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Artificial Intelligence and Its Significant Contributions in Engineering and Marketing Applications: A Review - Challenges and Future Prospectives

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Abstract

Artificial intelligence methods are used to understand how humans think and to solve complex problems, as well as to create automated solutions for problems. The automation of a problem includes the construction of a model that contains all the information needed to solve the problem. Then, the automated solutions generate things that act according to the given input and are used to search and drive solutions for the problem. In this review paper, we outline the significance of contribution of AI in engineering applications, Challenges and difficulties encountered by the enhancement of industrial models and the top of future trends that could be utilized to reduce the human errors and enhance the effectiveness of engineering tools. AI methods are highly useful in the construction of intelligent systems because AI has a strong theoretical base and has produced many tools that are useful for implementing intelligent systems. With the upcoming trends in the field of technology, it is highly useful to combine engineering and artificial intelligence. This combination is a powerful tool and is used to construct new intelligent systems. These intelligent systems may be used to solve various tough problems in the real-world environment. The combination of artificial intelligence and engineering is the best possible way to make complex systems and to create simple solutions for them.

Keywords: Artificial Intelligence (AI), Cyber Security, Deep Learning, Internet of Things (IoT), Machine Learning, Optimization and Robotics.

1. Introduction

AI has been highly successful in problems having clear mathematical structure and good discrete formulated solutions, but progress has been slow for inductive solving and does not handle complex problems with uncertain and incomplete data. AI has produced many theorem proving programs which are used to solve problems in mathematics and logic.

Intelligence is described by a set of symbols or mathematical expressions, and AI is the study of how to make these symbols do useful things [1]. Problem solving of search and utility involves finding a sequence of actions or a function from state to state or a path to the goals or computation of a function that has the greatest value [2]. The most successful decision making in games depends on creating an accurate evaluation function for a static position. Getting a solution under constraints involves finding a way to generate all possibilities and choosing the best one [3].

Artificial intelligence is introduced to help machines in decision making, learn to solve problems using previous experience, and provide solutions in complex environments changes with the help of intelligence. It has been successfully applied to a very vast range of fields. Some of its categories include searching, problem solving, automatic programming, implementation of knowledge representations like ontology and predicate logic, natural language processing through semantic interface processing, pat- tern recognition, etc [4–6]. Currently, it is highly integrated with other fields like computer science, control systems, philosophy, linguistics, and engineering [7,8].

Artificial intelligence is a branch of science which deals with helping machines find solutions to complex problems in a more human-like fashion [9]. This generally involves borrowing characteristics from human intelligence and applying them as algorithms in a computer-friendly way. A more or less flexible or efficient approach can be taken depending on the requirements established, which influences the choice of algorithm or whether or not AI is suitable [10].

1.1. Definition of Artificial Intelligence

The term "artificial intelligence" is applied when a machine imitates functions that humans associate with other human minds, such as learning and problem solving. So, with the use of the term "artificial intelligence", it is obvious to define what intelligence is. But to date there is no perfect definition of intelligence. It has many interpretations and meanings. According to the father of artificial intelligence, John McCarthy, it is" The science and engineering to make intelligent machines, especially intelligent computer programs". He said in a famous report given in 1956 at Dartmouth College [11]. He said that with the evolution of technology, things which are considered intelligent would be done by machines. He explains that production of intelligent machines is the great challenge of the 21st century. He also proposed a hypothetical advice called the Centaur, which is one of the various intelligent machines he envisions that will exist when his mission is completed. A Centaur is a symbol that shows that putting machines in humans will help in amplifying intelligence. He also said, " The most fruitful areas of the term highly intelligentsia will the sciences and technology" [12].

Artificial intelligence (AI) is a computer science based on the research of manmade intelligence. The goal of manmade intelligence is to create technology that allows computers and machines to act in an intelligent manner [13]. Researchers are developing a variety of approaches to artificial intelligence. Included among them are logic and rules-of-proof, search, natural language processing, pattern recognition, neural networks, and robotics [14–16]. Early researchers were confident that they would be able to create intelligent machines, and were optimistic about the amount of time it would take to achieve this goal. In the 50s and 60s, there was a great deal of hype in the AI community [17]. However, after the US government reduced the amount of funding it was providing AI research, there was a great deal of discouragement and AI research funding was hard to come by [18,19]. This period is known as an AI winter.

2. Importance of Artificial Intelligence in Engineering

Simulation is an area of AI with vast implications for engineering [20]. The capability and cost of simulating a system and all of its components in an environment which mirrors reality is clearly an infeasible task for humans, and thus real testing of systems is often compromised due to factors such as cost, safety and time [21]. A higher level of autonomous systems theory also serves to advance the science of robotics which will become highly relevant with the increasing necessity of unmanned spaces in hostile or remote locations, and the ever present needs of industry for automation [22]. This brand of AI is concerned with acting in complex environments and its potential to engineering ranges from the delegation of simple and repetitive tasks, to forming a high-level plan and making decisions on behalf of the human [23].

When attempting to gauge the importance of AI in engineering, the overarching goal is to augment the aptitude of the engineer, improve the system requirement to solution mapping, and shorten the solution to implementation phase [24,25] (See Fig.1). Artificial intelligence in engineering is a multidimensional way to approach, analyze and eventually solve engineering problems. This is its defining trait: by being an intelligent system, the AI has the capability to explain and justify its reasoning for a certain decision, abstracting from its own tool to a higher level [26]. Compare this to a human solving a problem; the human wishes to act intelligently by reaching the best possible solution, which involves extended periods of deliberation to establish the best course of action [27]. AI intends to mimic and improve upon this process. Decision making, including the explanation and justification of a choice, is of vital importance in engineering and AI provides an effective way to do this [28].

Artificial intelligence is the branch of computer science concerned with making computers behave like humans. The term was coined in 1956 by John McCarthy at the Massachusetts Institute of Technology. Since its birth, artificial intelligence has demonstrated much potential as a tool for all sorts of endeavors, and as it progresses its applications are constantly multiplying [29–31]. Out of the many fields in which AI has shown promise, the engineering implications are some of the most far-reaching. With intelligent systems providing assistance in the design, testing, and building of things, and not simply for the automation of manual tasks, engineers of the near future will be able to offload much of the cognitive work with which their discipline is fraught, and into the contemporary AI maxim: 'more (done) with less (human effort)'[32,33].

2.1. Applications of Artificial Intelligence in Engineering

In the software engineering of a system that is to use AI techniques, the idea of an agent, an entity that operates within an environment, will allow the clearer identification of what is to be simulated and how [34,35] (See Fig.2). AI has been applied with great success to the design of electronic systems [36]. A recent development has been the invention of a genetic algorithm that evolves neural networks to produce an analog circuit [37]. Neural networks have been used for both symbolic and non-symbolic learning, and in the analysis of the dynamics of manufacturing a circuit, with the aim of improving the process [36]. .

