



Review Article

Artificial intelligence, machine learning, and deep learning applications in the engineering fields – A comprehensive review

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ABSTRACT

While Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) are revolutionizing engineering, their specific roles and interrelationships across different disciplines often remain unclear. This paper tackles that ambiguity by mapping the applications of these technologies across 14 distinct engineering fields. Through a systematic review of 150 peer-reviewed studies, we investigated which techniques are being used, the tools employed, and the outcomes achieved. Our analysis revealed that Machine Learning is the dominant force, appearing in roughly 73% of the studies reviewed. This prevalence isn't accidental; ML's decades of development have resulted in versatile, robust, and interpretable algorithms that engineers find adaptable to a wide array of challenges. In contrast, Deep Learning, while powerful, is typically reserved for niche applications involving high-dimensional data or exceptionally complex patterns, such as in image or speech recognition.

A key contribution of this work is clarifying the practical hierarchy between these terms: AI is the overarching field, ML is its data-driven engine, and DL is a specialized subset of ML. By systematically comparing their use across disciplines, this study offers a new framework for understanding how each technology contributes to engineering innovation. Our findings provide practical guidance for researchers selecting the right tool for their specific problem, ultimately helping to steer future applications of AI in engineering.

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INTRODUCTION

Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) are today a big component of daily life, shaping the way of how we interact with diverse information and apply the technology. AI is about formation of machines that have the ability to think and act in ways same as humans. ML is a branch of AI that enables the systems to learn from data and be developed over time without the need for direct programming. DL takes things to the next level—Using layered neural networks that are modeled after the human brain to deal with more complicated tasks.

The use of these technologies is widespread, from voice assistants and recommendation systems to image recognition and self-driving cars. By making processes faster, automating routine work, and creating personalized experiences, they are making a difference in industries such as healthcare, finance, and education.

While people may use AI, ML, and DL interchangeably, they do not mean the same thing. Figure 1 shows a chart that highlights their key differences, and the sections that follow explain AI, ML, DL, and RF in more detail, including the main algorithms used in each field.

This comprehensive review delves into the transformative impact of AI, which is the umbrella of ML, and DL across 14 diverse engineering domains. Our contributions are summarized in the following three points.

- Each engineering type is meticulously examined, unraveling the employed methodologies, innovative applications, and succinct summaries of outcomes;
- This research illuminates the pervasive influence of cutting-edge technologies in reshaping and optimizing various facets of engineering, offering a valuable synthesis of advancements that bridge theory and practical implementation; and
- A statistical section is also provided that clarifies the percentages of AI, ML, and DL application in the engineering fields.

These contributions collectively advance the understanding of AI, ML, and DL's role in engineering, providing a foundational reference for future research and development, which is the novelty of this work.

Artificial Intelligence

In simple words, AI is the process of transferring the information, data, human intelligence to machines. The fundamental objective of artificial intelligence is the development of autonomous entities endowed with the capacity for human-like thought processes and actions. Such entities execute tasks by engaging in problem-solving through research and emulation of human behaviors. The majority of AI systems emulate natural intelligence in order to address intricate challenges [1].

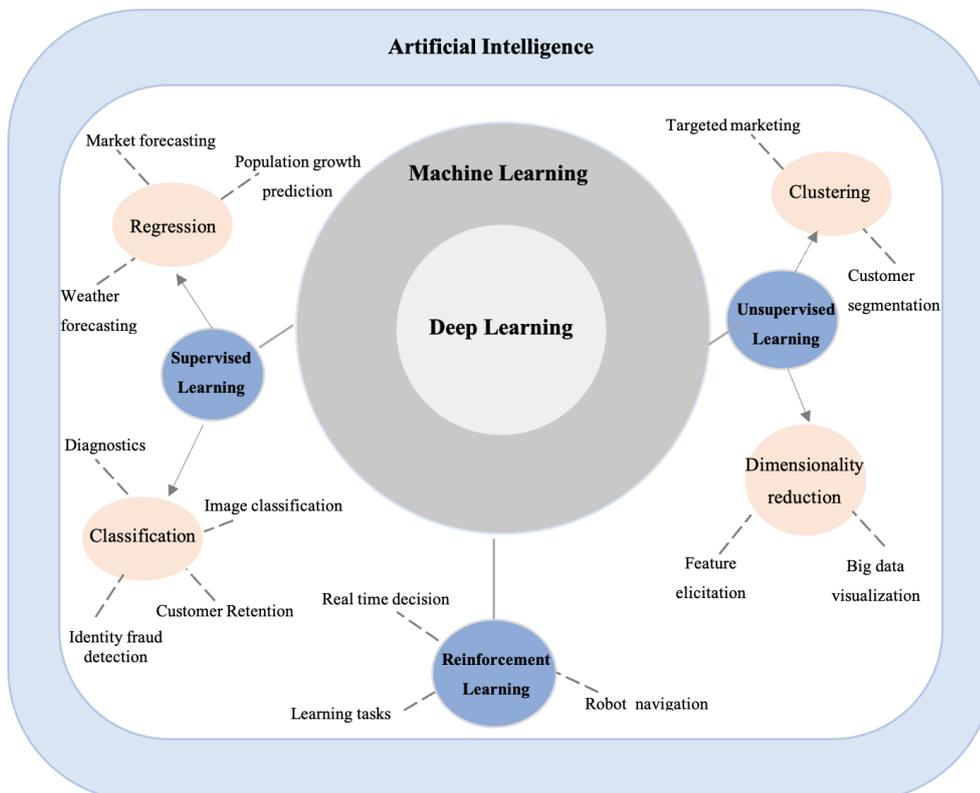


Figure 1. AI, ML, and DL configuration.

The word AI refers to the computer algorithms, which simulate cognitive processes or activities observed in living organisms. Nowadays, AI is integrated into the scientific discovery for many purposes such as collect and interpret large datasets, design and guide experiments, helping scientists to introduce some hypotheses, accelerate research process, provide reliable and actionable models integrated with the scientific workflows, and refine measurements. Moreover, AI can be used in decision-making, suggestion, problem-solving, estimating, understanding, and learning [2-3]. AI along with the Internet of Things (IoT) are mandatorily required to handle massive data effectively in less time by applying the theorem of algorithms even though the training along with the execution of the algorithms requires substantial storage, power, and massive data to be trained [4-5]. Nowadays several AI tool are used not only in engineering field but in general, the following subsection discuss the most known one, which is helpful for the researchers in general.

ChatGPT

OpenAI introduced ChatGPT, a generative pre-trained transformer model [6], which is defined as an intelligent chatting robot that has the ability to give an immediate response based on the instruction provided by the user [7].

For instance, Figure 2 shows a request from the user asking ChatGPT to give knowledge about AI in only one paragraph and the response was exactly as requested. ChatGPT showed an incredibly powerful in generating several tasks extended from trivial tasks to several language understanding. Some of these tasks are story writing, debugging, grammatical correction, and multilingual machine translation [7]. Moreover, natural language processing problems could be also solved by ChatGPT such as semantic annotation and acceptance of the text going towards natural language understanding (NLU) like word sense disambiguation (WSD), providing answers for the provided questions in the input text box, a relatively simple binary classification of texts like spam, aggression detection, sarcasm, and other tasks like a more complex multi-class and multi-label classification of texts such as sentiment analysis, emotion recognition [8]. These days, ChatGPT has gained much attention due to its ability to provide high-quality as well as fluent responses [9]. However, this tool is very helpful if and only if it is used wisely, the educational facilities can encourage academic integrity and avoid the disruptive impacts of this technology by introducing guidelines and clear policies [10]. GPT is being improved continuously started from GPT 1 to GPT 4, Table 1 clarifies the differences between these versions [7].

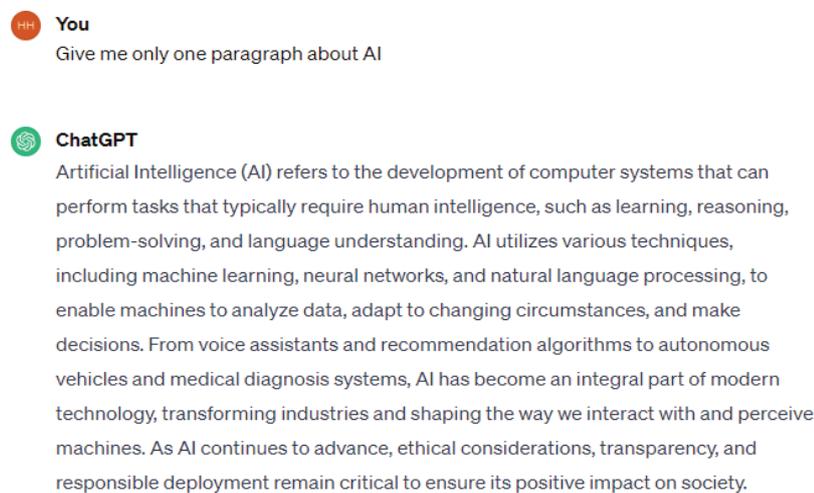


Figure 2. An example of how ChatGPT works.

