

Artificial Intelligence and Applications in Mechanical Engineering

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ABSTRACT: This paper describes the early thoughts and efforts which gave rise to robotics and artificial intelligence. Computing machine had challenged and defeated human brain in playing game of chess and go. AI is growing very fast and helping in growth of various industries and comfort to human life. Mechanical engineering is responsible for development of industry-based society. Initially, it was steam power, followed by electricity, digitalisation, and now artificial intelligence. Mechanical engineering covers various areas such as design, manufacturing, simulation, predictive maintenance. AI find applications in areas requiring automation with minimum human intervention and big data handling.

KEYWORDS: AI, ANN, Big data, robot, AI applications, Mechanical Engineering.

I. INTRODUCTION

Aristotle [1] invented syllogistic logic in 5th century BC. It was the first induction of logical argument that put in deductive reasoning system. Rabbi Loewe [2] in 16th century created Golem (Fig.1), an artificial man out of clay, who was to protect his master. Pascal [3] in 17th century invented a mechanical calculator to perform calculations and was used to performing tedious tax accounting. Wolfgang von Kemppe Len [4] in 18th century invented the mechanical Turk, a chess player capable of beating human chess players. In fact, a mechanical illusion in which a human chess master used to hide inside to operate the machine. These concepts have raised the horizon of human thinking.

Charles Babbage [5], a great philosopher and mechanical engineer of his time developed a mechanical computer with the help of Lady Lovelace in 19th century.

Karel Capek [6] wrote a play Rossum's Universal Robots through which he gifted the world with the word 'robot'. At the same time Alan Turing [7] wrote an article on 'Computing Machinery and Intelligence' on the topic of artificial intelligence which is known as the Turing Test.



Fig. 1: A Prague production of Golem [2].

II. CHALLENGE TO HUMAN BRAIN

The chess playing supercomputer, Deep Blue defeated the grandmaster of chess Garry Kasparov [8]. Deep Blue can identify the position of chess pieces and make prediction about the move of the opponent and accordingly it makes the next move. The algorithm of this machine was based on the last tournament which Kasparov had won. However, the algorithm was not enough as later Kasparov had won 3 consecutive game which challenged IBM developers. Later they developed Deep Blue 2.0, which had logics of all the tournaments which Kasparov had played, and it defeated Kasparov in 6 straight games. It was the first time in history that a machine had defeated a skilled human.

Similarly, there is a Machine named AlphaGo [9] which was developed by DeepMind technology. AlphaGo was equipped with AI and It beat a human Go player in board game Go. It uses Monte Carlo tree search algorithm to predict its own move as well as the opponent move based on machine learning. With the help of artificial intelligence, it can predict its own move and the winners move. This results in higher quality of moves and stronger self-play. It defeated Lee Sodal, one of the finest Go players in 2016 in five game matches.

The other aspect of these competitions is that human brain weighs 1.3 kg, occupies 1.2 litre volume, and uses 45 W of energy whereas these playing machines are super computers occupying a large space and consuming power in kilowatts.

III. AI AND TYPES

Sir John McCarthy [10, 11] titled as the father of artificial intelligence lead the foundation of artificial intelligence. He defined that an artificial intelligence machine can have human like behaviour and capabilities to solve a problem rather than solving it in its own boundary.

It uses human thinking behaviour to respond and deal with the problem. Sir John did his first demonstration of AI algorithm at Carnegie Melon University. In year 1929 he discovered the List Processing Program (LISP). Ernest Davis said that in our unconscious speaking but these tasks are difficult to program on a computer. Hence there is a development of AI to perform these tasks.

AI is accomplished [12, 13] after studying how human brain works while learning, solving problems, reasoning, executing tasks and then using the result of the same as the basis of innovation, development of smart application software, machine, robots etc. AI has become a important part of our lives. Directly or indirectly we are using its services. Sectors like media, politics, engineering are taking full advantage of the services of AI. Humans had created AI to bring humans and machine closer so that we can create new products to have modern, creative, and smart future. As shown in fig 2, Machine learning is the subset of artificial intelligence which use statistical methods to enable machines to improve with experiences. Deep learning makes the computation of multi-layer neural network feasible and is a subset of Machine Learning.