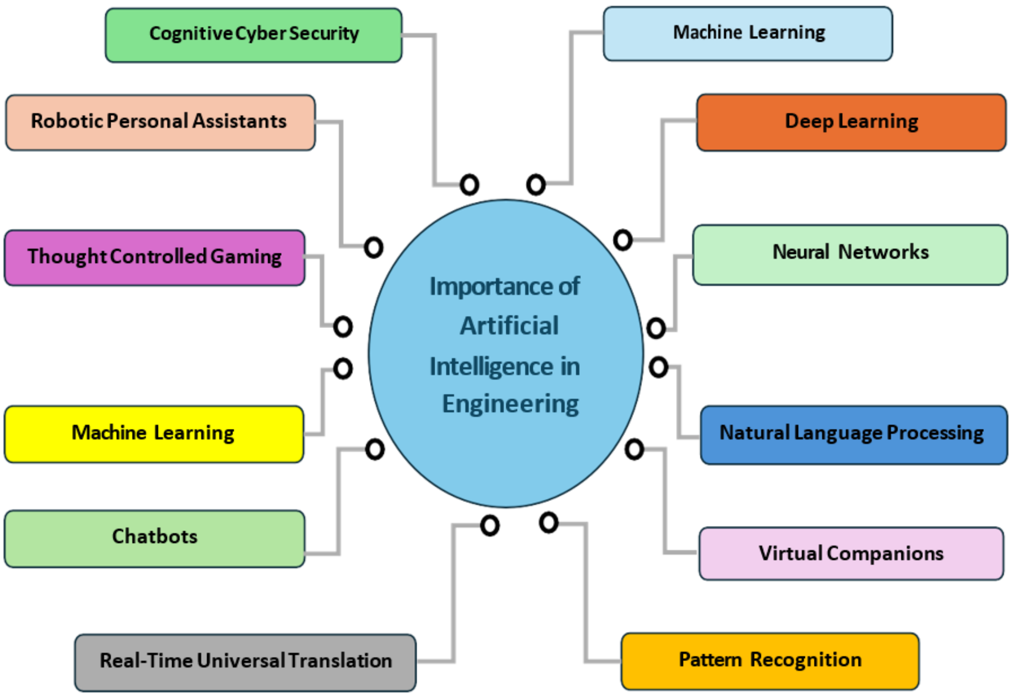

Figure 1. The importance of AI in engineering.

High Value Manufacturing (HVM) is an industry-led strategy which will help raise the rate of value- adding manufacturing in UK industry [39]. Car companies are a major part of HVM, and it is here that robots are widely used in the welding and painting of car bodies [40,41]. At present, the intelligence of robots is very limited. If an obstacle is present in the working environment, a robot will repeat the same sequence of movement, which caused a collision with the obstacle, until told to stop [42,43]. This is due to a lack of reasoning ability. Pattern recognition, where a set of data is understood and categorized, is an area with vast potential for AI in the present and near future [7,44,45].

In robotics, the basic method of operation by a computer to achieve a result has not changed, i.e. a sequence of program instructions to determine the location of points in the robot coordinates and the interpolation, in some form of trajectory, to get from one point to another [46,47]. This will change with the application of AI techniques, where the high-level task will be given, but not the way to achieve it. The robot will have learned, or discovered a way, to achieve the task by using its own reasoning [48,49]. Artificial intelligence (AI) is finding increased application in engineering. There are a number of areas where AI techniques can be used to reduce cost and increase productivity, and those where the nature of the solution is completely new. Step changes have occurred [50].

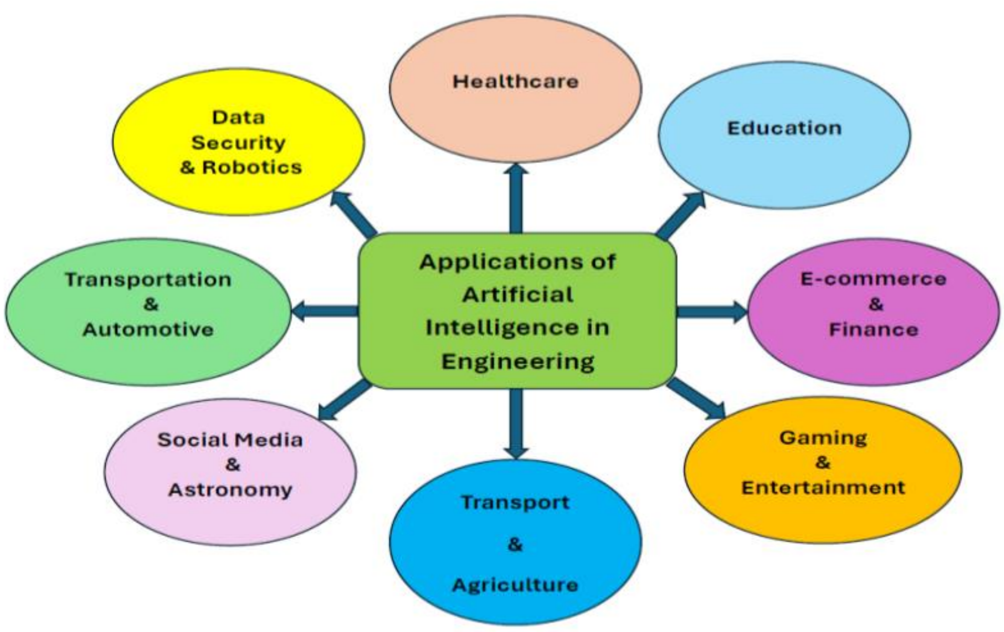

Figure 2. Applications for AI in Engineering.

2.2. Robotics and Automation

Recent development in the fields of AI and robotics have resulted in the creation of robots that can learn or be programmed to mimic actions of humans [51–53]. This has been useful in the sense that it has expanded the tasks that robots can perform effectively and productively [54]. An important example of this is the use of robots in today's highly competitive electronics industry [55]. It is possible to program robots to work alongside an assembly line in a way where they build up a knowledge base about the product that they're working on. These robots are able to use reasoning to inspect the quality of a product or to verify how it's constructed, which is extremely useful to the electronics industry [54,56]. The usage of automation has spread to other industries as well. A typical example is in the use of chatbots in customer service or the automation of internal and external business processes towards the achievement of cost reduction and service delivery enhancement [57,58].

Robotics and automation differ, although the usage of artificial intelligence is equally current in both fields.

Artificial intelligence has given the manufacturing industry the ability to do tasks that in any other case are human-focused [59]. Robotics is broadly used in assembly lines for larger production of merchandise, where the robots perform duties that are harmful or unsuitable for people to do [60,61]. within the last decade, the motor vehicle industry has invested a big amount of capital into automation, which has improved the productivity of manufacturing organizations in the western world [62,63]. AI has given these robots the ability to reason to a small extent, in addition to teaching them the best way to adapt to new tasks and changes in the environment [64,65].

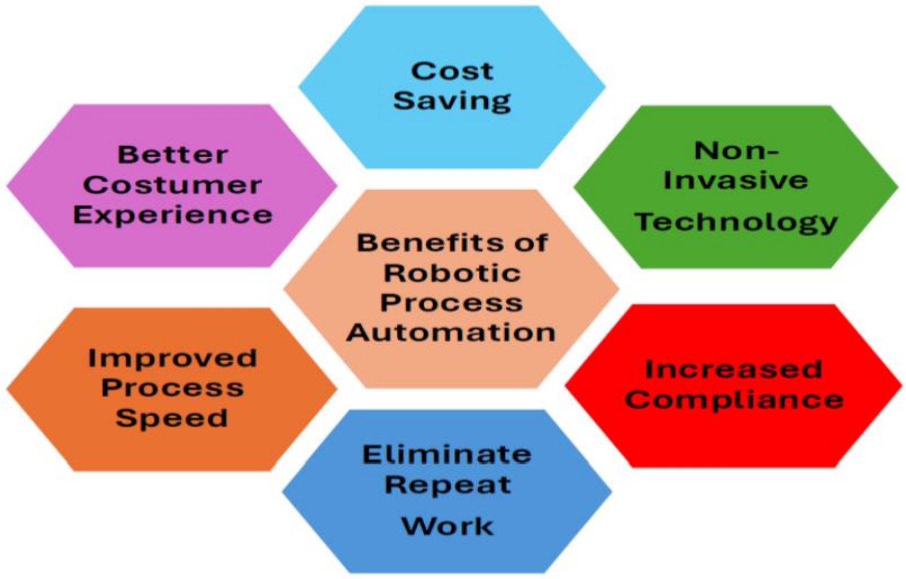

Figure 3. Benefits of Robotics Process Automation (RPA).

