Evolution of Artificial Intelligence

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Introduction

Concept of intelligent machines is as old as abacus. Invention of a digital computer in 1950's, has reshaped the building of intelligent machines as a software exercise. In 1956, at the famous conference at Dartmouth USA, Professor John McCarthy coined the name Artificial Intelligence (AI) as the subject area of science and engineering of building intelligent machines. Thus, AI has two broad goals: **a**) scientific goal – understanding of intelligence of human, animals and machines; and **b**) development of intelligent machines. At this point it should be emphasized that Artificial Intelligence is about modelling of natural intelligence into machines. In other words, AI does not talk of an artificial form of intelligence. Birth of AI made a breakthrough in mankind. AI has recorded an unprecedented development over the last 65 years. The developments in AI has also immensely contributed to accelerate the research and development process in many areas including medicine, engineering, business, science, etc. Undisputedly AI has offered smart solutions for complex engineering designs, sophisticated medical diagnosis, forecasting in an unpredictable business environment, and simulations in large scale expensive and hazardous research. AI has shown its power to solve complex real-world problems that could not be solved by conventional techniques.

In the modern world AI has been recognized as the fuel for the fourth industrial revolution. Modern developments in AI promote man-machine coexistence, where the gap between man and the machines will be drastically reduced day by day. As such we are heading to an era of machines with biological organs/brains and humans with AI chips. Further, AI will be the most influential candidate of technological singularity where technology will be developed to a level at which machines surpasses mankind. Many researchers believe that singularity is coming soon. However, since AI promotes man-machine coexistence, the singularity by AI will not be harmful to mankind. This article presents how AI could be understood in a simple manner as gestation of AI; foundation of AI; developments in AI; and future of AI.

Rest of the article is organized as follows. Section 2 gives material for understanding AI in a simple manner. Section 3 is on gestation of AI, while section 4 presents foundation of AI. Major developments in AI are discussed in section 5. Section 6 is about Four schools of thoughts, which reports on different views of AI. Section 6 outlines future trends in AI.

2. AI made simple

The roadmap of AI records not only a heap of exciting developments, but also has loads of misconceptions and criticisms. Such criticisms have arisen due to attempts of some people to make AI difficult and so complex to the society. In fact, until the mid-1980s, development of AI happened to be invisible and secretive. This resulted in making people skeptical about AI. Consequently, it is essential to help the society to understand the true picture of AI.

Let us see how we can make the understanding of AI simple. In doing so, the behavior of the brain can be taken as the best inspiration to understand the