Table 1. Comparison between GPT-1, GPT-2, GPT-3, and GPT-4

	Released year	Context window	Size of pre-training data	Data source	Learning target
GPT-1	2018	512 tokens	Around 5 GB	Book corpus and Wikipedia	Unsupervised learning
GPT-2	2019	1024 tokens	40 GB	Web text	Multi-task learning
GPT-3	2020	2048 tokens	45 TB	Common crawl	In-context learning
GPT-4	2023	8195 tokens	Unavailable information	Unavailable information	Multimodal learning

Machine Learning

The field of machine learning (ML) has undergone substantial advancements over the preceding two decades, transitioning from an experimental pursuit confined to laboratories to a pragmatic technology entrenched in pervasive commercial application. Within the domain of AI, ML has ascended as the preeminent approach for the formulation of functional software across diverse domains such as computer vision, speech recognition, natural language processing, robot control, and various other applications [11]. ML has emerged as a crucial method for harnessing the capabilities of data, enabling businesses to enhance their innovation, efficiency, and sustainability [12].

ML involves the examination of data and the creation of algorithms to make predictions based on the, previously, trained data. ML programs rely on a computer’s ability to learn without explicit programming. The ML model may either be predictive or descriptive, to gather information about input data [13].

Constructing an effective machine learning model involves two crucial stages: training and testing. During the training phase, a significant and research-intensive process, the system is presented with labeled or unlabeled inputs. These inputs are stored in the feature space for future reference in making predictions. Subsequently, in the testing phase, the system is presented with an unlabeled input, and it must predict the correct output based on its training [14]. ML enhances task performance and productivity by incorporating learning mechanisms and self-correction in response to new data by five main steps, which are clarified in Figure 3 [15].

In the first step, the required data will be collected from several sources such as World bank or Kaggle, and in the second step some analysis for the data will be made such as the missed data, or handling the invalid data by several analytical techniques and finally the data will be preprocessing for

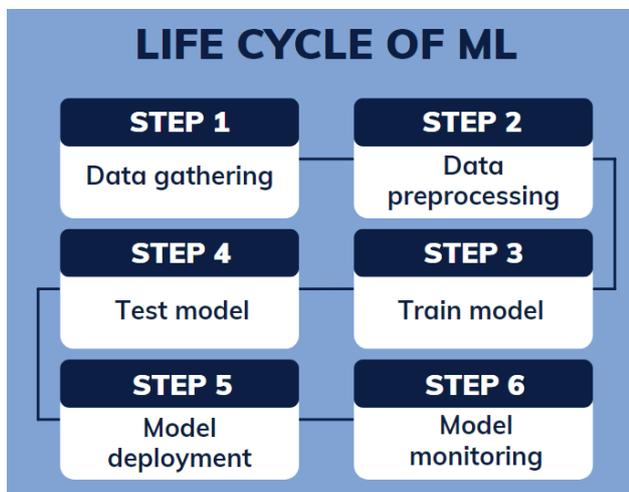


Figure 3. steps of applying ML.

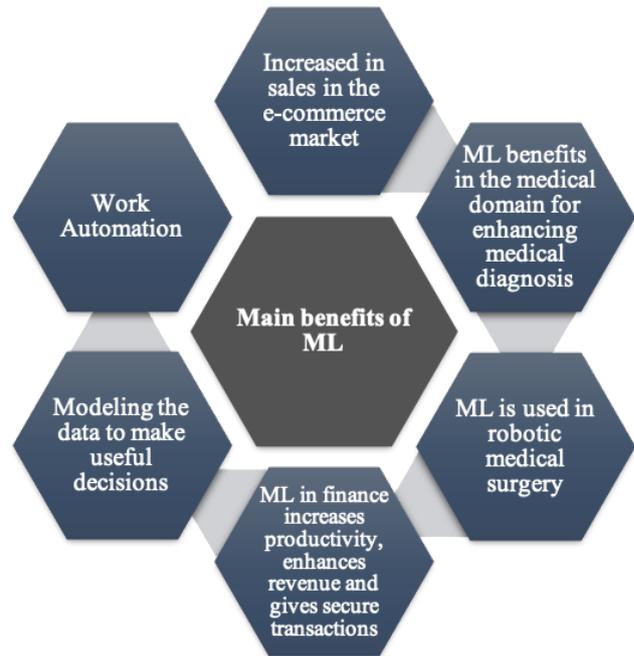


Figure 4. Main benefits of ML.

feature extraction, feature analysis, and data visualization. The data then will be divided into two main parts for two main goals; training and testing. In the third step, the testing part of the available dataset will be used to train the model by various ML algorithms. In the fourth step, the accuracy of the model will be tested by the second part (testing part of the data). And in the fifth step, model deployment, the ML model will be integrated with an existing production environment that takes the input and gives the output to make decision making or to achieve any another goal. Several technologies can be used to deploy the ML model such as: Azure ML Service, Docker, Kubernetes, MLFlow, AWS SageMaker. Finally, the last step the obtained model will be monitored from several aspects such as the crashes, errors and to assure that the model still provides the desired performance [15]. In general, ML have wide advantages and benefits, which are shown in Figure 4, and accordingly this promotes it to be applied in several applications as represented in Figure 5 [15]. ML is divided into three main types, and each type is familiar with specific sorts of dataset. These three types are clarified in Figure 6 [16].

Supervised Learning

The preeminent ML type is the supervised learning model, primarily employed for addressing practical applications in the real world [17]. This model predicts results based on specific input sets and pairs of input/output examples. Each training dataset in supervised learning comprises input goals, an input vector, and a desired output value known as a supervisory signal. These examples train machine learning algorithms, leading to the derivation

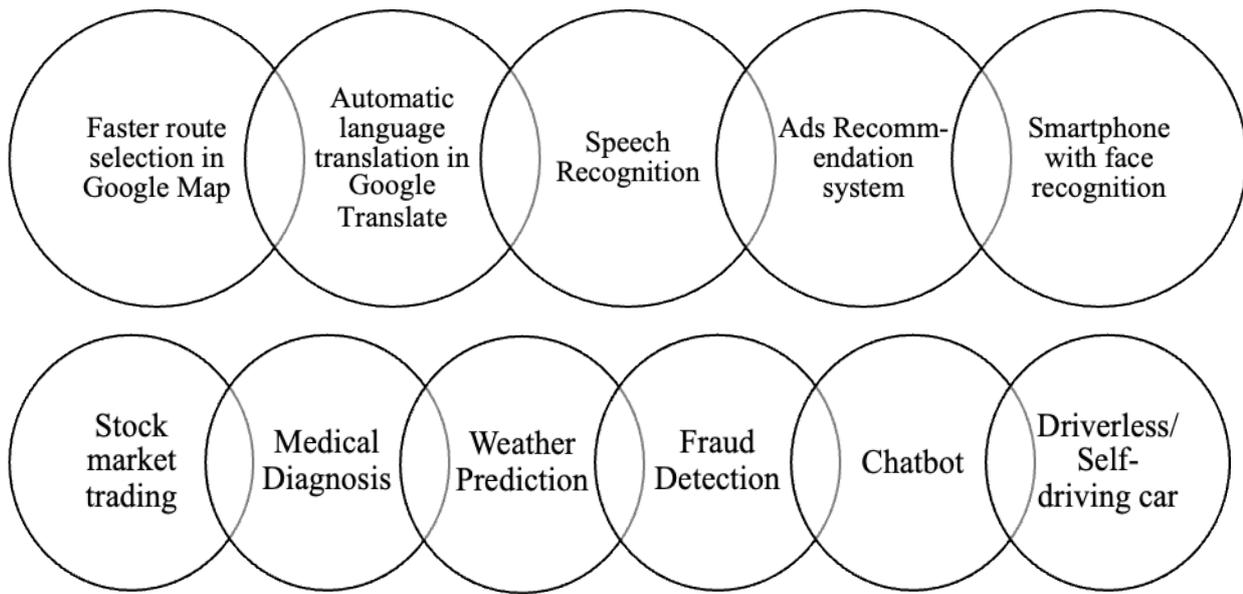


Figure 5. Real-world applications of ML.

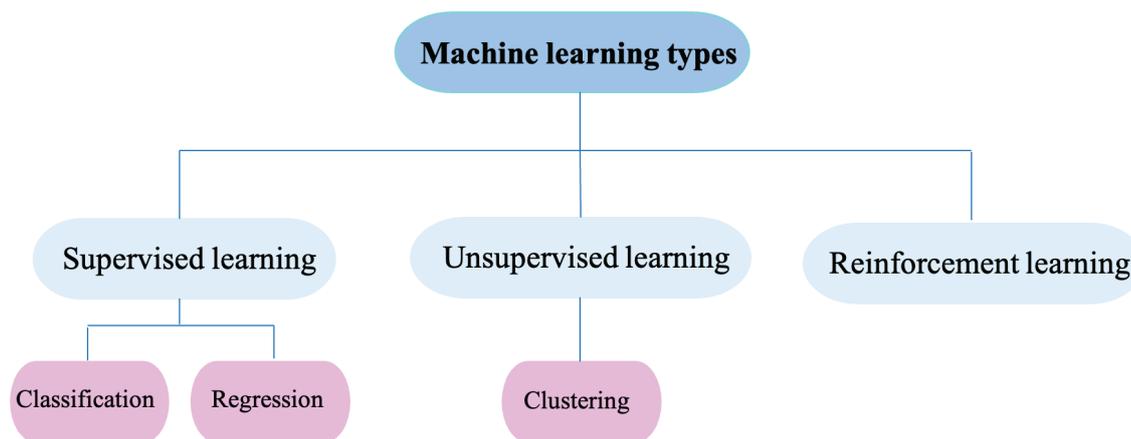


Figure 6. Machine learning types.

of a classifier function through dataset analysis. The goal of supervised learning training algorithms is to forecast one or multiple outcomes using different input features. While supervised learning is effective, it has the limitation of necessitating a substantial amount of labeled data for the creation of a comprehensive labeled dataset [18]. Supervised learning models are widely employed for tasks involving classification and regression as shown in Figure 6.