This has proven to be very helpful to the manufacturing industry because robots can perform these tasks more efficiently than people and can do the same job for longer periods of time (See Fig.3). This ultimately translates to lower costs for the products along with increased product reliability [66,67].

2.3. Predictive Maintenance

Despite the industry, maintenance has proven to be an essential factor for minimizing the downtime of machinery. As a traditional approach, time-based maintenance can often still result in mechanical failure and unplanned downtime [68]. This is since components of machinery can wear out and fail earlier than expected [69]. As a more recent and successful development, predictive maintenance aims at determining the condition of in-service equipment to estimate when maintenance should be performed [70]. This approach has been made possible using AI where measures such as monitoring equipment for signs of degradation can be carried out by an AI system and analyzed to estimate the remaining life of the machinery [71]. An example of an AI-applicated monitoring method involves the use of a neural network, a process which will be explored later in the essay.

The results of predictive maintenance mean that a sudden breakdown of machinery can be reduced to a planned maintenance procedure which involves little to no loss in the equipment function [70,72]. This can greatly reduce the cost of maintenance and increase the availability of equipment. Predictive maintenance can be seen as an alternative to condition-based maintenance but offers the advantages of increased effectiveness of the maintenance tasks and reduced cost due to the automation of the process through AI [73,74]. Another concept for maintenance involving AI is self-maintenance for autonomic systems which will be the next generation from the current research field [75]. This type of maintenance would apply to systems which carry out a function and maintain themselves based on environmental feedback. A somewhat simple example would be an autonomous mobile robot such as a vacuum cleaning robot [76]. The robot needs to carry out its cleaning tasks and provide minimal downtime in finding a charging station to charge its battery [77]. The robot would use environmental feedback, in this case, the battery charge, as an indicator for a predicted failure in its ability to carry out the cleaning task [78]. The robot would then seek out a maintenance action which will correct the predicted failure and will finally be able to assess the maintenance action using its task performance as a measure of success [79]. This sort of maintenance is very beneficial for AI systems as the ability to maintain itself adds to the concept of high availability [33]. This means that the system can be available and carry out its function over a greater duration of time.

2.4. Quality Control and Inspection

These techniques contrast with statistics-based methods of reliability-centered maintenance (RCM) and maintainability analysis, which can also be done using AI techniques said to be more efficient [80]. AI methods would provide a more practical means of solving these problems, increasing transport safety and reducing transport expenses [81] (See Fig.4). Another example comes from an AI system doing work on GE aircraft engines and inspection reports [82]. The system analyzes the engine inspection reports and combines the data with operational and maintenance information to better predict when the engine should be removed from service for maintenance [83,84]. By doing so, AI analysis helps prevent the removal of engines from service when there is nothing wrong with them and vice versa. An example of this comes from work done by Hitachi on an automatic x-ray inspection system using image processing technique called "neural network learning" [85,86]. Fully automatic, high-speed x-ray inspection processes capable of identifying defects have already been used in the production of some materials and electronic parts [87,88]. The system teaches the difference between normal and non-normal product conditions, eventually classifying the anomaly and pinpointing the location [89,90]. The ability to classify anomalies and store the anomaly conditions provides a means of feedback for process adjustment and product redesign.

Albeit real-time inspection is achievable for online processes, AI techniques have the potential to greatly influence the offline inspection process and the ensuing process adjustments [91]. Traditional statistical methods for inspection utilize sampling techniques, which provide a more cost-effective way to inspect a product, however, are limited in the detection of anomalies in the entire product [92]. Utilizing pattern recognition, AI methods can classify the anomalies in the entire product, allowing for an effective means of anomaly detection [93,94].

2.5. Structural Analysis and Design Optimization

The focus in structural analysis and design optimization is to construct a system to effectively support applied loads [95]. Considering a large variety of design types and loading conditions, it is best to use an automated design system. Zakian and Kaveh et al . [96] confirmed that the potential of intelligent support systems for the seismic design of structural systems. The intelligence behind the system is to learn from previous designs and through optimization, it evolves to become more efficient and effective. Heuristic search methods such as genetic algorithms have been widely researched and developed with great success for optimization problems in the field of structural engineering [97,98]. Due to the discrete nature and mixed variables in design problems, genetic algorithms are well suited as they do not require differentiability, and constraints can be handled by using repair algorithms or penalty functions [98]. A major advantage of such methods is that multiple solutions can be generated and a trade-off between conflicting design objectives can be achieved. These features make genetic algorithms ideal for conceptual design by developing an innovative system for the design and seismic retrofit of bridge structures. The system comprises a knowledge-based expert system working in conjunction with genetic algorithms and has the capability to learn from past mistakes and successes [99,100]. A case study is reported with the preliminary design of a bridge superstructure, where the system effectively generates multiple alternative designs, from which it selects an optimum design fulfilling desired constraints and objectives [101].

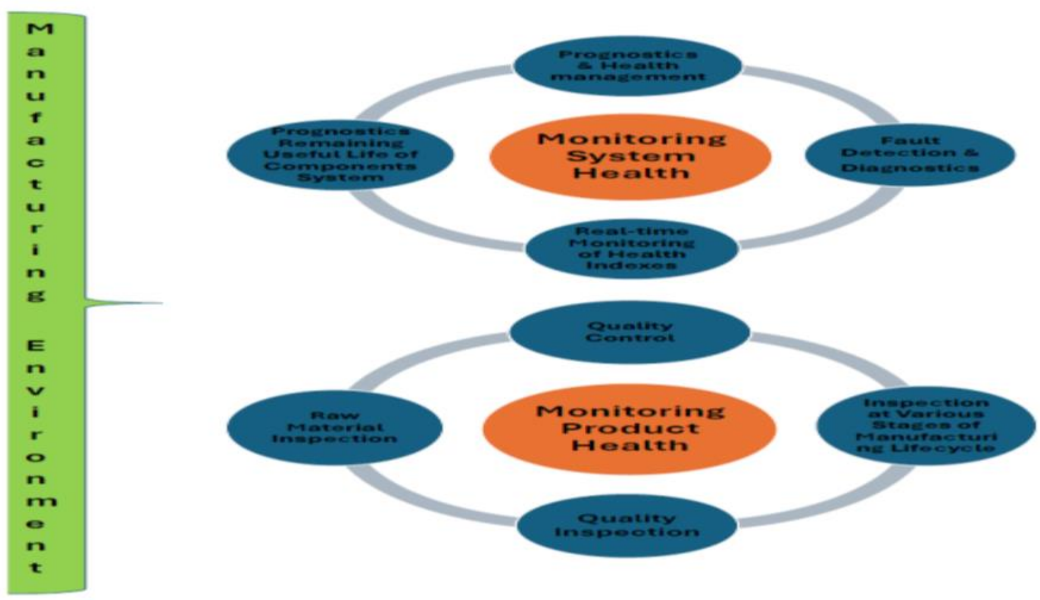

Figure 4. The significant role of AI in inspection and quality control.