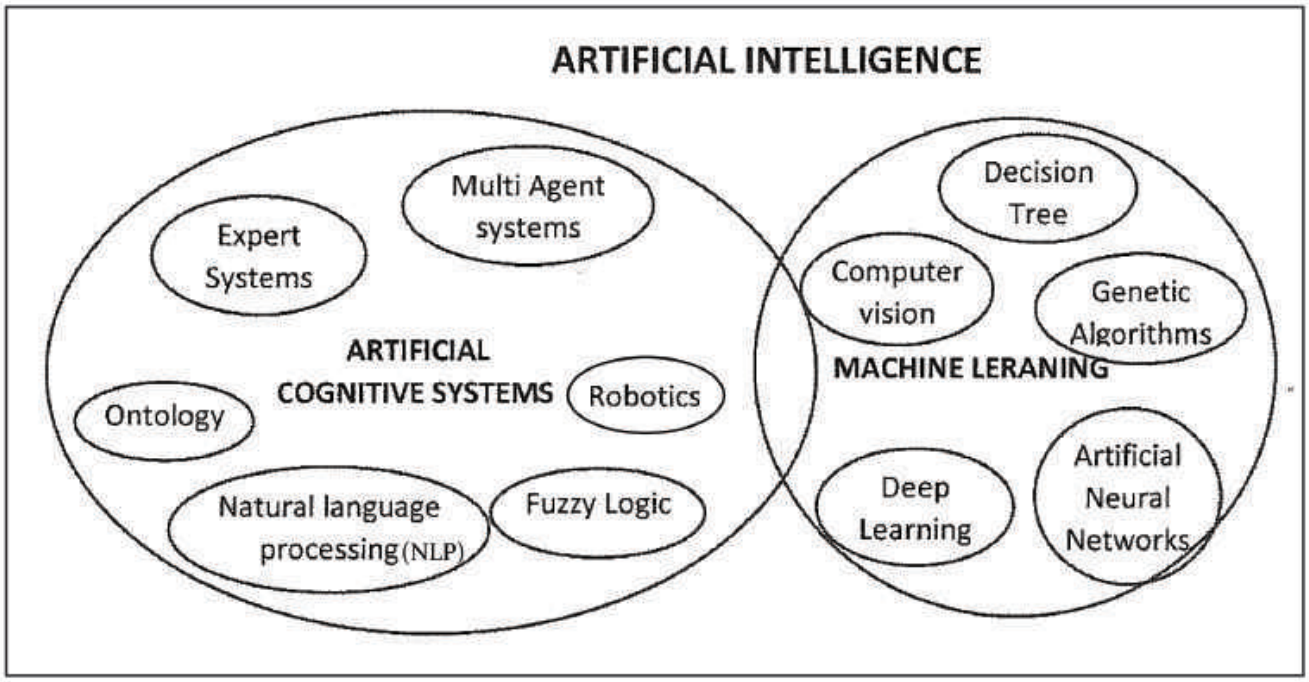

Fig 01 : Classification of some AI technologies

foundation of AI. According to neuroscience, brain manifests two forms of intelligence. One form of intelligence is associated with analytical/logical reasoning in the brain, while the other form is generated by training. These two forms of intelligence postulate two broad areas of AI as cognitive systems and machine learning respectively. These two phenomena are evident from the way a child prepares for an examination by learning theories in a logical manner and training to solve problems by doing past papers. Intelligence required for tasks such as music, driving, and swimming are largely based on training. In contrast, mathematical problem solving, engineering designs, scientific justifications require analytical/ logical reasoning of intelligence.

In general, intelligence with animals have largely emerged by training. For example, many animals such as dogs, horses, elephants and cats can be trained to do various things. There are also instances, where some animals show their analytical thinking as well. For example, when a cat is aiming at a rat, we have noticed the extent of strategic planning by the cat to reach the rat. We also notice, in some instances, a little rat also demonstrates its thinking ability to escape from the cat. Human beings claim that they are the most intelligent species of animals, by virtue of their power of analytical and logical reasoning. Nevertheless, we should not forget that cats are more competent than humans when catching a rat at home. Generally, both humans and animals have certain level of intelligence related to analytical/ logical reasoning and training.

Obviously, cognitive systems and machine learning approaches to intelligence are mutually beneficial to each other. For example, by knowing the theory of music, one can be trained faster to play music. Any AI technique including Expert systems, Artificial Neural Networks, Genetic Algorithms, Multi Agent Systems, Natural Language Processing (NLP), Computer Vision and Robotics could be classified under one or both of cognitive systems and machine learning. For instance, Artificial Neural Networks, Genetic Algorithms, and Decision Trees are recognized as machine learning techniques, while others come under cognitive systems. However, some AI techniques such as NLP, Robotics and Computer Visions can be considered under both artificial cognitive systems and machine learning. This is because, for example, we can process a language by learning grammar (theory) and by training or practicing a language. Figure 1 shows classification of some AI techniques under cognitive systems and machine learning.

3. Gestation of AI

Ending of the second world war in 1945 made people enthusiastic

in new discovery and inventions. In 1950, Allen Turing's seminal paper, Computing Machinery and Intelligence, also stimulated the idea of intelligent machines. Further, in 1948, the invention of the transistor marked the birth of modern digital computer, which deserves the credit for all kinds of developments in the modern world. Building the intelligent machine by programming was a major contribution of the digital computer to Artificial Intelligence. In the 1940's, Artificial Neural Networks were introduced as the very first AI program that can be trained for numeric data. However, in the early days, many people believed that intelligence has a strong connection only with symbolic processing (symbolic AI) in terms of logic, rules, sentences and strings. As such, during 1950's to late 1980's, the AI community put much emphasis on cognitive systems approach to intelligence, and was very critical of the machine learning approach. This trend continued for 30 years until machine learning was reborn in a new shape. Nowadays, cognitive systems and machine learning are beneficial to each other.