The supervised learning is divided into two main parts, classification and regression. When it comes to classification, a computer program is trained on a designated dataset. Through this training process, the program organizes the data into distinct class labels. The value of this algorithm lies in its ability to predict discrete values, such as differentiating between males and females, determining whether a

statement is true or false, or recognizing if an item is spam or not. In contrast, the goal of the regression algorithm is to locate a mapping function that connects input variables (x) to a continuous output variable (y). The use of these algorithms involves forecasting continuous values, such as predicting salaries, prices, ages, marks, and similar variables.

The primary objective of the ML - supervised type is to perform classification or prediction. A predefined set of examples is used by these methods to categorize and predict class labels. Classification samples can either be assigned to a specific class or cannot be assigned to a specific class. Partial membership in a class is not considered. The accuracy of all classification and prediction models achieved is always affected by the presence of missing values. There are two classification types: binary and multiclass. Binary

classification is the process of sorting data into two categories. For example you might be predicting “yes” or “no”, spam, or even no regression at all (just saying something fails one of your tests).. In most cases, these two groups are represented as 0 and 1. On the other hand, multiclass classification deals with three or more predictable classes, such as identifying different cancer stages, where classes are denoted as 0, 1, 2, and so forth.

A technique to solve the problem is supervised learning as illustrated in Figure 7 [14], and the way of working the input data for this purpose is shown in Figure 8. After that, the procedure includes: Such approach usually requires some steps. First of all, the kind of training examples is one of the most important sources to be determined when we

seek for a solution to a problem. Second, a training dataset is established by foremen or real measurements. The dataset should be representative of real-world scenarios such as the location in which the model will be operating. And the input features must be selected carefully (i.e., they should carry sufficient information to make accurate prediction following Eq. Eventually, the proper training algorithm is chosen to train the model. The assembled training set is then used with the learning algorithm once design has concluded. At this level, some supervised learning techniques may require human intervention to fix the values of certain control parameters, in particular when it comes to prediction task [19].

Steps to solve a problem by the supervised learning

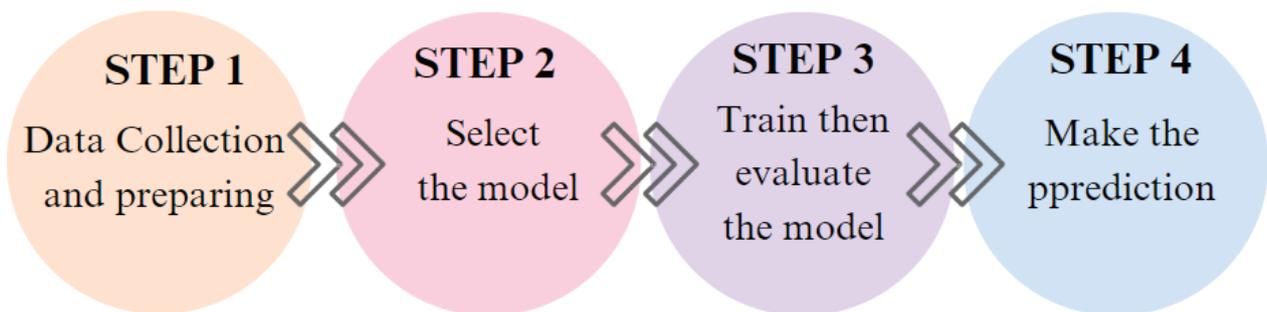


Figure 7. Followed steps in supervised learning.

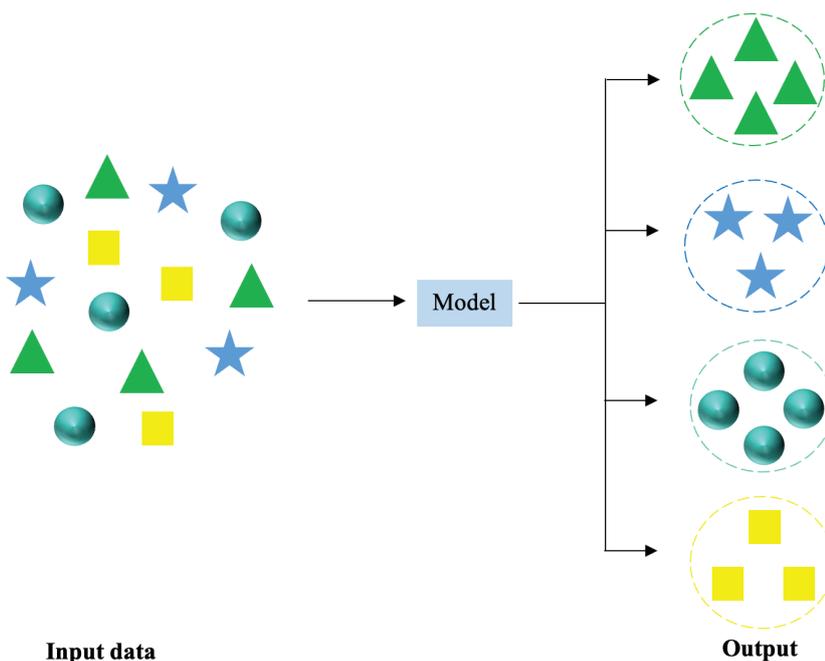


Figure 8. Principle of supervised learning.

Unsupervised Learning

In the second type, unsupervised learning, the algorithm learns from an unlabeled dataset and endeavors to comprehend the data by autonomously extracting features, identifying co-occurrences, and revealing underlying patterns [20].

Unsupervised machine learning serves the purpose of discovering concealed patterns in data without predefined labels. Various effective applications have employed this approach, but their evaluation can be challenging. This difficulty arises from a deficiency in training related to unsupervised machine learning, leading to a lack of clear measures such as error or reward indicators for assessing potential solutions. The absence of a reward signal is a notable distinction between supervised and unsupervised machine learning. In statistical applications, unsupervised learning finds utility in approximating data density.

Neural network model (NN) [21], self-organizing map (SOM) [22], and adaptive resonance theory (ART) [23] are unsupervised learning. Unsupervised learning consists of two steps: data transformation and clustering. Data Transformation During this step, the dataset is modified to represent information in a different and easier-to-understand format: for humans/key stakeholders and machine algorithms. Clustering methods are used to categorize data into clusters of similar items. One of the most basic and straightforward algorithms is K-means clustering which groups similar set of data. It operates in two steps: during the assignment step, datapoints are assigned to their closest cluster center; while in the update step the cluster centers are updated as the mean of all points belonging to that cluster.

One of the main problems with unsupervised learning is knowing how well it works. In supervised learning, outcomes can be checked against identified labels; in unsupervised learning there are no right answers — and it's harder to evaluate accuracy. For this reason, it's often applied for

exploration, such as finding patterns in data and preparing the data for supervised algorithms. . In fact, trying out new ways of representing data with unsupervised methods can sometimes improve the performance of supervised models.

To figure out the difference between the classification, regression, and clustering, Figure 9 shows a representation for them and how they can be applied in the data analysis. Most of the ML models can apply both types of data, the labelled and the unlabeled, in some certain conditions. However, labelled data are employed in supervised learning [14].

Reinforcement

The third approach, reinforcement learning (RL), is a branch of machine learning that deals with agents which are able to take decisions in an environment aiming to maximize rewards across time. The environment is the stage on which the agent learns and acts. The environment reacts to the actions of the agent by either providing rewards or transitioning to another state. In the reinforcement learning approach, the emphasis is not on instructing the agent on how to perform a specific task but on providing incentives, either positive or negative, based on the agent's behavior [24]. In this type, the model acquires behavior in an environment by taking actions and assessing the resulting reactions. In RL, the objective is to select actions that optimize positive outcomes in specific situations. The reinforcement model determines which actions to undertake for a given task, emphasizing the importance of learning from experience.

Used Algorithms

In this paper, we examine machine learning (ML) algorithms in three primary categories: reinforcement learning, supervised learning, and unsupervised learning. Support vector machines (SVM), decision trees, and neural networks are typical examples of supervised learning models that use

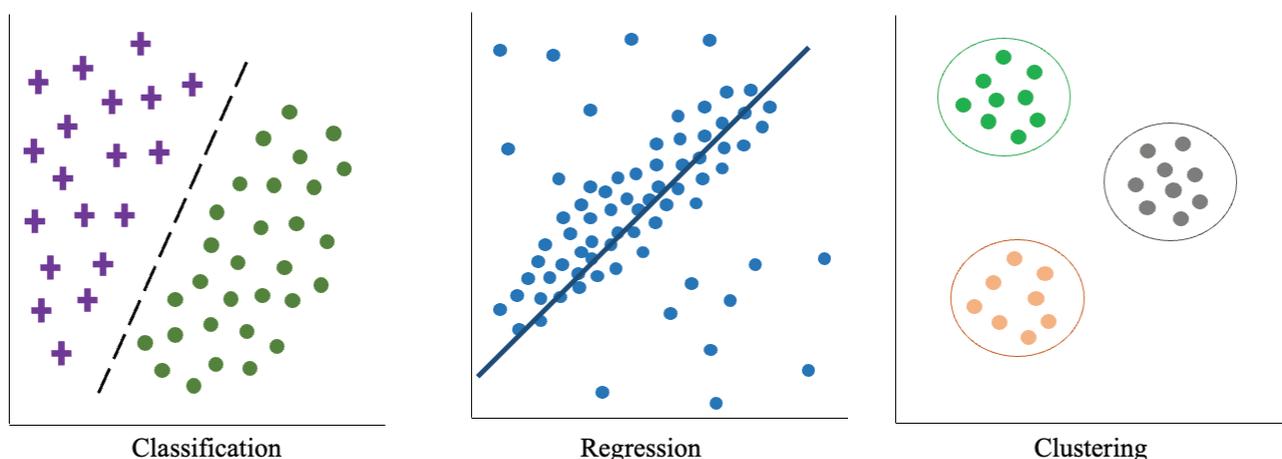


Figure 9. Representation of classification, regression, and clustering.