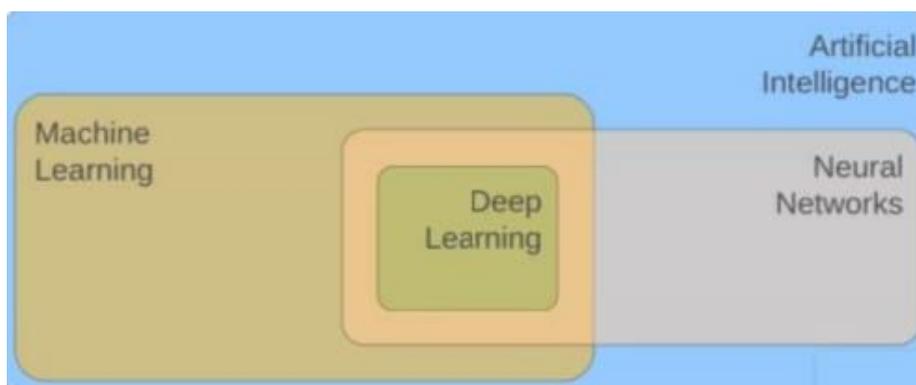


Fig. 2: Block diagram of Artificial Intelligence.

There are 4 types [12, 13] of artificial intelligence which helps to differentiate one machine from another. The main goal of the advanced technology is to build a machine which can perform multiple tasks.

The four types of artificial intelligence are-

1) Reactive Machines-It is the most primary type of artificial intelligence system which is purely reactive. These machines cannot store memories and previous log hence they do not affect the future action and decision making process of reactive machine. In late 1995 IBM developed a gaming computer known as Deep Blue is a perfect example of this type of machine.

2)Limited Memory- The second type of artificial intelligence can store limited memory. Self-driving car (Fig.5) by Tesla and the chatbots are the perfect example. These cars are built in such a way that they can observe speed, movement, and direction of other car and thus they can settle itself relative to other cars. However, this cannot happen in one go and requires time for identifying and monitoring the objects over time. These are saved to the static data in the memory such when to change the lane, where to stop and follow traffic rules.

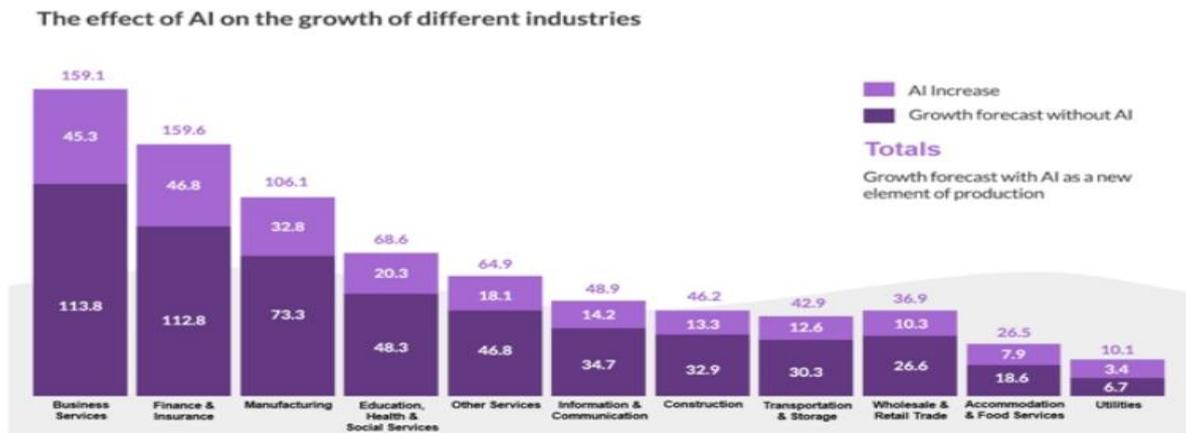
3)Theory of mind- This type of AI is a concept or a work in progress. It deals with the concept of building potentially strong machines in coming years. These machines will be so powerful that it will understand the human behaviour like expression, feelings, motives, emotions, and intentions. These are future machines and are in the process of building. It is estimated that by 2040 these machines would be in reality.

This will be the most modernized model of machine which will analyze the situation, environment and how human action can alter feelings and behaviour. The theory of mind concept was formed considering the human nature and evolution. It analysis the way human works, interact with people and society, form law, live a structured lifestyles. The machine will be able to understand human emotions, feelings, expression and behaviour. The idea of theory of mind is to propagate the information of mental states to the machine. Mental states are the thoughts that run in the human mind 24/7. Machine implement simple functions so that by mental state it is assumed that AI will make machine so powerful and invincible that it can literally have a sense of brain. It can have expression, beliefs, emotions and feelings.