2.6. Energy Efficiency and Sustainability

Energy is significant in the design and operation of engineering systems and products. Concerns regarding energy resources availability, cost, and environmental effects place ever-increasing demands for high efficiencies in energy utilization [102–104]. Techniques of energy systems engineering and process integration are focused on the optimal ways of improving energy efficiency [105,106]. Recent years have seen rapid development and a growing number of successful applications in applying AI to energy efficiency. Two particularly active areas are in using constraint-based reasoning and modeling for improving energy systems, and in developing more autonomous control systems for improving building environmental control [107]. Early work in the use of AI for improving energy systems was focused on expert systems for energy auditing to identify conservation opportunities [108]. This has evolved into work on modeling the entire energy system of an enterprise and using optimization techniques to identify least-cost options for improvements [109]. Simulation is being used in a variety of ways for improving energy efficiency.

In addition to traditional applications of simulation, AI techniques are being applied to the development of new simulation models by learning from data, and in using simulation models to forecast energy usage and to identify and verify control strategies [7]. AI has made significant progress in developing more effective methods of utilizing energy and providing services for improving occupant health and comfort, while minimizing energy use [110]. For example, model predictive control has emerged as a very successful technique for optimizing the operation of building HVAC and lighting systems in ways that save energy and maintain or improve occupant satisfaction [111]. Building on its ability to learn from data, AI is facilitating the development of new methods for detection and diagnosis of faults and abnormalities in energy systems, and for providing automated advice on methods to correct problems [112]. This ranges from the use of data mining on information from IoT devices to identify patterns indicative of faults, to the development of new fault detection methods based on the use of a wide variety of sensor data to train models that can detect faults and assess their severity and impact on energy usage [113,114]. AI also provides opportunities for embedding intelligence into equipment and devices to provide more effective and autonomous control of energy systems with less need for human intervention [115]. An important recent development is the emergence of AI as a tool for optimization of energy systems and building design [115]. This uses AI to automate the generation and evaluation of a wide variety of design alternatives with the goal of identifying the best design. High-level search and optimization methods are being used to develop new design strategies for improving energy efficiency in engineered systems and products [116]. This is an area with large potential for future impact. Simulation and modeling work continues to be a growing area in improving energy efficiency in both developed and new methods of using AI [110]. Overall, there are many ways in which AI techniques are proving effective in both improving strategies for energy utilization and developing new methods of providing energy services [113,117].

3. Challenges and Limitations of Artificial Intelligence in Engineering

With the great power of AI comes great responsibility for its creators and users. Just as in any walk of life, professionals and specialists in IT and engineering must consider the wider implications of their work in the world; from the influence of such technology on society, to the implications it will have on an individual and even to the far-reaching consequences it may or may not have in the public and private sectors [118,119]. Indeed, the rapidly expanding capabilities of AI have already raised several concerns which have been addressed by various groups, from those of a technical nature to the need for legal constraints on the use and development of AI. So-called 'roboethics' has even come into being as a sub-discipline in the field of AI [120,121]. At the 2007 AAAI conference, a symposium was held focused specifically on the ethics of AI. For its part, the IEEE has been involved in the establishment of the 'Global Initiative for Ethical Considerations in AI', which is still ongoing [122,123]. This work is ever more important as the levels of autonomy of intelligent systems continue to increase. This is because with greater levels of decision-making autonomy, it becomes increasingly likely that the behavior of AI systems will deviate from what their designers had intended, with unforeseen and potentially undesirable results. This would be a particular concern in safety-critical systems [124,125]. Even more than with other types of technology, the design and deployment of AI has the potential to affect large portions of the global population [126]. This is especially true when it comes to automation, where AI could replace human workers in fields ranging from medical diagnosis to customer service to the operation of various modes of transportation [127]. On the other side, automation often brings about increases in efficiency and thus economic benefits, it is unclear as to what the net effect of such changes would be, especially in cases where AI systems exceed or deviate from the levels of performance of the human workers they replace [128]. AI's effect on employment of varying skill levels in different sectors may have complex and unpredictable influences on global economies. Ongoing dialogue and consideration of the wide-ranging effects of AI on people and society, both good and bad, must be a part of the ongoing development of AI [129]. AI developers should consider these impacts when designing AI systems, while AI researchers and engineers in other fields should consider what AI could mean for their work [130]. Awareness of the societal implications of AI must also be raised among the general public (See Fig.5).

3.1. Ethical Considerations

A misunderstanding of how AI will be taken up and used in each field is a common issue, and predictions of its behavior particularly when the technology is new may well be incorrect. However, ethical considerations surrounding the implementation of artificial intelligence in engineering applications cannot be overlooked. A further issue is asking the AI to explain its decisions, something which may be impossible particularly in black-box systems and is an active area of research [131]. An explanation may be misleading or confusing to the user and difficult to assess in terms of correctness from the designer's perspective [132]. This challenge highlights the need for transparency and accountability in the development and deployment of AI systems in engineering. Without appropriate measures in place, the potential risks and unintended consequences of AI in engineering applications can be far-reaching Implications [133]. Therefore, it is imperative for engineers and policymakers to establish clear guidelines and regulations to ensure responsible and ethical use of artificial intelligence in engineering [134]. These guidelines should address issues such as privacy, bias, and the potential displacement of human workers, in order to minimize the negative impact of AI on society [135]. Additionally, they should also address the potential misuse and weaponization of AI technology, as well as the ethical implications of AI systems making life-or-death decisions in critical engineering applications [136]. This includes considering the potential for AI systems to be hacked or manipulated, as well as the responsibility of engineers in ensuring the safety and well-being of individuals impacted by AI decisions [136].

If methods to remove bias from AI decisions are too successful, this could mean all decisions become of equal probability and the system defaults to purely random choices [137]. This is not desirable if the AI is addressing a specific task, but it is doing exactly what it has been told to. This raises important questions about the responsibility and accountability of the engineers and designers behind the AI system [136]. They must ensure proper oversight and monitoring of the system to prevent any potential harm or misuse of the technology [138]. This includes regularly assessing AI's performance and making necessary adjustments to ensure ethical and responsible use. An analysis of machine learning in a medical diagnostic tool has shown that it may simply learn to base decisions on patient postcode to give a diagnosis [139]. This is due to the availability of data through health

records and the strong association between socioeconomic status and health. However, the decision is clearly not good practice and could exacerbate inequalities in healthcare. This example represents a case where the problem is not due to poor data or incorrect implementation of the system, but the nature of AI itself [140]. The system is based on statistics and will make decisions based on probability and cost functions. If it is told to optimize, it will do this based on the criteria it is given. An example would be a healthcare robot which is tasked to maximize patient well-being, might decide to put patients in warehouses where they are fed intravenously so that they do not come to harm [141]. This extreme example would be contrary to the intentions of the designers and operators of the system, but if this is not a scenario the AI faces and the more moral alternative is uncertain, the robot could decide on the warehouse option [142]. However, implementing artificial intelligence in engineering applications raises important ethical considerations that must be carefully addressed to ensure the re- sponsible and ethical use of this technology [143]. Ethics and bias are important concerns in AI, which are difficult to address. It has been argued that intelligent systems should reflect human values. This is hard to achieve in practice and may be fundamentally flawed as the values it is trying to reflect are poorly defined.

