THE ENGINEER STORY

e-ISSN: 3009 - 0792 Volume 12, 2024, 1-4

ACCELERATING DIGITALIZATION: THE APPLICATION OF ARTIFICIAL INTELLIGENCE (AI) AND ITS CHALLENGES IN ENGINEERING FIELD

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INTRODUCTION

Artificial intelligence (AI) denotes computational systems that replicate human cognitive abilities with enhanced speed, efficacy, precision, and efficiency through computational means. AI has constituted a significant domain of academic exploration since the 1950s; nevertheless, its importance is currently growing as a result of its ability to evaluate and react to vast datasets with faster, efficient and more logical conclusions. The fundamental distinction between AI and conventional software lies in its capacity to process incomplete and ambiguous datasets. By establishing semantic connections among data points, it becomes feasible to draw inferences regarding historical events and formulate predictions concerning future occurrences. Currently, AI has been widely used in decision making, evaluation, reasoning, categorization, deduction, interpretation and evaluation in various engineering applications.

ARTIFICIAL INTELLIGENCE

As shown in Figure 1, AI constitutes a specialized domain within the discipline of computer science, dedicated to the creation of autonomous systems that possess the capacity to perform tasks, engage in cognitive processes, and render decisions analogous to those of humans (Jenis et al., 2023).

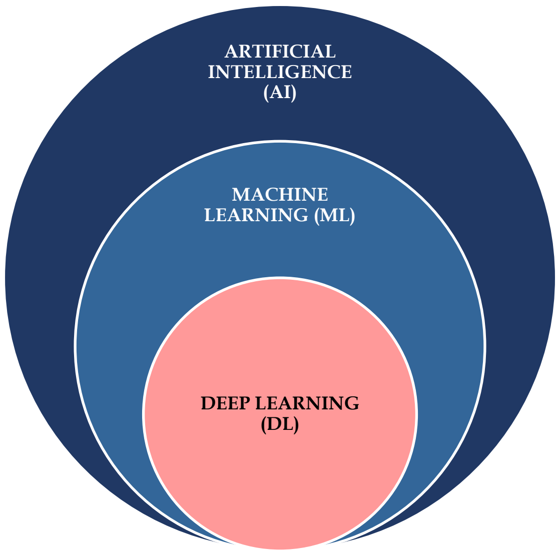

Figure 1: Configuration of Artificial Intelligence, Machine Learning and Deep Learning.

MACHINE LEARNING

Machine learning (ML) represents a domain within AI and computer science that leverage data and algorithms to replicate the cognitive processes of human learning while progressively enhancing precision (Taye, 2023). In the framework of data mining, classification and prediction algorithms are constructed using statistical approaches to generate important insights. A ML algorithm-training system consists of three components (Kollmannsberger, D'Angella, Jokeit, & Herrmann, 2021):

i. **Decision-making Process:** ML techniques are commonly used for prediction and classification where the algorithm identifies data patterns based on specific input, which may be labeled or unlabeled.
ii. **Error Function**: The error function assesses the model's predictions.
iii. **Model Optimization:** To improve the model's fit to the training data, the algorithm adjusts the weights to minimize the gap between known examples and the model's predictions. This process continues until the algorithm achieves a desired level of accuracy.

DEEP LEARNING

Deep learning (DL) is a specific category within the broader domain of machine learning (refer to Figure 1), which itself is a subset of artificial intelligence. DL represents a particular form of machine learning that is inspired by the architecture of the human brain. The algorithms associated with deep learning strive to derive conclusions that parallel those obtained through the continuous examination of data governed by an established logical framework (Alzubaidi et al., 2021). To achieve this, deep learning utilizes complex, multi-layered algorithmic configurations recognized as neural networks. A neural network is made up of linked units, often known as nodes, as shown in Figure 2. These nodes are referred to as neurons. These synthetic neurons accurately mimic the organic neurons of the human brain. A neuron is simply a graphical representation of a number. Any connection between two artificial neurons is analogous to an axon in the biological brain. Numerical numbers are utilized to connect neurons. As an artificial neural network learns, the weights and strength of the connections between neurons change. Weights for each job and dataset are unique. The neural network must learn these weights in order to predict the values.

