Conceptual Paper

The Past, Present and Future of Artificial Intelligence

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Abstract

Artificial Intelligence (AI) is touching everyone's lives in today's world. The term 'Artificial Intelligence' was coined by John McCarthy in 1956 at the Dartmouth Conference. From its birth till now, AI has emerged as a diverse and flourishing research domain. This article explores the events leading to the birth of AI domain and its establishment (i.e., past), and traces the more recent achievements of AI and its current major themes (i.e., present). Based on these historical trajectories and novel influences, the article attempts to explore the future of AI. The future of AI domain is extremely promising with major possibilities including big data, cognitive science and artificial life.

Keywords

Artificial intelligence, big data, expert systems, cognitive computing, artificial life

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Introduction

Artificial intelligence (AI) has emerged as a popular and established domain in research, academics and business. This field emerged from research on early computers and found relevant business applications in emerging software and digital technologies. This led to increased demand for trained professionals, and to fulfil this demand AI proliferated into academics.

Today, there is widespread research and business applications of AI. This has led to AI becoming a buzzword in common conversations as well as corporate boardrooms. Of course, AI has come a long way. Nevertheless, how far have we

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progressed? This article tries to envisage the future of AI, based on the past and present trends in AI research.

The Past

The roots of foundational work leading up to the emergence of AI as a domain can be traced back to the early philosophers and mathematicians. Turing (1950) was the first paper to discuss the possibility of AI. John McCarthy coined the term 'Artificial Intelligence' during the Dartmouth Conference in 1956, and the field of AI as a domain was established.

The Conception

One of the earliest streams of research, directly leading to the birth of AI, was the neural net stream of AI research. McCulloch and Pitts (1943) were the first to trigger the field of neural net research. The different research streams on Cybernetics (Wiener, 1948), Information Theory (Shannon, 1948) and Theory of Computation (Turing, 1936) came together to envisage the possibility of an artificial brain.

In a parallel development, Alan Turing and other researchers were interested in understanding the process and limits of computability. These attempts led to the development of the Turing Machine by Alan Turing (1936; 1950), the Lambda Calculus by Church (1936), and the Production System by Post (1943).

The Birth

Marvin Minsky, John McCarthy, Claude Shannon, and Nathan Rochester organised the Dartmouth Conference of 1956 (Crevier, 1993; McCorduck, 2004; Newquist, 1994; Russell & Norvig, 2003). The conference proposal mentions: 'every aspect of learning or any other feature of intelligence can be so precisely described that a machine can be made to simulate it' (McCarthy et al., 1955). Ray Solomonoff, Oliver Selfridge, Trenchard More, Arthur Samuel, Allen Newell and Herbert A. Simon, participated in the conference and went on to contribute towards early research on AI (McCorduck, 2004). Newell and Simon presented the first working program (i.e., 'Logic Theorist') and McCarthy coined AI as a domain (McCorduck, 2004). The 1956 Dartmouth conference is widely accepted as the time and place for creating AI as a domain. Crevier (1993, p. 49) writes, 'the conference is generally recognized as the official birthdate of the new science'.

The Baby Steps

The AI domain has evolved with researchers focusing on varied aspects and resulting in multiple themes. These varied AI themes arose out of different philosophical assumptions about AI as well as other historical influences. Some of these early developments in various AI themes are highlighted briefly below.

Neural Nets

One of the themes is the neural networks stream of research, which also played a key role in the emergence of AI. Marvin Minsky developed the first artificial neural network called SNARC in 1951. The SNARC was able to simulate a mouse running in a maze.

Among the earliest artificial neural nets developed was perceptron by Rosenblatt (1958), which stimulated interest from many researchers. The enthusiasm for research on perceptrons was negatively impacted by Minsky and Papert's (1969) conjecture that perceptrons had inherent limitations which would continue to exist even in future developments. While their hypothesis was later proven incorrect, this did not help stimulate research on perceptrons. The research on Parallel Distributing Processing (PDP; McClelland et al., 1986; Rumelhart et al., 1986) again stimulated research on neural nets in the 1980s.

Machine Learning

Arthur Samuel (1959) developed the checker-playing program as one of the early machine-learning initiatives. He developed a program that was capable of 'learning', and thus contributed to the evolution of 'machine learning' as one of the important themes within AI domain.

Problem Solving Simulation

One of the early interests among AI researchers was to attempt and prove that machines can be programmed to solve abstract problems requiring intelligent reasoning, similar to the ability of human minds. The 'logical theorist' displayed at the Dartmouth Conference (1956) was the earliest program in this stream of research. The logical theorist used a means-ends framework to analyse and choose the appropriate means to approach towards the desired ends. Simon and Newell (1959) developed 'general problem solver' and Gelernter developed 'geometry theorem-prover', which were among the early systems developed in this research stream.

