]</sup> deepfakes,<sup>[145]</sup> medical diagnosis, military logistics, foreign policy<sup>[146]</sup>, or supply chain management.

Game playing has been a test of AI's strength since the 1950s. Deep Blue became the first computer chess-playing system to beat a reigning world chess champion, Garry Kasparov, on 11 May 1997.<sup>[147]</sup> In 2011, in a Jeopardy! quiz show exhibition match, IBM's question answering system, Watson, defeated the two greatest Jeopardy! champions, Brad Rutter and Ken Jennings, by a significant margin.<sup>[148]</sup> In March 2016, AlphaGo won 4 out of 5 games of Go in a match with Go champion Lee Sedol, becoming the first computer Go-



playing system to beat a professional Go player without handicaps.<sup>[149]</sup> Other programs handle imperfect-information games; such as for poker at a superhuman level, Pluribus<sup>[o]</sup> and Cepheus.<sup>[151]</sup> DeepMind in the 2010s developed a "generalized artificial intelligence" that could learn many diverse Atari games on its own.<sup>[152]</sup>

By 2020, Natural Language Processing systems such as the enormous GPT-3 (then by far the largest artificial neural network) were matching human performance on pre-existing benchmarks, albeit without the system attaining a commonsense understanding of the contents of the benchmarks.<sup>[153]</sup> DeepMind's AlphaFold 2 (2020) demonstrated the ability to approximate, in hours rather than months, the 3D structure of a protein.<sup>[154]</sup> Other applications predict the result of judicial decisions,<sup>[155]</sup> create art (such as poetry or painting) and prove mathematical theorems.

AI content detector tools are software applications that use artificial intelligence (AI) algorithms to analyze and detect specific types of content in digital media, such as text, images, and videos. These tools are commonly used to identify inappropriate content, such as speech errors, violent or sexual images, and spam, among others.

Some benefits of using AI content detector tools<sup>[156]</sup> include improved efficiency and accuracy in detecting inappropriate content, increased safety and security for users, and reduced legal and reputational risks for websites and platforms.

### Smart traffic lights

Smart traffic lights have been developed at Carnegie Mellon since 2009. Professor Stephen Smith has started a company since then Surtrac that has installed smart traffic control systems in 22 cities. It costs about \$20,000 per intersection to install. Drive time has been reduced by 25% and traffic jam waiting time has been reduced by 40% at the intersections it has been installed.<sup>[157]</sup>

### Ethical machines

Friendly AI are machines that have been designed from the beginning to minimize risks and to make choices that benefit humans. Eliezer Yudkowsky, who coined the term, argues that developing friendly AI should be a higher research priority: it may require a large investment and it must be completed before AI becomes an existential risk.<sup>[222]</sup>

Machines with intelligence have the potential to use their intelligence to make ethical decisions. The field of machine ethics provides machines with ethical principles and procedures for resolving ethical dilemmas.<sup>[223]</sup> Machine ethics is also called machine morality, computational ethics or computational morality,<sup>[223]</sup> and was founded at an AAI symposium in 2005.<sup>[224]</sup>

Other approaches include Wendell Wallach's "artificial moral agents"<sup>[225]</sup> and Stuart J. Russell's three principles for developing provably beneficial machines.<sup>[226]</sup>

## IV. CONCLUSIONS

Thought-capable artificial beings have appeared as storytelling devices since antiquity,<sup>[17]</sup> and have been a persistent theme in science fiction.<sup>[19]</sup>

A common trope in these works began with Mary Shelley's *Frankenstein*, where a human creation becomes a threat to its masters. This includes such works as Arthur C. Clarke's and Stanley Kubrick's *2001: A Space Odyssey* (both 1968), with HAL 9000, the murderous computer in charge of the *Discovery One* spaceship, as well as *The Terminator* (1984) and *The Matrix* (1999). In contrast, the rare loyal robots such as Gort from *The Day the Earth Stood Still* (1951) and Bishop from *Aliens* (1986) are less prominent in popular culture.<sup>[230]</sup>

Isaac Asimov introduced the Three Laws of Robotics in many books and stories, most notably the "Multivac" series about a super-intelligent computer of the same name. Asimov's laws are often brought up during lay discussions of machine ethics;<sup>[231]</sup> while almost all artificial intelligence researchers are familiar with Asimov's laws through popular culture, they generally consider the laws useless for many reasons, one of which is their ambiguity.<sup>[232]</sup>

Transhumanism (the merging of humans and machines) is explored in the manga *Ghost in the Shell* and the science-fiction series *Dune*.

Several works use AI to force us to confront the fundamental question of what makes us human, showing us artificial beings that have the ability to feel, and thus to suffer. This appears in Karel Čapek's *R.U.R.*, the films *A.I. Artificial Intelligence* and *Ex Machina*, as well as the novel *Do Androids Dream of Electric Sheep?*, by Philip K. Dick. Dick

considers the idea that our understanding of human subjectivity is altered by technology created with artificial intelligence.<sup>[233]</sup>

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