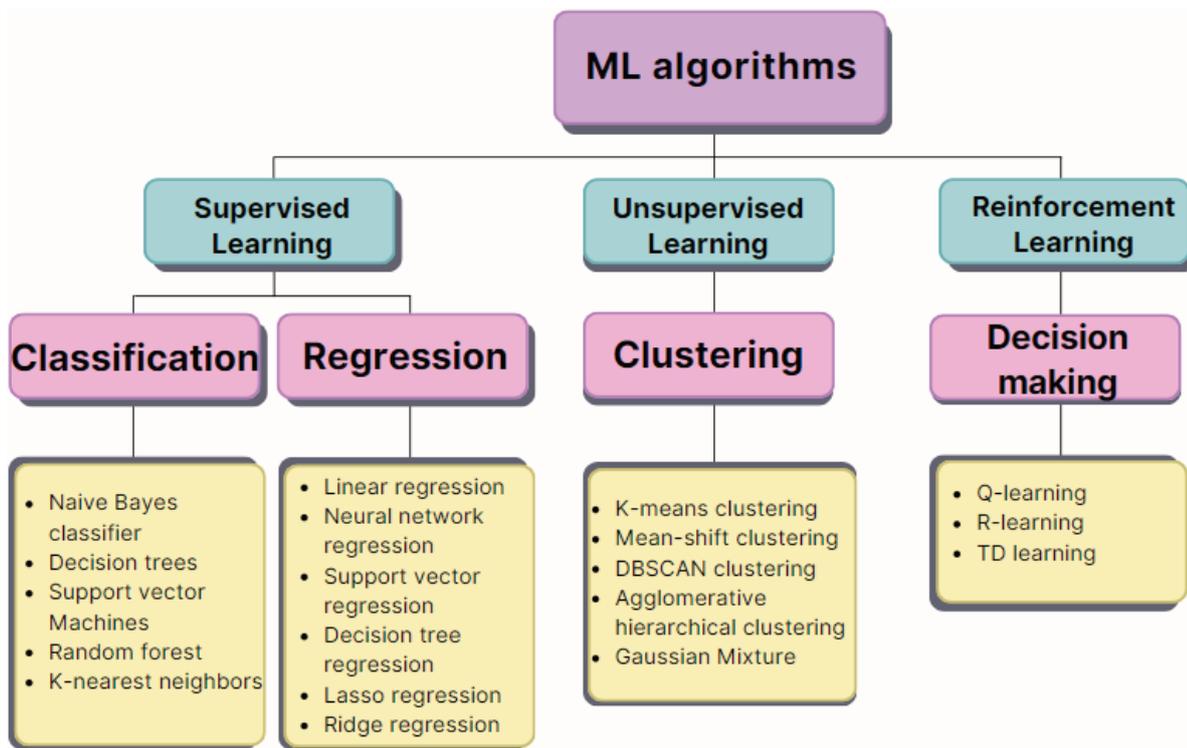


Figure 10. List of used algorithms used in ML.

labeled data to predict results for new inputs. Unsupervised learning dives into unlabeled data, looking for patterns or hidden structures. Think of methods like K-means clustering, Principal Component Analysis (PCA), or gaussian mixture models (GMM)—they all help make sense of data that doesn't come with instructions. Reinforcement learning takes a different approach. Here, the goal is to train agents to make smart decisions in unpredictable settings by using rewards and penalties. Popular algorithms in this area include Q-learning, deep Q networks (DQN), and Policy Gradient Methods. This section gives a quick look at the

machine learning algorithms used in this research. Figure 10 shows which algorithms belong to each category [15,25].

Decision Tree

The decision tree algorithm provides a visual guide for navigating a series of choices or decisions that are guided by specific conditions. As a subtype of the classification tree, it organizes instances into various categories based on their property values. Each node within the decision tree embodies a unique characteristic of an instance essential for classification [26]. Figure 11 shows the schematic representation of the decision tree algorithm [27].

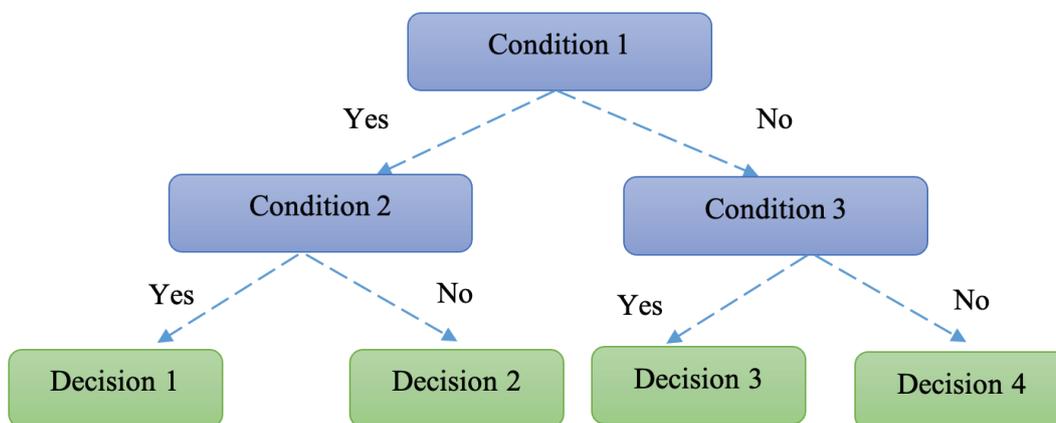


Figure 11. Decision tree algorithm principle.

Logistic Regression

Logistic regression is a statistical technique employed for prediction and classification. It is particularly effective for forecasting categorical results and can operate with both categorical and continuous input variables. The primary objective is to assess the likelihood of an event happening based on the specified independent variables. Since the output represents a probability, the dependent variable always falls between 0 and 1. This logistic regression model is formally expressed through Equation (1) [28] and Figure 12 clarifies the representation of this algorithm [29].

$$\text{Log} \left(\frac{p}{1-p} \right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \beta_{12} X_1 X_2 + \dots + \beta_{n-1,n} X_{n-1} X_n \quad (1)$$

Where p is the probability which is associated with an event occurrence, β_0 is the coefficient of the intercept term,

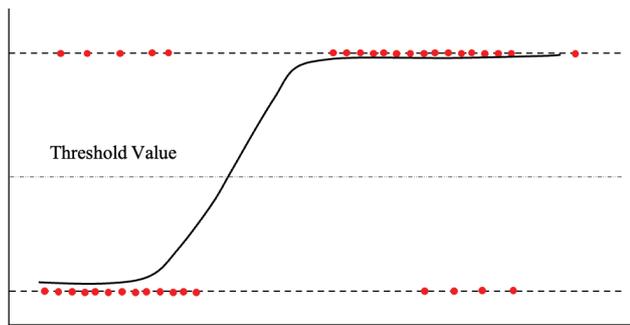


Figure 12. Logistic regression algorithm representation.

and β_1 to β_n are the coefficients of the independent variables (X_1 to X_n).

Support Vector Classifier (SVC)

Support Vector Classification (SVC) is a significant supervised machine learning technique employed to examine input data and recognize patterns for classification and regression activities. It is commonly utilized in fields like digit recognition, handwriting assessment, facial detection, cancer diagnosis, and forecasting time series [30].

Vapnik and Cortes invented the Support Vector Machine (SVM) algorithm, a highly successful machine learning technique recognized for its prowess in data analysis and pattern recognition. It is a crucial tool for binary and

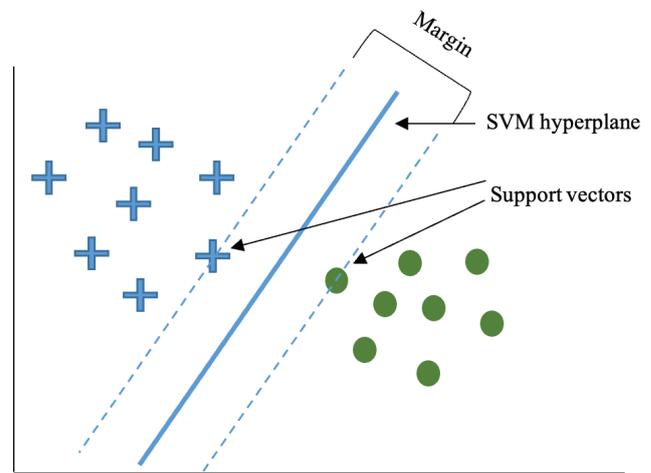


Figure 13. representation for SVC algorithm.