Natural Language Processing (NLP)

One of the important streams of AI research is concerned with understanding language. Winograd (1972) developed the SHRDLU, which was one of the earliest programs in this stream of research. The SHRDLU was capable of understanding English language commands and moving objects accordingly. This stream of research remains an important and flourishing field of research.

Expert Systems

Some AI researchers were ambitious and tried to solve real world problems, rather than develop programs having ability to deal with abstract problems. This needed 'knowledge' related to the specific real-world domain, in addition to solving capabilities. This gave rise to 'expert systems' (also called knowledge-based systems) stream of AI research. Joshua Lederberg, Edward Feigenbaum, and Bruce Buchanan developed 'Dendral' in 1965, which was developed as the first expert system developed to leverage knowledge of organic chemistry for identifying molecular structure from mass spectrometers (Lindsay et al., 1980). This was followed by other expert systems such as Mycin (Davis et al., 1977) which helped in medical diagnosis.

The Present

Today, the AI research has progressed greatly in a variety of themes. After discussing the history, birth and early developments in the AI domain, some of the recent developments as well as major research themes are discussed in this section to provide an informed perspective.

Recent Developments

The AI domain has progressed over a period. There have been some significant milestone events in this journey, which contributed as success stories of AI and keep inspiring the interest of researchers in this domain. Some of these are discussed below.

Expert Systems

Expert Systems have become a major force in driving AI applications in businesses. One of the commercially successful expert systems was XCON (McDermott, 1980), which contributed by saving a lot of money for DEC (Digital Equipment Corporation). The expert systems contributed greatly to making AI a popular buzzword across the world.

Deep Blue

In 1997, the World Chess Champion Gary Kasparov was defeated in Chess by the AI program 'Deep Blue'. This marked an important stepping stone and made headlines across the world, as AI had now successfully defeated human intelligence. The Deep Blue was developed by IBM and was inspirational for future researchers.

Robbin's Conjecture

E.V. Huntington developed three axioms to characterise a Boolean Algebra in 1993. Herbert Robbins proposed a substitution for the third axiom. This Robbin's conjecture was considered one of the unsolved problems in mathematics, till an AI program called EQP (Equational Prover) solved this (McCune, 1997). This was another win for AI over human intelligence.

Watson at Jeopardy

An AI program called Watson contested against two successful human champions in the 2011 famous TV Show called Jeopardy. Watson was able to defeat both the Human opponents by using its NLP algorithms for answering the trivia questions as part of Jeopardy. This was one more instance of AI beating humans at our own game.

Game AI

The computer gaming industry is one of the largest users of AI. The industry needs to rely heavily on AI capabilities for programming the behaviours of their virtual characters and digital environment. The ability of these AI characters and games to successfully engage humans in a challenging environment is considered a success story for the application of AI.

Major AI Research Themes

Given the emergence of AI from an amalgamation of various overlapping and parallel streams of research, as well as the distinct focus areas of researchers, the AI domain covers multiple research streams. Each of these research streams boast of a thriving research community including dedicated journals and conferences. Some of these are discussed below.

Knowledge Representation

AI programs need to be able to take some input, process it, and provide some output. This needs the AI to use some approach for representing the input as well as the process outcome in some form of knowledge representation, so that the appropriate output can be delivered. This central argument highlights the focus on knowledge representation as an important theme in the AI domain.

Expert Systems

One of the early subfields of AI domain is the expert systems stream of research. Researchers in this area of knowledge are interested in aspects related to process of reasoning, representation of knowledge and knowledge engineering. They aspire to apply these AI processes to solve real-life problems.

Planning

Assigning sequences of action in most efficient and effective manner remains a prominent area of AI research called planning. This enables optimisation of the planning process. This is found to be very useful for a variety of applications ranging from manufacturing plant operations to space exploration.

Heuristic Search

This stream of AI research uses different heuristics to find satisfactory solutions, rather than optimal solutions. These programs use rules of thumb, called heuristics, to find a solution that satisfies the given constraints. These are useful for data mining, games, web searching and other applications.

Natural Language Processing

NLP subfield of AI domain includes the generation as well as understanding of natural language. This traces its history to the early evolution of AI domain, and continues to flourish. This finds applications including voice recognition, machine translation, automatic summarisation and many other processes.

Machine Vision

The Machine Vision subfield of AI domain deals with the recognition and analysis of visual images. This is enabling applications of AI in traffic surveillance, military surveillance, space imaging, product inspection, and many emerging applications.

Machine Learning

The AI subfield of Machine Learning focuses on the ability of machines to learn. This is among one of the earliest subfields of AI domain. This is evolving and

progressing to include supervised learning, unsupervised learning, autonomous agents and developmental robotics.

Artificial Agents

This stream of AI research encompasses the AI programs which operate in an environment and respond to inputs in a manner that their earlier actions may influence their subsequent inputs, environment, and actions (Franklin & Graesser, 1997). These artificial autonomous agents range from programs operating on data and/or the internet, visual characters visible on monitor screens, voice characters talking to humans and robots taking actions in real world.