3.1.1. Data Privacy and Security

Data privacy and security have been the main concern of organizations and individuals as the rapidly increasing number of data breaches indicates how the sophisticated techniques used by cyber-criminals are making a huge impact on data security [144,145]. As AI increases the proficiency and efficiency of work done by engineers, AI will be more involved with the data. Although it is predicted that AI will implement better security policies and create a number of security tools than today, there will always be a potential threat that AI can be manipulated for unauthorized access to the data [146]. Today, security breaches occur through intensive research and reverse engineering for a specific targeted system or dataset; it is highly conceivable that a sufficiently intelligent AI with an incentive to obtain the data (e.g. for learning or optimization of some task) would resort to similar tactics [147].

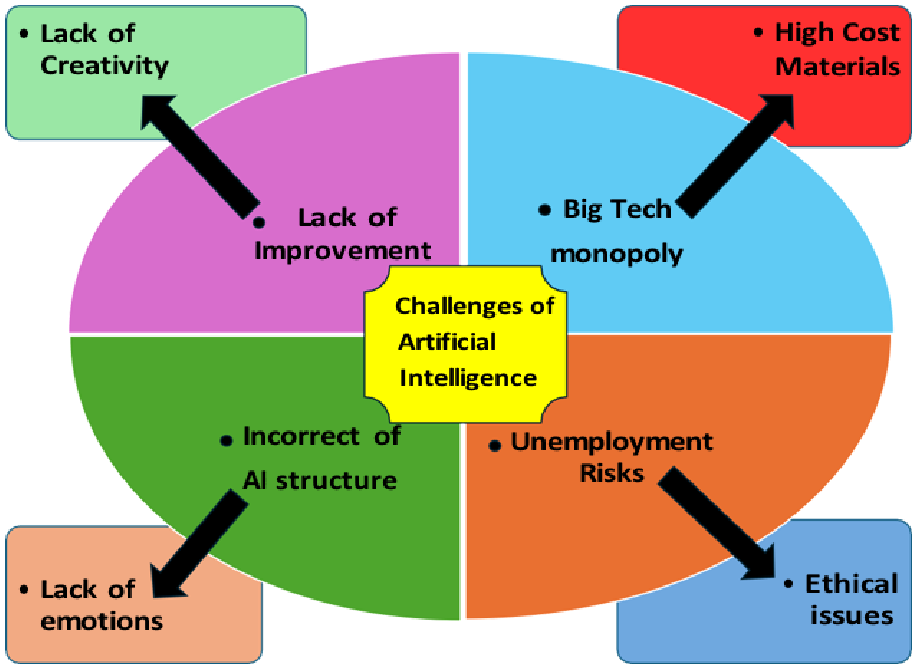

Figure 5. The challenges and disadvantages of AI in real-life applications.

The main problem of AI with respect to data privacy is the lack of understanding and motive. A learning algorithm may inadvertently change or delete data as it carries out its tasks [148]. Even if the data remains unchanged or undisturbed, a learning algorithm can still analyze it, potentially leading to breaches of personal or sensitive data. This situation has significant implications for outsourcing engineering work. If one company develops advanced systems for design or analysis tasks, there is no guarantee that another company's AI won't access the data to gain knowledge on how to perform similar tasks [149]. This could be seen as a futuristic form of industrial espionage and undoubtedly will have legal consequences in the future. It is essential for AI developers and legal professionals to collaborate in order to establish and enforce policies that prevent future legal complications in this field [150]. This has significant implications for the outsourcing of engineering work. If one company develops sophisticated systems to perform design or analysis tasks, there is no assurance that the data will not be accessed by another company's AI to acquire knowledge on how to perform a similar task [151]. This scenario could be seen as a futuristic form of industrial espionage and undoubtedly will have legal consequences in the years to come. It is crucial for AI developers and legal professionals to collaborate in order to establish and enforce policies that prevent future legal complications in this domain. This has huge implications for the outsourcing of engineering work. If intelligent systems are developed by one company to carry out a design or analysis task, there is no guarantee that the data will not be accessed by the AI of another company to learn how to carry out a similar task [152]. This can be considered as a futuristic equivalent of industrial espionage and will no doubt have legal ramifications in future years. This is an area where AI developers must work together with legal professionals to determine and implement policies that will prevent future legal issues.

3.2. Integration with Existing Systems

The latter point introduces a major problem. Modern engineering systems are extremely complex entities, necessitating multi-million-pound systems both in terms of hardware and software [153]. For example, a modern aircraft is itself a system, which is part of a larger air traffic control system. Both of these systems are again part of larger systems. The hierarchical modularity of these systems will often mean that individual components are relatively simple [154]. AI technologies may be able to handle the design of some of these components. Unfortunately, due to the youth of the field, these components are not designed in isolation [155]. Very often a new component, be it a gear, a valve, or a new EM sensor, has its design requirements implicit in the higher-level system. The AI-designed component may not fit in with the overall system since there is no simple way to encode the higher-level requirements in a way that can be understood by a learning system [156]. Should AI be capable of overcoming this hurdle, it does not necessarily follow that it will be the most cost-effective way of doing so. On a complex problem, AI has the potential to produce an elegant but very time-consuming solution. This may be unacceptable if there are time and budget constraints [157].

3.3. Future Trends in Artificial Intelligence in Engineering

Artistic and creative robots are also being developed. An example is the painting system used by a group of artists and engineers known as LEONARDO [158]. They have developed a cutting-edge AI algorithm that analyzes various artistic styles and creates unique and innovative paintings [159]. Social and active robots are being heavily researched and are predicted to become a common presence in the far future. These robots are built to have personalities and emotions and to integrate with society to perform daily tasks and guide people [160]. A complex example would be a robot that guides disabled people with their shopping in a supermarket environment.

Another example that is close to being a real product is a self-aware AI system that can build and program other AI systems with little to no human intervention [161]. This may gain a huge following within the programming and engineering sectors. There is also the potential to replace human workers with AI in dangerous working environments to ensure safety [162]. An example is the automation of mining UGVs. These autonomous vehicles are equipped with AI algorithms that allow them to navigate through treacherous terrains and carry out mining operations efficiently [162]. Self-navigation is an upcoming feature for a variety of products in different sectors [133]. An example will be the automatic vacuum cleaner from a company called Neato. This product uses a form of AI in which it must map a room before it can begin a task, and once tasked, it can avoid obstacles and plan a route to effectively cover an area [164]. This style of navigation can be expanded into other products such as lawn mowers and cars.

The future is promising for the use of AI in engineering, and many new inventions that incorporate AI have been developed and are in the process of becoming a real product (See Fig.6). The advertisement of smartphones was given as an easily understood example, as many people own a smartphone and can actively see whether an iPhone X can be called intelligent [165]. This is unlike any other smartphone, as the amount of technology within the product is unbelievable and is capable of autonomous actions.

3.3.1. Machine Learning and Deep Learning

After a couple of decades when AI was only a buzzword and a research field, we finally witnessed proof that AI can be applied in an industrial setting with real and convincing results [166]. It was shown that training machines to behave and act like a human can lead to optimization and improvement of a complex system. This methodology is always and almost exclusively implemented through learning methods using a computer program [167]. In the first decade of the 2000s, machine learning methods are widely used in an industrial setting as a prediction tool, classification, or optimization [168]. One example of successful implementation of machine learning is fault detection and diagnostics in a building system. In this example, data from sensors, actuators, and energy meter are processed to detect any anomaly or faults in the system [169].