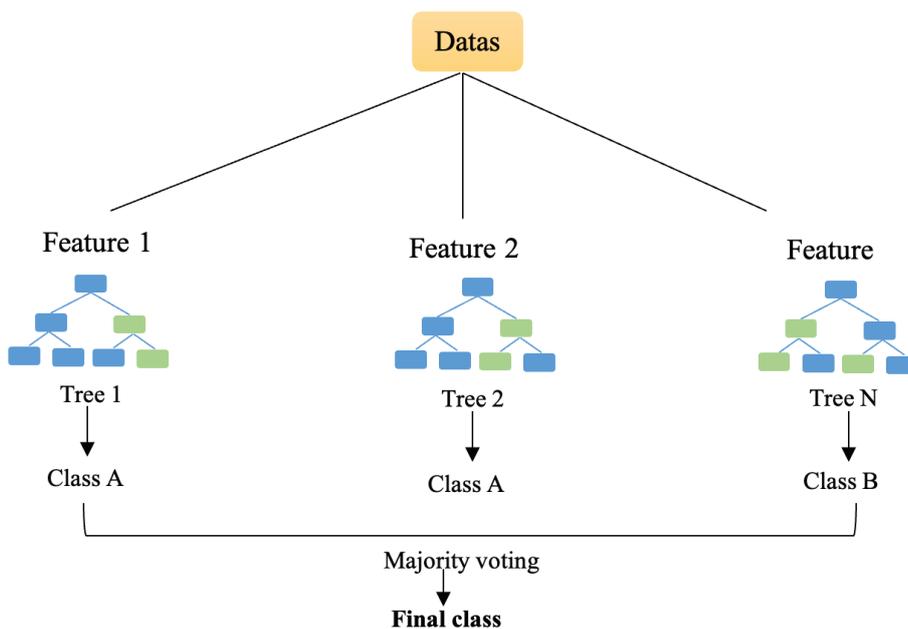


Figure 14. Representation for random forest tree algorithm.

multi-class classification because of its capacity for global optimization and resilience against overfitting. SVM's versatility has been demonstrated by its successful applications in fields like gene-function prediction, text classification, handwriting recognition, and remote sensing. Although it works most effectively with smaller datasets, outliers and the selection of kernel functions can affect how effective it is. Moreover, the efficacy of SVM hinges significantly upon judicious selection and fine-tuning of kernel functions [31]. Figure 13 shows the representation of this algorithm.

Random Forest Classifier

The risk of overfitting that frequently arises with single decision trees is lessened by the Random Forest algorithm. It is an ensemble method, meaning it trains multiple decision trees at the same time. Each tree makes its own prediction, and the final result is determined by combining these predictions—using averaging for regression tasks or majority voting for classification tasks [28]. Refer to Figure 14 for a graphical depiction of this algorithm.

Deep Learning

The notion of deep learning (DL) has a longstanding history, but recent years have witnessed its transformation due to the accessibility of extensive datasets and advancements in computing capabilities. Deep Learning (DL) is a rapidly growing field that has become widely popular in recent years [32]. This approach employs algorithms to complete the data-driven learning process for better predictions or decisions. Neural networks are one of the most important tools for deep learning, which makes possible to learn from a massive amount of data [33-41]. The emergence of deep learning has seriously brought us into a new era of research and innovation; it has made significant breakthroughs in various fields e.g., healthcare, finance, transportation, etc [32].

While ML and DL are often used interchangeably, they are distinct sides of artificial intelligence. ML involves programming computers to learn from data without explicitly telling them what to do. On the other hand, DL is a kind of machine learning, which makes use of neural networks to mimic human brain structure and functionality. They are extremely good at learning from unstructured data and have been incredibly successful in solving difficult problems such as image recognition, and even speech recognition. [42-48].

Based on the previous sections, and based on [49-67] a comparative Table 3 for AI, ML, and DL is shown for better understanding.

Applications of the Aforementioned Techniques in Engineering

As stated, this research concentrated on showing the applications of AI, ML, and DL in engineering fields. Table 3 illustrates how these techniques are applied in 14 fields of engineering science.

Statistical Analysis

After closely examining the literature, it was found that AI, ML and DL techniques give satisfactory results in many fields of Engineering. Figure 15 visualizes the proportions for all of these techniques based on the aggregated studies described in the literature. The presented percentages give an inclusive insight into what is the actual practice of AI, ML and DL in the case of JEA. This figure is a useful summary, capturing the combined effect and effectiveness in studies that are comprising these advanced technologies.

ML stands out as the most influential technique in engineering applications when juxtaposed with its counterparts. This prominence is justifiably attributed to the relative ease with which ML algorithms can be implemented. The practical benefit of ML is that it can achieve performance at a similar level to that obtained with DL without the requirement in

Table 2. Advantages and disadvantages of AI, ML, and DL

Technique	Advantages	Disadvantages
AI	AI includes a wide range of methods, such as machine learning and deep learning, to mimic human intelligence. It can handle complex decision making and has applications in many disciplines.	Developing AI systems can be computationally intensive and require specialized expertise. They can also be rigid, unable to handle novel situations without plenty of reprogramming.
ML	ML algorithms learn from patterns of data in order to make predictions and perform tasks automatically. These are used in a wide variety of businesses to help make processes more efficient and inform better decisions.	ML models are dependent upon labelled data in the training phase and can be very complicated.
DL	DL has proven particularly adept at processing large, unstructured data like images and text. It has the ability to learn useful features automatically, outperforms in tasks such as image classification and natural language processing.	Deep learning models tend to be computationally expensive to train; also, in the case when data is scarce, it's easy for a model to overfit. Moreover, these models are for the most part "black boxes," so it is challenging to interpret why they make decisions.