Intelligent Tutoring Systems

The AI subfield dealing with programs that can tutor or teach humans interactively is called Intelligent Tutoring Systems. The existing approaches in this stream of research include tutoring in mathematics and short textual paragraphs. The kay challenge in this field is the ability of the Intelligent Tutoring System to gain adequate knowledge of a human domain of knowledge. This remains a domain with a promising future.

Robotics

Robotics owes its origins to mechanical engineering researchers trying to develop mechanisms to perform actions such as grasping and lifting objects. Today, AI domain has brought more intelligent control systems—to capture a variety of inputs, better processing abilities, and more complex outputs—to develop better robots. Robotics is now an important stream of research in the AI domain.

The Future

The above sections discuss the developments from the birth of the AI domain to its important developments and themes. We discuss the future of AI based on some of the trends. This section highlights the direction of future progress of AI domain.

AI and Big Data

The world is increasingly growing digital, and more and more data is now captured. With the increase in the quantity of data, speed of capturing, and variations in types of data—commonly known as Big Data—the data scientists are increasingly turning to AI. It is becoming humanly impossible for statisticians to deal with analysing the Big Data. AI provides the ability of analysing large amounts of rapidly increasing complex data for identifying relevant patterns. This is an increasingly dominant application of AI in future.

Agent-based AI

Most of the AI programs employed in today's world are increasingly found to be some form of autonomous AI agents. The agent-based AI (Varela et al., 1991) is

increasingly finding applications across the world. The recent proliferation of various generative AI programs (e.g., ChatGPT) is evidence of its great potential. This holds promise for the future of the AI domain.

Soft Computing

Soft computing is the stream of AI research that deals with a range of computational techniques focusing on humanly difficult computations involving uncertainty, ambiguity, and other challenges. These include fuzzy logic, neural nets, evolutionary computing and artificial immune systems. The increasing use of hybrid soft computing programs along with the increasing volatility, uncertainty, complexity, and ambiguity in the real world highlight the increasingly need for applications of soft computing in the AI systems of the future.

Cognitive Computing

Cognitive computing includes diverse perspectives including self-aware systems, autonomic computing, artificial general intelligence, cognitive robotics and development robotics.

Self-aware systems are the subfield of AI domain that focuses computer systems being aware of themselves. Brachman (2004) explains:

> A truly cognitive system would be able to…explain what it was doing and why it was doing it. It would be reflective enough to know when it was heading down a blind alley or when it needed to ask for information that it simply couldn't get to by further reasoning. And using these capabilities, a cognitive system would be robust in the face of surprises. It would be able to cope much more maturely with unanticipated circumstances than any current machine can.

Autonomic computing focuses on systems capable of organising, analysing, and repairing themselves. This is one of the promising areas for the future of AI domain research.

Artificial general intelligence deals with creating artificial programs that are almost as intelligent as humans in exhibiting general intelligence, rather than a narrow functional intelligence. This is still a nascent, but extremely potent research area within the AI domain.

The cognitive robotics subfield of AI domain attempts to create robots with cognitive skills. The idea is to evolve the focus of robotics from 'how to perform certain action?' to 'which action to perform?'

Another constituent of Cognitive Computing area of AI domain is Development Robotics. This approach focuses on enabling robots to learn themselves continually, similar to humans. To achieve these ambitious goals, development robotics relies on overlap of development psychology, robotics, and machine learning. This aspires to prepare robots for a future contingency that may be unpredictable or unimaginable.

AI and Cognitive Science

Modelling of human intelligence and human cognition is a fundamental aspiration for the AI domain. The science of AI therefore continues to attempt deeper understanding of cognitive science. In this process, while AI domain borrows a lot of knowledge from cognitive science, the AI domain applications also generate data and information that needs to be compared and validated in cognitive science. This has generated immense future possibilities in the AI domain. Today cognitive science is one of the emerging and futuristic subfields of AI domain.

Artificial Life

One of the exciting frontiers of AI domain is exploring artificial life. Artificial life is currently explored in three different approaches—hard life, wet life and soft life. Hard life refers primarily to the hardware that is able to act like living beings, and includes robots. Wet life refers to the life forms created in test tubes in laboratories using biochemical processes and generally resemble small bacteria, but may include more advanced beings with progress in biotechnology. Soft life refers to software programs that emulate life like actions in their software environment. The future aspires to combine there three forms of artificial life, to perhaps produce the perfect human like living machine. This is a challenging but exciting field of future exploration.

Conclusion

The discussion above describes the history, birth, development, current state, and future possibilities of the AI domain. The field has taken great strides and made impressive progress. However, the initial aspirations of achieving human level intelligence remain unachieved. While there is an increasing realisation of the complexities and milestones for machines to achieve human intelligence, there is also an increased exploration of the opportunities and risks hidden in the future possibilities of the evolution of AI.

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