4) Self Awareness- This the future technology with which AI will be super intelligent, which will have sentiments and consciousness.

The Artificial Technology is also classified as (i) Artificial Narrow Intelligence (ANI)[which includes all the reactive and limited memory AI], (ii) Artificial General Intelligence (AGI) [it includes AI systems which replicates multi-functional capabilities of human beings], and (iii) Artificial Superintelligence (ASI)[it includes AI systems which replicates the multi-faceted intelligence of human beings, because of overwhelmingly greater memory, faster data processing and analysis, and decision-making capabilities.].Fig 3 shows the growth of various sectors with and without use of AI.

The bar chart illustrates the growth forecast with AI as a new element of production:



Great Value Added in 2035 for with respect to the Manufacturing sector

Fig. 3: Effect of AI on different industries [12]

A.AI APPLICATIONS IN DAILY LIFE

Google Home performs work through voice command.Netatmo Welcome works as a guard and protects from intruder and fire. Kuri Home Robot (Fig. 4) performs basic household work and entertains also.

Kuri Home Robot



Fig 4: Smart home robot [14].

Smart Car (Fig. 5) or self-driving or autonomous car[15] observe speed, direction and moment of other car and objects and settle itself relative to other objects and obstructions. These activities are not influenced by human failure such as distraction and misjudgement.



Fig. 5: Future smart car [15].

Smart Drones use machine vision for surveillance and workplace jobs without risking human life. Smart Thermostat and Light for temperature control and lighting. Smartphones are in daily use and are equipped with AI features.

IV. APPLICATIONS IN MECHANICAL ENGINEERING

There are various areas where AI finds applications in mechanical engineering. It comprises of data handling and automation, to perform the work with minimum of human intervention. Fields such as machine design, manufacturing, crash simulation, predictive maintenance, robotics, industry 4.0 applications etc come under Mechanical engineering [17]. These are discussed below. Ismail et al [20] concluded that AI is being used in areas where large data is generated, and models are available to predict performance and diagnostic for failure and preventive maintenance.

A.MACHINE DESIGN

Mechanical design is the first step in the process of conceptualising a component, a product or a process. Dixon [16] reviewed the use of AI in mechanical engineering design and concluded that unlike electrical engineering domain, it involves material selection, analysis, and geometry. It cannot be done just by analysis alone as it is iterative and is

intellectually important. It has weak and strong solution approaches. Geometry is important as it has features for manufacturing and functioning. Application of AI will require comprehensive models at each stage of design process. AI finds application during design analysis.

B. VIBRATION ANALYSIS

Thorsten et al [17] used AI for vibration analysis of a cracked beam. Initially analytical data obtained from FE analysis on Ansys, was used for learning of AI/ ANN and then it was used for predicting the natural frequencies of cracked beam without using computer modelling and simulation. These are shown in figs 6 & 7.

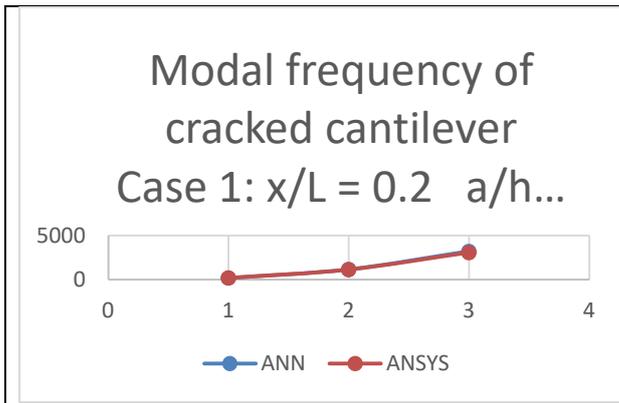


Fig 6: Modal Frequencies for case 1.

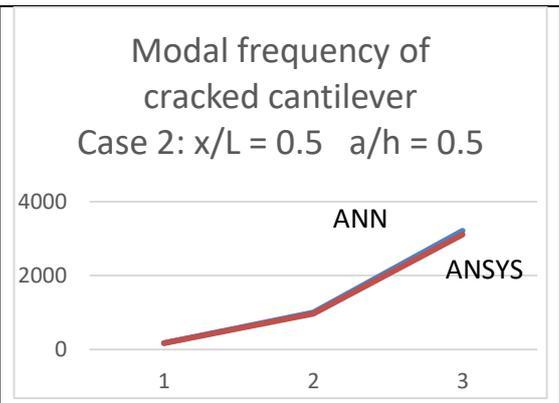


Fig 7: Modal frequencies for case 2.