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields

Automobile Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[68]	ML	---	In this study, the authors applied a combination method between ML and analytical methods to improve the vehicle routing problems (VRP).	The outcomes showed that the VRP can be enhanced by ML models, and the corresponding performance of the vehicle could be improved.	The background, problem statement, the research objective, and the methodology were introduced in a very good way assuming that the reader has a brief knowledge of this field.	2023
[69]	DL	Matlab	In this study, the authors developed a novel model, an improved hybrid ANFIS, to design a practical, accurate, and simple Lithium-Ion battery state of charge estimator.	The outcomes showed that the built four models achieved a better accuracy of 0.5% in comparison with the 2% stated in the previous studies.	The study was, totally, conducted theoretically. Future research may apply and test the adopted methodology practically.	2023
[70]	ML	GT-Suite	In this study, the authors developed a parametric ML model with the aid of GT-Suite software. The parameters included in the study are energy consumption, distance traveled, vehicle speed, state of charge of battery, and motor power.	The proposed method showed a good performance with an accuracy of 89% in being able to predict the state of charge of the battery, and this can help automobile engineers to design scalable and more efficient electrical vehicles.	In general, the analyzed different cycles should include the worst scenario. For instance, the distances traveled scenarios in the study varied between 4.1 km and 20.1 km. it would be better if the study investigated longer distances.	2023
[71]	AI and ML	Matlab	This study proposed a method to predict the required time for EV charging based on collected data from 500 EVs. The proposed method depended on using the ML algorithms and the AI was also adopted to optimize the parameters of ML.	The outcomes showed that the best model was GWO-based ML as it achieved better results compared with the rest ones.	this study did not consider the challenges in charging that are met.	2022
[72]	ML	----	In this study, the authors investigated the charging system of EV in a smart grid by using several ML algorithms to achieve the goal of reducing load fluctuation, power loss, and expenses. Then, the proposed algorithms were evaluated and compared.	The outcomes showed that Long Short-Term Memory (LSTM), could be employed to provide EV control in particular circumstances in addition to keeping the billing costs minimal.	The proposed method has several limitations, which are already included in the paper.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Agricultural Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[73]	ML	---	In this study, the authors analyzed the existing ML models and applications in agriculture engineering starting from the process till the outcomes. Each application was discussed with its advantages and its corresponding weaknesses.	The key outcomes from this study showed that the farm management should be evolved with the reality by linking the related data of it with sensors to provide better suggestions that can enhance the final products from the agriculture	The paper suggested to apply real-time on new applications as it is the gap in this research field.	2020
[74]	ML	WEKA	In this study, the authors designed and applied an ML workbench, WEKA, that admits rapid experimentation on a given dataset by using several ML schemes.	The processing of data from ARFF format to its final representation as a set of rules or a decision tree was facilitated by the WEKA workbench. A variety of state-of-the-art, robust, and efficient ML schemes were provided for experimentation, and a concentration on simplifying access to standard schemes for performance evaluation and comparison was maintained.	The study linked how the animal affect the agriculture, which is a good addition.	2023
[75]	AI and ML	---	The study investigated and showed the applications of ML and AI in agriculture engineering along with some other sectors. The methodology of this study can be simply introduced by discussing several techniques and algorithms of ML and AI.	At the end of the study, it was stated that AI, ML, and DL can be applied to enhance the production of crops and design a reliable product quality monitoring system.	This paper investigated the applications of ML and AI in several aspects besides the agriculture such as the health care, disease prediction, and water waste controlling in a readable well-organized way	2023
[76]	AI	---	This study analyzed several relevant articles on AI applications in the agriculture sector. For instance, some applications such as detecting the smallest insects in the farms by AI, how to provide proper guidance on water management by AI, how to Increase agricultural yield and productivity, and how to Increase farmer profitability were investigated in this paper.	The outcomes from this study showed that AI technologies, which use data like precipitation, temperature, solar radiation, and wind speed in combined with some ML algorithms and images taken by drones or any other technologies can effectively predict crop sustainability and, accordingly, ease the process for the farmers to evaluate farms for the presence of diseases or pests and inadequate plant nutrition.	A deep discussion was provided for each application.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Agricultural Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[77]	DL	Matlab	This study employed some data related to the humidity and temperature in some algorithms such as KNN to find a model that could be used for climate prediction based on a previous observed data.	The outcomes from this study showed that the yield production depends mainly on the soil nutrients. Moreover, it was concluded that Remote Sensing area and data mining are used to provide some algorithms and prognosis strategies for soil attribute classification.	The resolutions of the figures and tables are not well enough.	2023
Aerospace Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[78]	AI	---	This study proposed a novel artificial bee colony algorithm that was implemented as part of a hybrid method to solve flexible job-shop scheduling problems by extracting the key manufacturing information through an aerospace workshop.	The outcomes showed that the proposed method was effective	In this field, the cost is one of the key points that should be considered. However, this paper did not investigate how the cost will be affected.	2023
[79]	ML	python	The authors developed a new ML algorithm to predict the fatigue damage of the material by preprocessing the received signals	The outcomes showed that the proposed algorithm gave good performance and accuracy.	This paper handled the complexity of the nonlinear equations effectively.	2023
[80]	ML and DL	Teachable Machine and ANSYS	The authors proposed a DL framework to identify faulty components due to malfunctioning in the aerospace industry. This could help the engineers in focusing on choosing the most proper material in the manufacturing stages. Moreover, the study employed the CNN approach to recognize the intermediate abnormal situations.	The outcomes showed the importance of the proposed method especially in managing the operation cost along with reducing the reducing rework-induced delays. The statistical outcomes showed a 34.32% and 52.88% reduction in total cost and time delays respectively.	The cost was considered in this paper as a key objective, which is a good contribution.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Aerospace Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[81]	ML	Python	This paper proposed a model to predict fatal occurrences in aviation events by applying some data on ML models. This is very helpful for the engineers as the safety standards are very rigorous,	It was found that random forest was the most accurate model as it achieved an accuracy of 90%.	a large number of the limitations was considered and discussed in this research, which is a good contribution.	2023
[82]	ML	---	This paper compared between the ML models used in aircraft maintenance systems.	The outcomes showed that to enhance the aircraft maintenance system, several should be considered during the evaluation and comparison between the models such as the cost as well the time. Some model showed their superiority from the cost aspect while others showed their superiority from the time aspect.	No clear objective function was provided in this study.	2023
Architectural Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[83]	ML	MATLAB	This study proposes a real-time seismic damage simulation method for urban building portfolios by integrating a multiple degree-of-freedom (MDOF) shear model, flexural-shear model, and machine learning. In this research, formulas predicting periods of different structures are developed, and surrogate models for minimizing MDOF model is constructed.	Validated on two city-scale cases, the proposed method can predict maximum inter-story drift and floor acceleration accurately with MDOF models at a computational cost much lower than that of time-history analysis. The machine-learning-based surrogate model enhances efficiency with the maximum acceleration ratio of ~76,600 compared to conventional approaches.	additional testing in a variety of urban settings would reinforce its reliability. Generally, the method appears to be an effective and accurate approach for seismic risk assessment ageistic urban centers.	2023
[84]	AI	---	The MDOF shear and flexural-shear models are coupled machine-learning-based method developed for real-time seismic fragility simulation of urban building portfolios on multiple spatial levels. Type-formulas of periods for various structures are proposed, and surrogate models to achieve the optimum multi-degree-of-freedom (MDOF) views are made.	The city-scale cases show the potential of the method for real-time seismic damage simulation at an acceptable accuracy level. And the model developed does not require significant retraining for different urban building portfolios, indicating its potential for broad use.	The research highlights the efficiency and effectiveness of the AI-based approach in improving seismic risk management for an urban building stock.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Architectural Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[85]	AI	---	This paper explores how diffusion-based AI art platforms, such as Midjourney and DALL-E 2, Stable Diffusion (which is our contribution), can be applied to common use cases in architectural design. This paper analyzes the features of these platforms and their adequacy to the demands for task support in civil engineering architecture from AI art platforms.	The paper highlights the strong AI potential in architecture, notably for ideation, collages, building and style variants. Acknowledging the existing limitations due to certain difficult prompts, the authors expect that these will be alleviated with new diffusion models finetuned on BIM reasons about datasets.	Shortcomings in existing AI art tools for architecture include difficulties with nuanced prompts and reliance on certain design fads. Fields of developments comprise better understandabilities semantics and integration into architectural work. Continued study on the development of structural dynamics and construction technology will bring about a new age of AI-informed styles in architecture.	2023
[86]	AI	---	The study took a holistic approach to evaluate the adoption of AI, IoT and Big data technologies in the Architecture, Engineering and Construction (AEC) sector. The research included a breakdown of different AI models and methodologies underpinning Construction 4.0 and 5.0, as well as societal changes in Society 5.0.	IoT devices built into construction equipment and structures enabled the gathering of real-time data that has been at the heart of AI-driven predictive maintenance and other process optimizations.	The study identified a number of problems – technical, such as data integration, security, and scalability; ethical, related to workforce displacement and biases in AI algorithms.	2023
Biomedical Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[87]	ML	Matlab	The proposed algorithm used KNN on segmenting of the medical images and feature extraction in image only followed by classification based on NN to analyze the data.	It was found that KNN gave a very good accuracy in images classification, which is a very important phase in medical imaging.	A comparative analysis based on MSE, PSNR, and SSIM were applied for only the proposed algorithm.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Biomedical Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[88]	ML	Matlab	In this study heart disease was predicted by applying the ML techniques. The proposed method was created after a comparison phase between many ML algorithms by Matlab coding, since the effective ML strategy, in general, requires precise identification of the problem.	The results showed that the proposed method can be used to accurately diagnose the stage of a disease and its treatment using this approach.	Only three types of disease were included along with their symptoms, and prevention.	2022
[89]	DL	---	This study proposed a new IoT and DL enabled healthcare disease diagnosis model by using biomedical signals. The proposed model used a BiLSTM feature extraction to extract the feature to discover CVDs existence.	The experiment results proved the supremacy of the IoTDL-HDD model with an accuracy of 93.452%.	This paper has a strong mathematical foundation which supported the outcomes.	2021
[90]	ML	---	In this study, the authors analyzed the most recent studies that investigated the applications of ML techniques in medical data processing. 27 articles were discussed and the following aspects were included: deployed methods, proposed framework, the advantages and the disadvantages.	The analyses showed that 43% of the studies used the IoT. Moreover, the most used DL algorithm was the CNN.	The paper has a well-organized structure	2023
[91]	ML and DL	---	This study presented systematic studies related to applications of ML and DL in the detection along with classification of multiple diseases. 40 studies were collected from journals and conferences from 2014 to 2022.	The outcomes showed that the ML was used more than DL in medical diagnosis	This paper used some studies from 2014, which could be replaced with the most recent ones.	2022