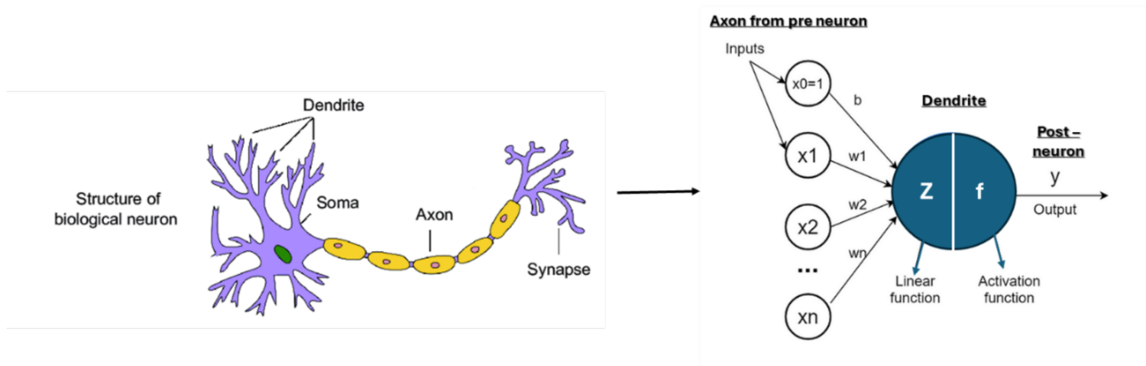

Figure 2: Architecture of Artificial Neural Networks

In a neural network, the data flows in forward or recurrent neural networks. Signals travel in only one direction in a forward neural network, from the input layer to the output layer. Power grids are made up of three levels: input, output, and zero or more concealed layers. They are often utilized in pattern recognition (Bebis & Georgiopoulos, 1994). On the other hand, recurrent neural networks (RNNs) manage a sequence of inputs utilizing their internal states (memory). Signals in these networks can propagate in both directions via network loops (hidden layers). They are commonly used for sequential tasks or related to time series conditions (Bebis & Georgiopoulos, 1994; Das, Tariq, Santos, Kantareddy, & Banerjee, 2023).

THE ROLE AND APPLICATION OF AI IN ENGINEERING

AI has shifted engineering by providing innovative solutions to complicated issues, increasing productivity, and allowing for more intelligent and automated systems. From design optimization to structural integrity, the integration of AI into engineering disciplines is making the processes more precise, cost-effective, and adaptive to future challenges which was summarized in Figure 3.

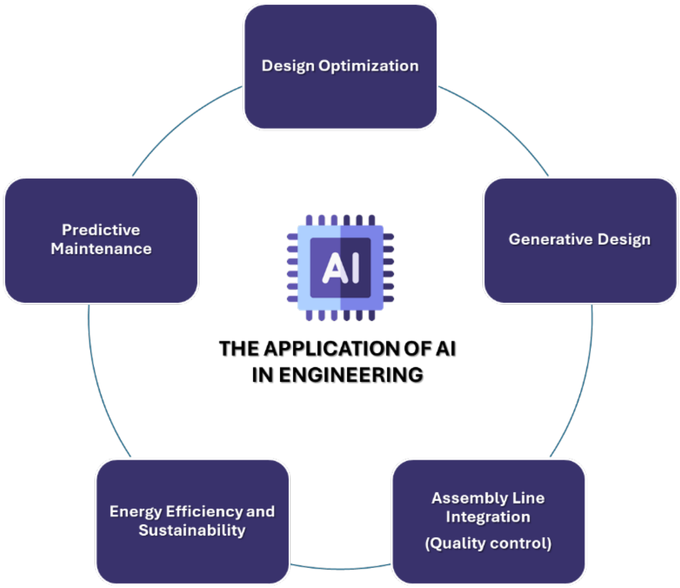

Figure 3: Outlook of Application of AI in Engineering.

In Design Optimization, engineers can use AI to develop designs by running simulations and analyzing large datasets to suggest improvements. Furthermore, AI may generate innovative design concepts based on specified factors. On the other hand, in the Generative Design tool, AI can enable engineers to input design objectives and limitations (such as material type, dimensions, weight, and strength requirements) while allowing the algorithm to produce a large number of design possibilities. These generated designs usually outperform conventional approaches in terms of efficiency and originality. The use of AI in predictive maintenance makes it easier to anticipate probable failures in machinery or components, allowing engineers to perform maintenance tasks before breakdowns occur. This approach diminishes downtime and repair expenditures, thereby enhancing operational efficacy. For example, in the automotive industry, AI can meticulously analyze sensor data from engines and other machinery to discern patterns indicative of wear or impending failure.From Process Optimization in Manufacturing perspective, AI can be employed to enhance production processes, encompassing material sourcing through to the final assembly of products. This application guarantees the efficient utilization of resources, minimizes waste, and accelerates production cycles. Lastly, AI can assist engineers in designing systems that are more energy-efficient, monitoring energy consumption, and minimizing waste across various industries.

BENEFITS AND CHALLENGES OF USING AI IN ENGINEERING

Integrating AI into engineering offers a wide range of benefits. It boosts efficiency by automating routine tasks, improves accuracy in design and analysis, and speeds up decision-making. AI also drives innovation with generative design, optimizes resource use, and helps prevent equipment failures through predictive maintenance. By enabling real-time monitoring and process optimization, AI reduces costs and increases productivity. Additionally, it enhances safety by predicting potential risks and providing valuable data insights, allowing engineers to focus on more complex, creative, and high-impact work.However, although the usage of AI bring benefits in engineering applications, there are certain challenges associated with AI implementation. There is a need for substantial amounts of high-quality data. This is because poor data quality, inadequate data, or biased data might result in faulty or unreliable AI predictions. Addition to this, integrating AI into existing systems or workflows can be difficult and requires substantial adaptation. Another issue with AI is that the algorithm inherit biases from their training data and reliability issues which could lead to flawed designs or unfair resource allocation. Finally, in terms of security, Internet of Things (IoT) devices are particularly vulnerable to cyber threats. Hackers have the ability to modify data or manipulate AI systems, resulting in disastrous failures.

CONCLUSION

In summary, integrating AI into engineering brings major benefits like improved efficiency, lower costs, better design capabilities, making real-time adjustment and advanced predictive features. However, some issues need to be overcome such as data quality concerns, high financial investment, regulatory hurdles, and the need for specialized expertise. Striking the right balance between embracing AI and addressing these challenges will be key to unlocking its full potential in the engineering field especially in meeting the Fourth Industrial Revolution (4IR), the Industry4WRD.

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