C. CRASH SIMULATION

Constantin et al [19] used machine learning to analyse crash simulation data. They had data of 1000 simulations of full-frontal crash with variations in design of car and impact conditions. Understanding of large amount of simulation data would have required lot of time and human effort. Such is also the situation in Robustness Analysis or Design Space Exploration data.

D. MANUFACTURING

Development of machine learning, advanced sensors has helped in the generation of autonomous robots. Voice recognition and other features have given rise to human and robot collaboration. Thorsten et al [20] have identified that large data is being generated in Industry 4.0. This data pertains to quality, environmental data, data from sensors of production line, machine tools and semantic data in different formats. This big data with the help of AI is used for process improvement and product quality sustainability.

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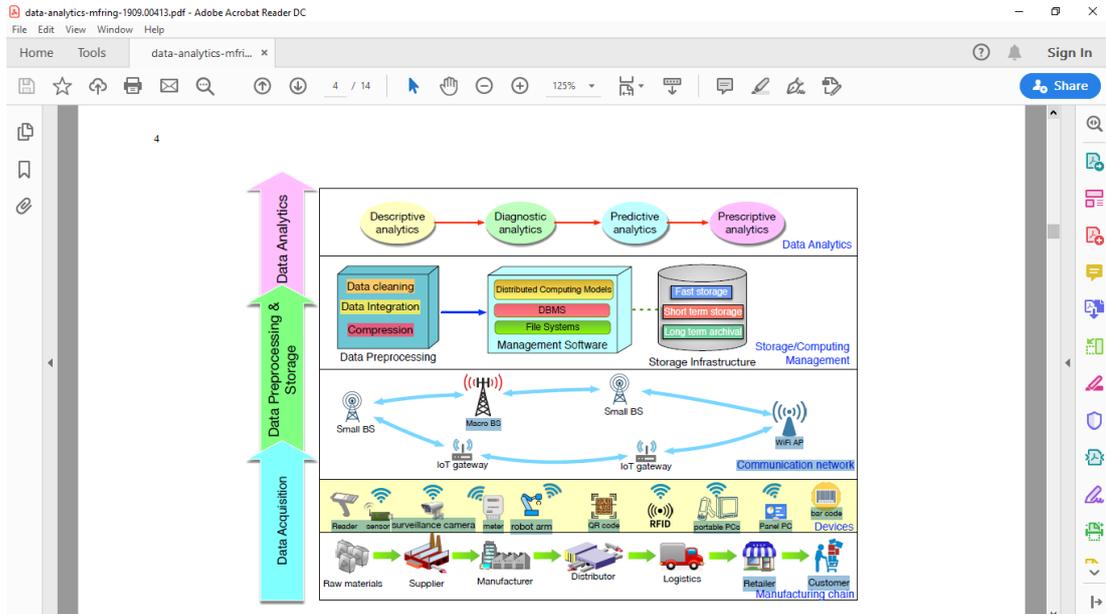


Fig.8: Sources and data generation in manufacturing [23].

David et al [21, 22,23] have studied the use of data analytics predictive maintenance. Fig 8 shows a predictive analytics framework in manufacturing system states. Which is responsible for the cost, quality, quality and sustainability. AI has transformed logistics and supply chain with the help of big data generated by using RFID data. The shift in paradigm from automated manufacturing industry to “smart manufacturing” or “smart factory” resulting in the formation of Cyber-Physical System (CPS). Fig 8 shows the sources of data generation in manufacturing.

Yongyi et al [24] have pointed out that a smart manufacturing predictive maintenance is a shift from the normal scheduled and breakdown maintenance. Predictive maintenance is based on the analysis of large data of machine tools, which is analysed by data analytical models, which predicts certain degradation or likely failure so that maintenance is performed. It is a novel maintenance paradigm.

V. CONCLUSIONS

From fiction AI has come to reality. With digitalisation and increasing computation power its finding uses in every field of knowledge and applications. It has challenged human brain because of its comprehensive hardware and software. Industries are creating and innovating new things. AI is finding use in applications used in daily life as well in advanced use in studies and research.

Industry 4.0 is establishing, and its main characteristics are digital twin, predictive maintenance, collaborative robotics, agile manufacturing. In the various areas of mechanical engineering AI is finding use in handling enormous data generated by sensors and process control, which helps human beings to take decision. These decisions are for the betterment of life and environment.

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