4. Foundation of AI

The term intelligence is not the property of a single subject area. As such the foundation of AI comprises various foundation stones including philosophy, mathematics, computer science, computer engineering, cybernetics, education, linguistics, neuroscience, basic science, and control theory. Philosophers have debated a lot about the term intelligence, and the benefits and limits of building intelligence into machines. Role of mathematics and statistics is inevitable in the context of intelligence. For instance, when AI becomes a science, mathematical reasoning and statistical inference work as some cornerstones of AI. Mathematics also provides the foundation for the concept of algorithms, which is used to program intelligence into machines.

Among others, computer science has offered a unique contribution, which enabled building intelligent machines as programming exercise. This has been possible since the computer is a machine that can be programmed to implement virtually any phenomena, provided that you know about the phenomena. As such, computer engineering should also get the credit for developing a programable machine like the computer. Development of the Internet and related technologies (cybernetics) has enabled AI to operate in distributed and interconnected environments.

Theories of education and linguistics are influential for building machines with the capability to learn and to do communications using Natural Languages such as English, Sinhala, Tamil, etc. The fast-growing areas of natural language understanding, machine translations, and chatbots, demonstrates the influence of linguistics on AI. Machine-machine communication and discovery of new knowledge by the machines would be an exciting future development of AI as powered by theories of linguistics and natural language processing.

Undoubtedly, neuroscience has made an unprecedented contribution to the development of AI. Neuroscience discovery of human brain as a network of massively connected neurons, was the foundation for the very first AI technology, Artificial Neural Networks, which was introduced in the mid-1940's. Future development of AI has also been very much influenced by neuroscience concepts such as neuroplasticity and EEG. In section 7 of this article, more details are given of the effect of neuroscience for future of AI.

Influence of basic sciences such as physics, chemistry and biology on AI is noncomparable. For instance, quantum theory in physics/chemistry has influenced the building of quntum computers. Credit should also go to biology for the development of AI technologies such as Artificial Neural Networks, Genetic Algorithms, Evolutionary computing, Multi Agent Systems, and Computer Vison. We should not forget that all artifacts are engineered on the basis of some scientific theories. The same scientific theory enables building of various artifacts. For instance, Ohm's law (V=IR) is the science behind all electrical, electronics and computing devices.

5. Development of AI

Cognitive systems approach to AI dominated the early development of AI. In fact, from early-1960s to mid-1980, machine learning was excluded from AI due to a serious criticism made by Prof. Marvin Minsky, a co-father of AI. Many AI programs including DART, Pathfinder and Deep Blue come under cognitive systems. However, until late 1980's, AI could not win the industry recognition and

trust among the general public. Nevertheless, by mid-1990, theories in AI were developed by adopting the scientific method. This has resulted in eye opening of people who could not believe in the power of AI.

By early 2000, in view of the advancements of computing technologies, research in almost all subject areas began to generate massive collection of data in the respective areas. On the other hand, social media, online transactions, web services, IoT (Internet of Things), and so on also recorded an exponential growth of real-time data, which are dynamic, noisy, incomplete, and virtually non-algorithmic by nature. As such, analysis, modelling and predictions on such data turned out to be a compelling need of the modern world. This has created a golden opportunity for machine learning techniques to expand into areas such as deep learning. Since 2000, many AI programs including Watson and AlphaGo demonstrated the power of machine learning. In the recent past, fantasy of machine learning causesd people to forget about the other side of AI, which is cognitive systems. Machine learning suffers from the inevitable issue of giving solutions without justifications. However, people have gradually recognized the importance of the hybrid approach to machine learning and cognitive systems for smarter AI solutions for complex real-world problems.

In the late 1990's, Agent technology emerged as a new programming paradigm for computing. Inspiration for Agent comes from behavior of entities such as bees, ants, etc. It is evident that operations of any massive system such as human body, sun, brain, bee-colony, etc. are governed by functions of tiny entities (Agents) such as cells, atoms, neurons, bees, etc. As inspired from such natural systems, we define the concept of Software Agent as a small computer program that can perform a specific task and communicate with each other. The concept of Agent can be used to build solutions for parallel and distributed complex systems undergoing so much of uncertainty and unpredictability. According to Agent technology, intelligence can be defined as an emergent feature of the brain due to interaction among the neurons.