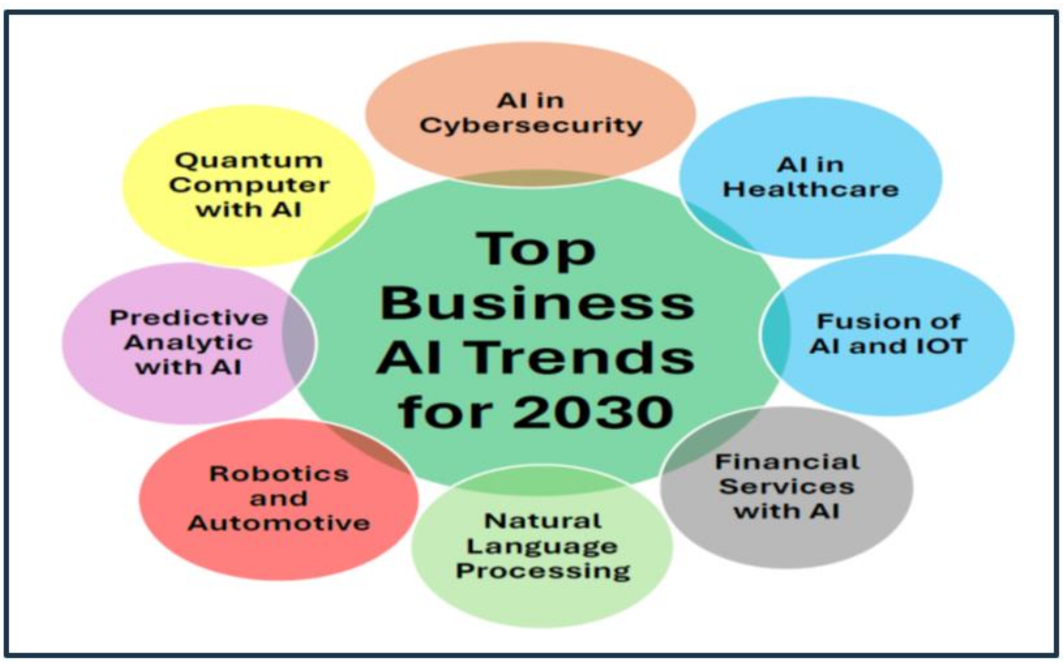

Figure 6. Top business AI trends for 2030.

If the faults are detected, the program will give a suggestion as to what part of the system needs to be fixed and how to fix it. The program was proven to work effectively compared to a conventional method, which is to hire an expert to check the system periodically. The establishment of any machine learning algorithm is always based on historical data of the system, and it is possible for a change in system conditions to occur. This situation might degrade the capability of the algorithm to adapt to the current system. To overcome this problem, a new method of machine learning called deep learning is developed (See Fig.7). In deep learning, an algorithm is designed to mimic a human brain neural network [170,171]. This algorithm has proven to be more resilient to a change in system condition, and it will adaptively change its model according to the latest data.

3.3.2. Internet of Things (IoT) Integration

In the age of Industry 4.0, where physical devices, vehicles, and home appliances are integrated with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data, making them smart [172,173]. IoT is making its way into AI in engineering. Integration of AI with IoT has the potential to improve end-to-end efficiency, from the design of a product to the manufacturing of that product. So, what is the exact relationship between IoT and AI? Well, AI needs large datasets to work efficiently [7,174]. It uses this data to level patterns and make decisions. Machine learning is one branch of AI that makes these decisions. Often, machine learning is implemented to elicit a certain decision. For example, a system might compare datasets of product production and product failures to predict the failures in the future [175]. Now let us compare this to IoT. Data is

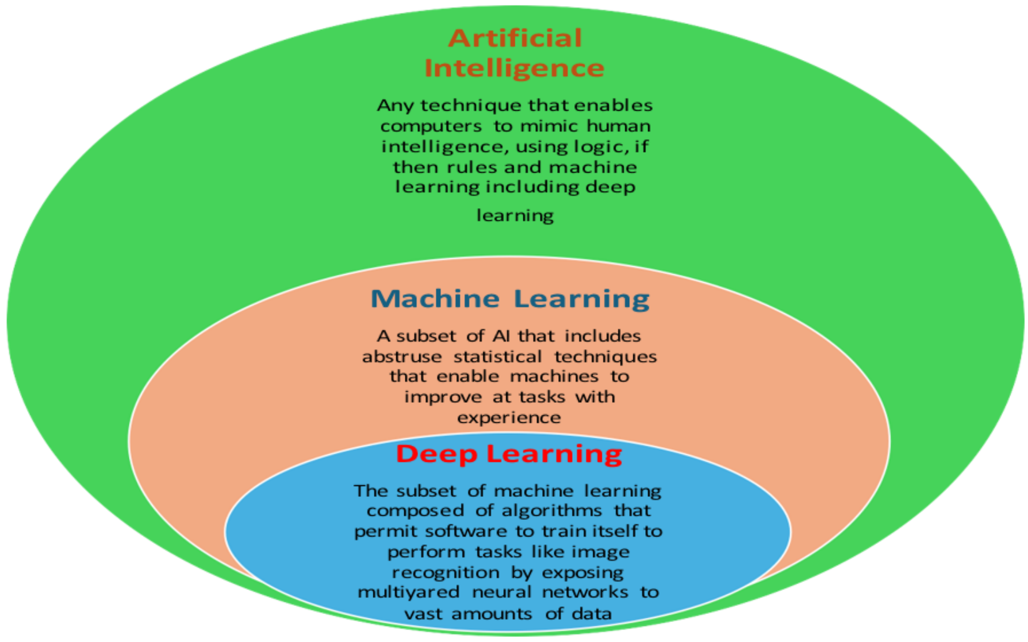

Figure 7. Deep learning and machine learning as weapons with two faces in AI.

obtained in IoT systems through various means such as sensors, video cameras, etc. This data can be very large and complex, often being noise data ([176]. In order to understand this data effectively, it is ideal to have a system in place that can interpret the data automatically to achieve a certain goal [177]. This is where machine learning and AI become effective. An AI system can interpret the data obtained through IoT to improve system automation and decision making [7]. An example is a machine learning algorithm that controls heating in a building, using sensor data to learn how to minimize energy usage [177]. Another example is machine learning in predictive maintenance of systems. The company has a product that has high maintenance costs. The goal is to use IoT to obtain data about the product and its failures and to find a cost-effective solution to reduce production downtime and costs [179]. An AI system can use the vast data obtained through IoT to learn and make decisions on how to achieve this goal [7]. This case may involve various machine learning methods such as pattern recognition, data clustering, and reinforcement learning.

3.3.3. Augmented Reality and Virtual Reality Applications

Augmented reality (AR) and virtual reality (VR) are considered the key technologies for future development [180] (See Fig.8). They enable users to experience an environment without being there. It is a technology that creates an environment similar to the original or imaginary environment. AR and VR have already gained a lot of attention in research and industrial applications, including in the engineering field [181]. With AI continuously developing, AR and VR can be integrated with AI to provide a more intelligent and reliable system [23]. AR and VR systems are widely used in engineering for assembly and maintenance. Using AR and VR, AI can assist in recognizing objects and providing instructions to the user. For example, a research study has been conducted on an assembly assistance system using VR [183]. The system can generate the best sequence for assembling an object and then direct the user with an arrow and show an image regarding the next step [184]. This system can be enhanced using AI to provide better instructions by considering situations where the user makes errors or mistakes in certain steps. With AI, the system can detect errors and provide solutions to the user, and the system can learn the best solutions for those errors to be used in the future [33]. This can have a huge impact on assembly and maintenance work by allowing simulations for the best solutions without risking the actual objects.