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Civil Engineering						
Ref #	Used technique (AI/ML/DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[92]	ML	---	This study employs six machine learning techniques to predict the compressive strength of self-compacting concrete. These are as such credible AI algorithms as ANN, ANFIS, ELM etc., combined with natural intelligence techniques IPBased MOFA and WHO.	The results validate that all the six machine learning models demonstrate high level of accuracy in predicting the compressive strength of SCC. ELM tuned with MOFA outperforms other methods in differentologic evaluation metrics and this indicates its superiorities. Visual results confirm the models are effective, so promising benefits such as quality control, cost saving and safety improvement can be expected in practical constructions.	Although the paper effectively illustrates the capabilities of machine learning methods for predicting compressive strength in self-compacting concrete, such could be strengthened by elaborating further on obstacles or complications faced when applying these techniques outside an experimental context.	2021
[93]	ML	---	The proposed study uses Mechanics-Informed Surrogate Models (MISM) for structural analysis, which embeds empirical data and mechanics prior knowledge, and re-presents rules or information about truss structures based upon graph neural networks (GNNs). The proposed method is applied to bi-dimensional and tri-dimensional truss structures, and shows a better prediction capability than standard surrogates, with a strong emphasis on the mechanics integration of this improved model interpretability.	The study demonstrates that the proposed Mechanics-Informed Surrogate Models (MISM), which are based on GNNs, can provide better fitting of deformations in structural systems than the typical surrogate models. Although dedicated hardware is needed due to the more lengthy training phase, we hope that such efforts at computational accuracy will lead to improved predictions in structural engineering applications and in extrapolating GNNs to predict nonlinear behavior of structures being studied.	the work does concede to the requirements of specialized hardware and training time, which may imply a trade off between computational complexity and enhanced accuracy worth considering in practice.	2024
[94]	ML	Python and MATLAB	This research combines advanced image processing and machine learning methods, which is more specifically the computer vision strategies, to predict structural behavior and quantify damage in RC exterior B–C joints. Using Python for data analysis and MATLAB for image segmentation, the study processes 500 images from 141 shear-critical specimens, employing thresholding and edge detection to extract crack patterns' textural and geometric attributes.	Regression analysis of the present data demonstrates reasonable predictive quality and statistically strong relationships between identified crack patterns and structural damage in exterior BJs&CEs. Its application has been shown to be effective in the estimation of damage states from surface crack patterns under various experimental condition and layout. The successful establishment of the relationship between surface observations and quantification on damage level with stiffness, loading and displacement proposed implies that image-based damage recognition for visual inspections of exterior beam-column joints in structural condition assessment may potentially be feasible.	The standalone approach based on Python and MATLAB for data analysis and image segmentation, shows strong predictive performances under different experimental conditions.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Civil Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[95]	ML	MATLAB	This study addresses the deterioration of civil structures in Japan by proposing an autoencoder-based damage detection approach using machine learning. Utilizing a Multi-Degree-Of-Freedom (MDOF) system model subjected to seismic responses, the study explores the correlation between the magnitude of reconstruction error and the degree of structural damage. The autoencoder, a three-layer neural network trained on normal data, is employed for unsupervised learning to distinguish between normal and abnormal structural responses.	Five seismic ground motions are prepared, and the autoencoder is trained using linear displacement responses from adjusted motions. The study demonstrates a relationship between the reconstruction error magnitude and the degree of structural damage, indicating the potential of the proposed method for detecting damage in civil structures.	The correlation established between reconstruction error magnitude and the degree of damage demonstrates the method's potential for accurate and efficient damage detection.	2023
Computer Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[96]	ML	Python	At the beginning, the authors explained how a physical concept of ML can be translated into practical work in engineering. They explored the ability of hybrid quantum-classical NN to enhance the accuracy of a model and reduce computational resources.	It was found that ML can be employed to minimize or even eliminate the errors on noisy intermediate-scale quantum devices.	No sufficient discussion was provided regarding the applied NN.	2023
[97]	AI	---	The author proposed a method to investigate and identify how the implementation of knowledge management principles in software engineering could enhance the future transformation of software-related jobs. Some quantitative data were analyzed to evaluate the AI role.	It was found that AI along with knowledge management can be used to improve software engineering activities such as error tracking, version control, monitoring software documentation, and onboarding new members.	This paper analyzed the already existing data, but no prediction step was conducted regarding the future situation.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Computer Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[98]	DL	Python	The authors conducted an empirical study of how the DL can be used for sentiment detection tools for software engineering.	The outcomes showed that DL tool could achieve the target effectively.	It needs more discussion and clarification regarding the error categories of DL	2023
[99]	ML and DL	Python	This article proposed a method that combines several algorithms and made the evaluation as well the validation based on several criteria such as the precision, F1 score and the recall.	The outcomes showed that the phishing attack could be detected by software engineering by the ML algorithms such as NB and SVM in addition to DL algorithm such as LSTM.	The methodology and the result sections were discussed in detail, which is a good contribution.	2023
Chemical Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[100]	ML	---	The study constructed a database of Ionic Liquid encapsulated Metal-Organic Framework (IL@MOF) composites. Molecular simulation was employed to identify the top-performing composites and elucidate the gas separation mechanism.	The utilization of ML techniques revealed essential factors influencing CO ₂ /N ₂ selectivity and CO ₂ permeability, showcasing substantial improvements in CO ₂ permeability and selectivity, surpassing known performance boundaries.	The full development of the database for this study when considering molecular simulation and machine learning (ML) methods has provided a solid foundation to find out promising IL@MOF composites towards technological applications.	2022
[101]	ML	---	The study adopts a high-throughput computational screening approach to screen 6013 metal-organic frameworks (MOFs) to discover the optimal methanol-MOF pairs for adsorption-driven heat pumps and chillers, establishes structure-performance correlations with six MOF descriptors, and employs four machine learning algorithms for predicting the performance metrics.	The maximum COP and WCOP under the heat pump working condition were 512.86 mg/g and 1.83, respectively; and this study contributes a knowledge of proper ranges of the MOF descriptors for improving the adsorption-driven heat pump performance using methanol as a working fluid.	This work is an important contribution to the field for characterizing effective pairs of working fluid and adsorbent to improve heat pump performance.	2020

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Chemical Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[102]	ML	---	The study computed and simulated metal–organic framework membranes MOFs from the CoRE-MOF database for Kr/Xe separation under atmospheric pressure. Important structural features were identified by univariate analysis, and classification/regression models are developed employing 5 machine learning algorithms.	Univariate analysis pointed to the critical role that of pore limiting diameter plays in separation and through comparison across a series of 3D MOF membranes, permeability and permselectivity were outlined to highlight desirable ranges as key guidelines for improved membrane designs.	The study demonstrates a novel methodology for evaluating numerous MOF membranes for Kr/Xe separation, offering a promising direction for future membrane design and improvement.	2023
[103]	ML	---	The use of machine learning models, such as the gradient boosting decision tree (GBDT), were used to predict how the polymer functional groups influenced the conductivities of Zn ²⁺ and protons.	The studies presented demonstrated the effectiveness of machine-learning-based predictions on directing polymer membrane design and synthesis for enhanced battery performance metrics for the Zn/MnO ₂ flow battery system.	Incorporation of the ML models reveals a strong advantage in designing specialized membranes for batteries compared to conventional materials synthesis.	2023
[104]	ML	---	The work combined high-throughput computational screening (HTCS) and ML to predict hydrogen separation performance among computation-ready metal–organic framework membranes (CoRE-MOFMs) for different gas pairs. Eight supervised ML models were used to predict the separation performance.	The selected MOFMs for H ₂ separation in this work were high-performing membranes, showing potential industrial use. Combining HTCS and ML expedites CoRE-MOFMs validation, presenting the possibility of a high-throughput discovery platform for gas separations.	---	2022
Electrical Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[105]	ML	LSTM	This study aimed to show how the data since can be applied in electrical engineering field. The role and the application of the data science (DS) and ML on edge, fog, and cloud levels of vertical industrial IoT concepts of power plants were presented by investigating the requirements and expectations of IoT. Moreover, the limitations in signal conversion were also considered described.	The study showed that the existing traditional management and control (M&C) concepts of smart power plants should be improved. In addition, this paper pointed out the advantages of the vertical IoT concept and described all IoT levels (edge, fog, and cloud).	The study involved a fuzzy logic control system but no sufficient description were provided.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Electrical Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[106]	AI and ML	---	This study proposed a Recurrent Neural Network (RNN) forecasting model incorporating a Dynamic Fitness AI-Biruni Earth Radius (DFBER) algorithm in order to forecast and predict wind power data patterns. Several popular models were used to test the performance of the model such as Grey Wolf Optimizer (GWO), Whale Optimization Algorithm (WOA), Particle Swarm Optimization (PSO), Fire Hawk Optimizer (FHO), and Jaya Algorithm (JAYA).	According to the evaluation metrics, RMSE, MAE, and R2, the proposed RNN-DFBER-based model outperforms the other models considered. This suggests that the RNN model, combined with the DFBER algorithm, predicts wind power data patterns more effectively than the alternative models.	This study did not include anything about data collection and preprocessing phases.	2023
[107]	DL	Python, Linux hping3, and Linux bwm-ng	In this study, a novel approach was proposed for online cyber attack situational awareness that improves the reliability of the power grid. The proposed approach employed a combination of DL convolutional network for time series classification-based anomaly detection and DL model of Graph Convolutional Long Short-Term Memory	The outcomes showed that the proposed method could identify active attack locations (control center, within substations, and wide area network) with an accuracy percentage exceeding 96%.	This study combined the introduction section with the related works. In general, it is better to separate these two sections to give a good knowledge for the reader then introducing the previous related work in the following section.	2023
[108]	DL	---	This study applied the DL in power quality enhancement, it showed that most of the applications of DL depend on supervised learning and unrealistic synthetic data with no proper labeling.	It was found that it is not easy to apply the DL in the power quality and the experts need to enrich their knowledge even with automatic feature extraction by DL approaches. Further, the research gaps in this field were introduced in this study which are related to the semi-supervised learning applications, explainable DL and hybrid approaches combining DL with expert systems.	This study suffered from a lack of novelty. Moreover, it mentioned the research gaps in this field but it did not handle it.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Electrical Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[109]	ML and DL	---	This study aimed to forecast renewable energy (RE) generation by using ML and DL techniques by reviewing the different methods and model that were used for RE prediction. The limitations, advantages, and the strengths of each model were discussed too.	It was found that the hybrid models, which consist of traditional time-series analysis along with ML and DL techniques are used for RE forecasting purposes effectively. On the other hand, the design of a hybrid model is not a trivial task.	The study showed the gaps existing in the research field without solving them.	2023
[110]	AI and ML	Matlab	This paper aimed to estimate the extractable power from wind in several sites in Jordan by applying the AI techniques (GA, BFOA, SA, and ANFIS) based on Weibull and Normal PDFs. Moreover, a Matlab tool was used to estimate the accuracy of the parameters of the aforementioned PDFs.	The study showed the superiority of SA compared with the rest algorithms. Moreover, Normal PDF showed its good performance in estimating the extractable energy from wind.	In this study, the authors showed their contribution in employing several techniques in wind energy estimating.	2022
Electronic Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[111]	ML	Matlab	The authors demonstrated how effective is the application of the ML in the solder joint geometry of electronic components by showing how the lifetime of these components will be enhanced.	The outcomes showed that there is an optimal size for the solder joint that will maximize the lifetime of the electronic component.	No related works were included in this study.	2021
[112]	ML	Pymatgen (Python Materials Genomics)	The authors proposed a method to predict the band gap of graphene in heterostructures. They employed an ML learning model on a dataset of 2076 binary compounds, followed by the usage of two main ML models to screen semiconductor components and form heterostructures with graphene.	the outcomes showed that the proposed method has an accuracy rate of 88.3% and the difference between the predicted and the calculated values was ignorable.	No related works were included in this study.	2023