The emergent feature should be identified as a property that does not become available with an individual agent at the beginning but comes up as a result of interaction among agents. In group discussions, members sometimes start with zero knowledge about a matter but after certain deliberations, they come up with amazing intelligence to generate exciting solutions. Agent-based modeling has already become the new approach to build intelligent machines.

6. Four schools of thoughts

As a fast-growing area, different people approach AI with different goals in mind. Having multiple definitions or lacking an exact definition for the goal of a discipline, should not be considered as a weakness of the discipline. In reality, when people attempt to establish multiple viewpoints, it flourishes as a discipline. For instance, according to Dolton's theory the atom is unbreakable, but Einstein's atom can be broken, and could generate nuclear energy, while Schrodinger's atom has uncertainty in existence. All these three viewpoints are valid within their scope. As another example, during the time of the Buddha there were 62 different schools of thought about life after death, and this environment stimulate a creative fusion for establishment of Buddhism.

There are four major viewpoints or schools of thought in AI. These schools offer four different viewpoints to build intelligent machines. These views are primarily based on two concepts: thinking and behaving as the main aspects of intelligence.

Acting Humanly

According to this school of thought, AI strives to build intelligence machines that can behave like humans. Perhaps this is the oldest and the most familiar notion of the intelligent machine for many people. We have already seen many AI programs such as Expert Systems, Game Player, Problems solvers, which behave like humans. However, this school of thought does not promote to exploit intelligent features of animals (e.g. bees, ants) to build intelligent machines. This school of thought has a lap in ignoring the importance of animal intelligence to building intelligent machines.

Thinking humanly

This school of thought says that objective of AI is to build intelligent machines that can think like humans. We are aware of many activities that require thinking,

and they are already built into machines. As examples, when we play a game, solve a problem or design an artifact we need thinking. Many game-playing and problems solving programs have already been developed as intelligent software. Some people argue that thinking is yet another undefined term. However, although we cannot define thinking exactly, we are sufficiently aware of tasks for which we need thinking.

Thinking Rationally

The thinking rationally school of thought defines the goal of AI as building machines that can implement logical thinking. Logic has been the most powerful way to draw acceptable conclusions. That is why logic is used in mathematics, science, engineering, and court of law for drawing conclusions. Although logic is very precise in representing knowledge, it cannot always guarantee to generate a solution. More importantly, the order in which the logical statements have been treated has big impact on efficiency of reaching to a logical conclusion. However, many AI systems such as Expert Systems, NLP, Multi Agent Systems, Ontology are built as logic-based solutions.

Acting Rationally

This school of thought defines the goal of AI as building machine that can do the right thing. Here the term right has many meanings including doing most appropriate, optimal, and practical thing. For instance, if a home robot preparing a cup of tea and come to you with a piece of chocolate when no sugar is at home, you might say that this robot is intelligent. In the absence of sugar, taking chocolate is a right thing to do, rather than terminating the execution of the tea preparation algorithm. If the robot is limited to think like human or become logical, tea will not come to you. Building rational agents is considered as a modern approach to AI.

7. Future trends of AI

Having witnessed the amazing power of AI, many people are now so much excited to hear about the future of AI. There are also multiple views on the future of AI. Some people say that AI ends human race. Another set of people argue that AI would be the champion of the technological singularity in which machines surpass mankind. We should not forget that everything has a bad side as well as a good side. For instance, Einstein's atomic theory can generate electricity for the betterment of mankind, but the same atomic theory can also build atomic bombs to destroy mankind. One can argue the same for AI. However, what is important is the way we use AI. Here I will take a more positive approach to views on the future of AI. In this sense, I use man-machine coexistence as the broader picture of the future of AI. Under man-machine coexistence, many future trends in AI can be discussed.