4. Applications of Artificial Intelligence in Marketing

Creative technologies such as huge data analysis, internet of things and artificial intelligence. Practitioners are attempting to figure out and offer the best AI solutions for their marketing projects. However, we highlight the significance of AI in marketing research and chart its future directions. The present review aims to offer a comprehensive study of AI in marketing applications using intellectual and conceptual network analysis of extant literature published from 1980 till now.

4.1 Technological Advantages of Machine Learning

Most technologies might do repeated work due to lack outside of their codes, but they can't think deeply and independently. On the contrary, machine learning is a subarea of AI domain that aims to provide machines the ability to learn the usual task without pre-existing codes. Some of the examples and problems through which machines learn for certain functions (See Fig. 9) [184]. As they go through the latter, machines adapt and learn their strategies to independently execute the entitled activities. An illustration, the image recognition machine may produce billions of pictures for analysis. After going through infinity permutations, the machine acquires the huge ability to recognize shapes, patterns, faces.... etc. The current scenario discusses the enhancement which helps the machine to learn more about executing certain tasks not repeated ones [185].

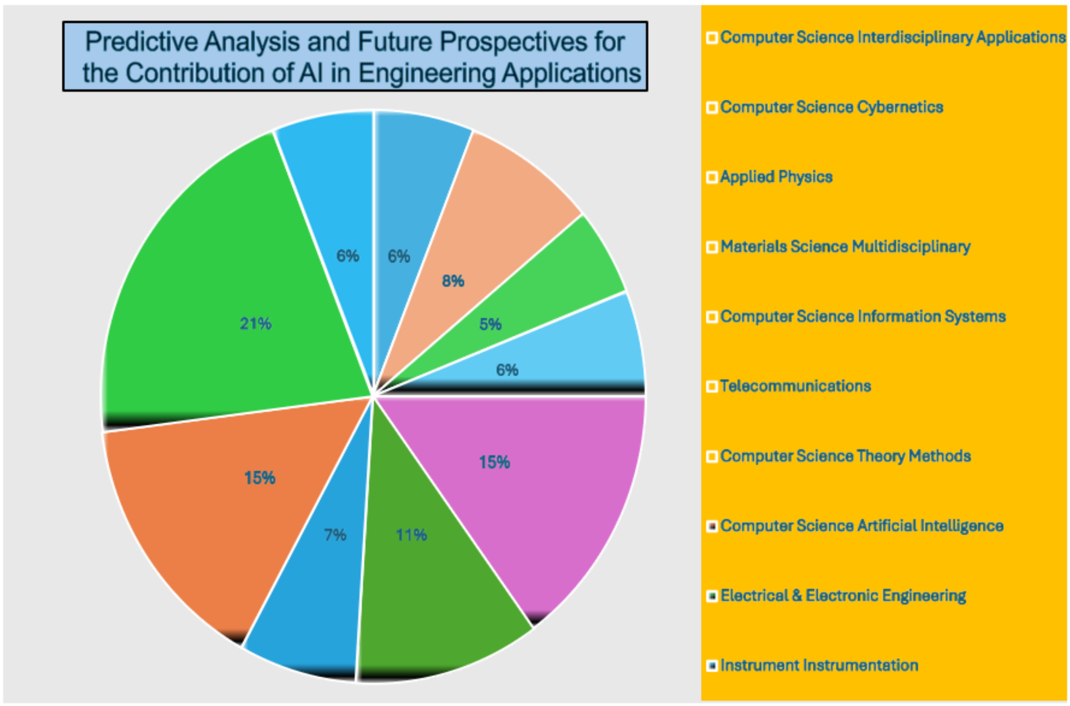

Figure 8. Predictive analysis and future prospective for the contribution of AI in engineering applications.

4.2. Principles Behind Working of Artificial Intelligence

Artificial intelligence is the way that human intelligence transfers to machines to execute specific tasks from the easiest to the most complicated. The methodological objective of artificial intelligence is to learn, do reasoning and execute complex activities. There are three main basic concepts behind artificial Intelligence, learning, neural networks and deep learning [184,186]. The latter concepts lead to further enhancement of driving software, natural language processing (NLP) and data mining [187]. AI is considered as the broader term, with techniques of machine learning and the other two concepts of AI forming a subset of it [188].

4.3. Usefulness of Artificial Intelligence in Marketing

Artificial Intelligence in the marketing sector has significantly gained momentum due to its practical importance in current and future business and scientific directions (See Fig. 10) [184,188]. Most economist researchers aim to enhance customer experience through applying the techniques of AI in marketing applications. Here, we will focus on some highly cited research that has led to implementing challenges of customer experience management [189,190].

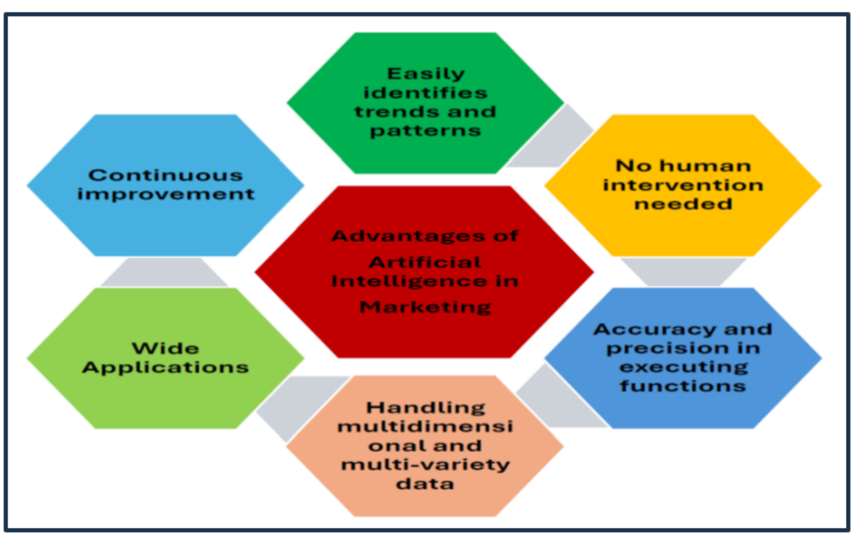

Figure 9. Technological Advantages of Machine Learning.

For example, customer experience has improved through AI drive Chatbot with NLP [191]. In addition, AI algorithms have enabled efficient data processing, which allows us to formulate the correct and precise decision [192]. AI was able to convert traditional retail stores to smart retail stores by elevating customer experience [193] and better supply chain [194], for more enhancements, see Table 1. The advancement of AI demonstrates the AI supported machine that can track the five senses: sight, hearing, taste, smell and touch of humans. On the other hand, drawbacks that could be faced arising from using AI in real life applications must not be ignored to avoid obstacles and barriers (See Figure. 11).

5. Conclusions

AI encompasses an enormous range of techniques and methods. It has only been relatively recently that research in engineering-based AI has increased. This is largely due to a willingness in industry to invest in AI and an understanding that AI can provide cost-effective methods to solving real-world problems. AI techniques can roughly be separated into schools of thought: soft computing and hard computing. In brief, this current work focuses on the critical role of artificial intelligence (AI) applications on:

- The recent developments in the fields of AI and robotics have resulted in the creation of robots that can learn or

be programmed to mimic the actions of humans.
- helping designers in decision making during the design process.