Man-machine coexistence

Man-machine coexistence envisages human and machines working together rather than competing with each other. In this context, the difference between man and the machine will be reduced, and tend to be very similar to each other. Just like the relationships between human and human, man-machine coexistence should enable sharing resources and transplanting/implanting organs and AI chips. In the 1990's, science fiction terminator, demonstrated the concept of using a biological brain within a robot. Nowadays, this has become a reality and successful experiments have been conducted to build robots with rat brains. Implanting AI chips in brains have already taken place at the therapeutic level and will be developed as a means of improving cognitive capabilities of human beings in the future.

Bionic and Cyborgs

Future of AI will be very much influenced by the advancements of neuroscience. Concepts such as neuroplasticity and electroencephalography (EEG) have identified ways and means of capturing electrical activity of the functioning brain, analyzing EEG signals to do various research about the brain. Methods have also been discovered to identify electrical activity of the functional muscles which also comprises of neurons. Such developments have postulated extending the physical capabilities of humans with the support from mechanical and electronic devices. The concept of biologically inspired engineering, known as Bionics, was also born in late 1950's. Developments in AI and Bionics have contributed to establishing another area known as cyborgs, which talks of extended biological beings (e.g. humans) with AI chips. Humans are increasingly becoming cyborgs. Operations of such beings are manifested by interfacing between brain and the machine. For instance, artificial body parts, generally known as

prosthetic, are now interfaced with the brain via Bluetooth technology. Such prosthetics uses EEG waves from the brain to control the body part in a natural manner.

Hybrid intelligence

Ray Kurzweil, the Arthur Clark of AI, predicts that in 2040 researchers will discover more areas in the brain and their specific functions. He also talks of what is called hybrid intelligence, which comes from a brain with one-part being the biological brain, and the other part comprising some AI chips. One of the biological brain, or the AI chip works at a given time, just like way a battery or engine works in hybrid vehicles. Obviously, the hybrid intelligence gives an opportunity for extending the cognitive capacities of humans and animals. This technology can also be extended to reach a desired level of relaxation of the biological brain of humans, by dedicating a relevant cognitive task to an AI chip. For example, if a driver feels sleepy, AI chip will undertake autonomous driving. Although AI chips have already been implanted in the human brain as therapeutic measures, there are not much discussion about hybrid intelligence.

Mind uploading

Building digital copies of biological brains of humans is emerging as a new research area. Here the digital copy of the brain stands for AI programs such as Artificial Neural Networks (ANN). For instance, in mind uploading, researchers strive to capture EEG waves created by a human brain when executing a certain task such as solving mathematical problems. Then the EEG waves will be used to build an ANN. In this manner, researchers intend to build digital copies of the human brain. This kind of researches enable us to come up with new means of preserving brains of scholars. On the other hand, the developed EEG based ANN of a scholar can be used to stimulate a brain of another person to achieve certain cognitive skills of the second person. These researches are currently being experimented with animals. For example, EEG based ANN of a trained dog can be used to stimulate a puppy's brain to achieve faster training of the puppy.

Biological programming

Another prediction by Ray Kurzweil says that in the future we will be able to program a human being, may be at the genetic level, to cure certain diseases such as cancer. Technically speaking, conducting a lecture can also be considered as programing of students to be able to certain tasks. All of us can be seen as programmed human beings by our parents, teachers and the society. In the near future, programing living cells may be as common as programming computers. Researchers at MIT have already developed tools to design DNA circuits for living cells. Undisputedly, biological programming will revolutionize the future of mankind in terms of education, medical treatments and even personality development.

8. Summary

This article has discussed the evolution of Artificial Intelligence from its inception to possible future trends in AI. According to John McCarthy, we understand AI as science and engineering of building intelligent machines. The article presented a brain as a nice analogy to understand scope of AI in a simple manner. We emphasize that AI is about building models of natural intelligence into machines. Then we introduced two broad areas of AI as cognitive systems and machine learning. Gestation of AI, foundation of AI, developments of AI, four schools of thoughts and future trends in Ai were also discussed. Influence of neuroscience for future development of AI was also highlighted. Man-machine coexistence, bionics/cyborgs, hybrid intelligence, mind uploading, and biological programming have been discussed under future trends in AI. This article pointed out that the future of AI will be heading to a society with man-machine coexistence, where the gap between man and machines will be increasingly reduced. Although singularity is coming, we take a positive standpoint that AI will not surpass mankind, yet support the well-being of mankind in numerous ways.

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