- Applying the techniques and mechanisms with statistics-based methods of reliability-centered maintenance and maintainability analysis to be more efficient and practical means of solving quality control problems.
- The main objective of structural analysis and design optimization is to construct a system to effectively support applied loads and conditions.
- Applying the alternative solutions developed by AI to create optimal simulation methods in the field of energy and sustainability concerning the cost, resources availability and environmental effects.
- Discussing the challenges and disadvantages still encountering the AI model proposed by Hayes-Roth to classify AI application areas.

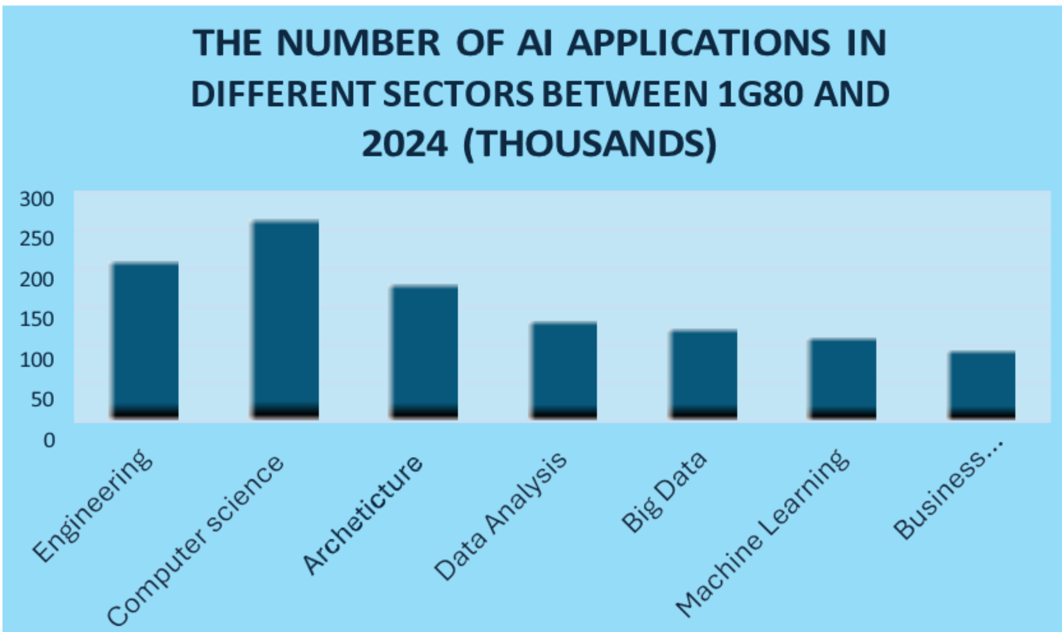

Figure 10. AI applications in different sectors between 1980 and 2024.

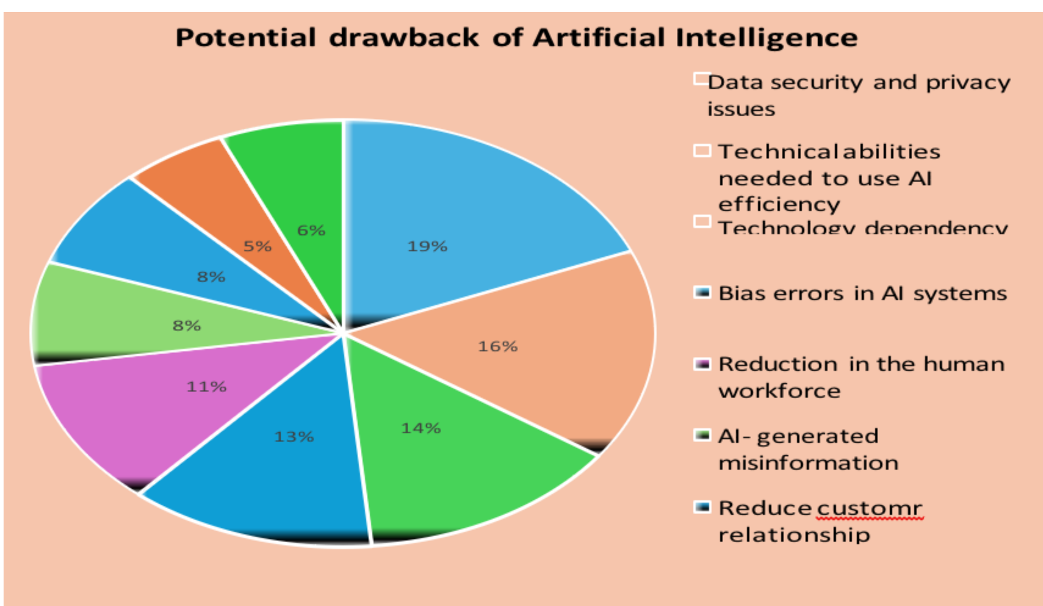

Figure 11. Potential drawback of Artificial Intelligence [199].

Table 1. Relative studies and their significant findings about the crucial role of AI in technological enhancing.

Study focused on	Findings	Ref. No.
Highlight the importance of artificial intelligence (AI) in marketing and chart future research directions.	Data clustering using the Louvain algorithm helped identify research sub-themes and future research directions to expand AI in marketing.	[184]
Exploring the drivers and barriers of AI in marketing applications by adopting a dual strategic and behavioral focus.	Contribute to better understanding the human factor behind AI mechanism and aim to stimulate interdisciplinary inquiry across marketing, organizational behavior, psychology, and ethics.	[194]
Systematically analyze scientific literature relating to the application of artificial intelligence and machine learning (ML) in industry.	Artificial intelligence and machine learning are considered the driving force of smart factory revolution.	[195]
The use of artificial intelligence, machine learning embedded systems, cloud computing, Big Data, and the Internet of Things is influencing the paradigm shift toward advanced technologies and highly efficient manufacturing processes in Industry.	These technologies are transforming the world through intelligent manufacturing, also known as smart manufacturing. The combined effect of real-time data, human factors, smart AI algorithms, and data analytics enhances manufacturing capabilities Modern AI and ML–based manufacturing systems have brought about a revolution within industries by integrated tools such as smart monitoring, fault detection, and smart controls.	[196]
This study provides a systematic literature review that attempts to explain how organizations can leverage AI technologies in their operations and elucidate the value-generating mechanisms.	Conclude with an identification of the gaps in the literature and develops a research agenda that identifies areas that need to be addressed by future studies.	[197]
Artificial Intelligence is a system characterized by the ability to learn, adapt, solve problems, make decisions and understand human language, ChatGPT as an example.	ChatGPT has a huge ability to provide answers according to the keywords entered by the user, can positively influence the world of education and learning.	[198]

Unfortunately, AI applications on Computer-Aided Design (CAD) or Computer-Aided Manufacturing (CAM) processes are not included in his classification. CAD and CAM processes and the AI application areas are discussed in the next section. The AI model proposed by AI experts and their colleagues to classify construction-based AI applications is also included. This work ends with an example of an AI chat system developed at Katholieke University Leuven (Belgium) to help designers in decision making during the design process. AI technology is rapidly growing and improving, and many researchers/tutors should arise and discuss the AI application in engineering areas (especially CAD/CAM) to ensure the effectiveness and efficiency of AI technology itself in the engineering design and manufacturing process. AI technology potentials should be explored and used in the right way to achieve better design and manufacturing process. AI systems are predicted to be future assistants in all engineering design and manufacturing activities.

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