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Environmental Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[113]	AI and DL	---	The study compared a method based on deep neural networks with statistical and traditional machine learning methods to record the temporal patterns in sensor data present in wastewater treatment plants (WWTPs)	This gives the ability to enhance monitoring efficiency, enabling timely responses to faults and optimizing treatment processes while minimizing environmental impact.	The paper deals with an important point pertaining to WWTPs since a fault detection becomes essential to improve the treatment efficiency and the energy consumption.	2020
[114]	AI and ML	---	The authors used neural network to estimate the quantity of waste and machine learning algorithm to optimize the waste collection.	The study proved Efficient waste prediction and reduction models. It achieved a gross amount of waste reduction by 90%, landfill analysis by 40% and transportation by 15%.	The study demonstrates the significant possibility of improving waste management performance and promoting sustainability in human society.	2021
[115]	AI and ML	---	The IFFNN was achieved by connecting a feedforward neural network (FFNN), which is more efficient and better performing the WWTP effluent quality prediction ability of a traditional FFNN.	The model successfully encapsulated intricate nonlinear relationships and predicted the information accurately. These findings indicated significant enhancements in prediction accuracy and suggested potential applicability for immediate regulatory decision-making in WWTP operations.	The existing IFFNN model doesn't include an optimal control system to simultaneously reduce real-time operational expenses in WWTP while meet the effluent criteria.	2022
[116]	AI and ML	---	The study used an electrically-enhanced membrane bioreactor setup to treat medium strength wastewater. An artificial neural networks (ANNs) based ensemble model effectively simulated experimental outcomes, showing strong correlations.	By using such an integrated system of electrochemical treatment and membrane bioreactor, the environmental pollutant concentration of wastewater was greatly reduced. For instance: COD (98%), nh4+-N (99%), PO43--P (97%); and nh4+-Step (92%).	---	2016
[117]	AI	---	The authors developed artificial neural network models to predict treatment plant efficiency using historical data. They evaluated biochemical oxygen demand (BOD) and suspended solids (SS) concentrations.	ANN models able to predict BOD and SS concentrations in effluent from the plant, reaching R2 values from 0.63 to 0.81 for BOD and 0.45 to 0.65 in SS over various data groups, are reported herein.	Highlighting the promising potential of ANNs as a valuable tool for forecasting wastewater treatment plant performance is this study's acknowledgment that accuracy in SS predictions is less (such noise and marking) than for BOD. As a result, ANNs can by no means be discarded Suddenly but rather must occupy a specific part of the technology process field. This suggests improvement in accuracy from future research with better coverage and fewer noisy data sets.	2004

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Environmental Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[118]	ML and DL	Python	By using ML to control precise aeration in WWTPs the study developed its own equivalent system, a variation sliding layer (VSL) that is Based on ML. The VSL was integrated into classic ML, deep learning, and ensemble learning models to enhance aeration control efficiency.	The systems based on VSL and ML significantly improved WWTP aeration control efficiency Predictive accuracy for air demand in WWTO systems was much higher than in traditional mechanistic ones-and showed marked improvements. In the study, it provided an illustration of the future potential for precise air demand prediction and control in AI technology areas such as WWTP, with a view to saving energy reducing consumption.	---	2023
Industrial Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[119]	ML	---	The research employs a knowledge-based intelligent supervisory system for rare quality event detection in manufacturing. An algorithm hybrid elimination of features with l1-regularized logistic regression learning as the learning algorithm and an optimal threshold-increasing technique to support defect detection	The study addresses the zero-defect policy requirement, offering a rare quality event detection strategy. Using l1-regularized logistic regression, the strategy is validated in automotive manufacturing and produces 100% defection rate.By removing irrelevant features and compression settings, the proposed strategy of enhancement see-classification results greatly contributing to promote quality standards in manufacturing.	---	2018
[120]	ML	---	The paper uses the supervised machine learning classification for such an issue as how to predict production batch compliance quality in manufacturing. A study is then implemented to validate the approach, combining the feature engineering and dataset information in classification algorithms of a multiprocessor appliance production line. The high accuracy (0.99) and Cohen's Kappa (0.91) indicate a powerful predictive value of the model for predicting compliance quality.	The machine learning algorithm exhibits an outstanding accuracy (0.99) and reliability (Cohen's Kappa of 0.91) to predict the compliance quality of the unit batches. By highlighting the importance of feature generation and learning for the specific dataset, this method can efficiently prevent defective product batches in advance and significantly reduce cost in recall expenses and logistics.	---	2020

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Mechanical Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[121]	ML	Python	Design of Experiments (DOE) was contrasted to Active Learning (AL) for performing data collection in mechanical engineering to examine the accuracy of ML models, sample efficiency, stability and predictive performance, using three cases generated by AL and DOE techniques.	Low-cost scenarios privileged random sampling, however in low budget was LHS and AL performing better. LHS showed more reliable or stable performance but had an initial point number which ranged dynamically before QBC was most efficient and stable in the bagging methodology whose testing commonly occurred after aggregate sample size compared to LHS especially for learning from high-cost data.	This article gives a detailed contrast of the DOE and AL techniques for the data collection procedure on ML models with respect to engineering application scenarios and actionable guidance about sampling strategies (both algorithms) engineered toward engineers and developers. Nevertheless, its concentration on particular methods such as LHS and QBC could potentially restrict its applicability.	2023
[122]	ML	---	The use of ML methods was applied to machine sensor data in order to assess the health of machining process and machine tool, using both supervised and unsupervised techniques such as PCA, CWT, with custom built and pre-trained CNNs.	PCA was effective at reducing the features while not significantly adversely affecting accuracies, with very high classification accuracies of nearly 100% for most failure modes. The GMM proved to be reliable in classifying failures while custom CNNs were found to achieve equivalent or higher accuracy when compared against pretrained networks, although assessment is based on simulations and may not reflect real-life performance comparisons.	The application of multiple ML techniques in analyzing big data and recognising failure modes is laudable, pointing toward the route of being able to detect faults 'on-the-fly' during production.	2020
[123]	ML	---	The diagnosed gear box faults are obtained by processing the vibration signal using wavelet-based features, which are collected at multiple states of gears. It assesses the efficiency of Morlet wavelet in feature extraction.	It is identified that proximal support vector machines (PSVM) provides better classification than artificial neural network (ANN) for classifying the features extracted from gear box, and thus more accurately recognize gearbox faults.	The comparative analysis of classification techniques offers insights into the efficiency of PSVM over ANN for accurate fault identification, which is a notable strength.	2021
[124]	ML	---	The work is devoted to the recognition of gear and bearing faults of gear units based on a multilayer neuron network (MLP). By means of standard deviation of wavelet packet coefficients, it constructs a feature vector from vibration signals and identifies faults with high precision.	The proposed ANN-based system achieved a good performance and full accuracy in failure diagnosis of gear and fault detection of bearing using a small two hidden layer MLP network.	It does effectively emphasize that preprocessing techniques, such as wavelet transform, are crucial to improve the accuracy of fault detection and thus advocate their application in practice; it thus contributes to the advancement of the domain.	2007

Table 3. Comprehensive review of AI, ML, and DL applications in engineering fields (continued)

Mechanical Engineering (continued)						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[125]	DL	---	In this paper, the normalized sparse autoencoder (NSAE)-based local connection network (LCN) is designed as NSAE-LCN for automatic feature extraction and fault diagnosis of machine vibration signals.	The study demonstrates the capability of NSAE-LCN in learning dissimilar and meaningful features while properly recognizing mechanical health statuses. Comparison with traditional diagnostic technologies shows that NSAE-LCN is superior, and demonstrates its great potential in intelligence diagnosis for machinery.	the handcrafting of parameters in NSAE-LCN could be optimized with more advanced methods to enhance adaptability and performance, which suggests the prospect for future enhancements.	2018
Telecommunication Engineering						
Ref #	Used technique (AI/ ML/ DL)	Used tool	Methodology	Summary of the outcomes	Comments	Year
[126]	ML	Python	In this study, the authors proposed a method for telecommunication fraud detection by a convolutional neural network (CNN). The data used were images that were applied to computer vision techniques such as image augmentation.	The outcomes showed that the proposed method achieved 89.98%F1 - score. Moreover, it was stated that the performance of the model can be improved to 91.09%F1-score.	This study discussed the methodology section stepwise in a perfect way.	2023
[127]	ML	Python and C++	In this work, the authors proposed a distributed congestion control mechanism for generic multi-hop systems. Several data types were considered and applied by ML algorithms, certainly, the CatBoost algorithm.	The proposed system showed a good performance and the objective was achieved.	In this study, the cross validation was set to 20, which gives an accurate model.	2023
[128]	ML	Python	The authors provided an overview of 5G network slicing and applied some ML models, the accuracy of each model, of how effective it is in detecting network slices, was investigated.	The outcomes showed that telecommunication engineers could create optimized network slices to minimize the response time with high throughput for applications.	The gaps in the mentioned related works were not overcome. However, the paper explained the code of applying the ML in this field from scratch.	2023
[129]	DL	Python	In this study, the authors proposed a hybrid quantum DL model that compared between the CNN and the Recurrent Neural Network (RNN).	The outcomes showed that the proposed model achieved an accuracy of 97.16%	The related work section did not cover wide range of recent studies.	2023
[130]	AI	---	The authors proposed a novel method for smart healthcare systems by employing the 5G along with the Industry 4.0 standards. The proposed method used the network simulator N2S.	The outcomes showed that several challenges and constraints are met the 5G methods such as performance tradeoffs.	The outcomes from this research depended on strong well-known mathematical equations in the field instead of using the software.	2023

Percentages of AI, ML, and DL application in Engineering Fields

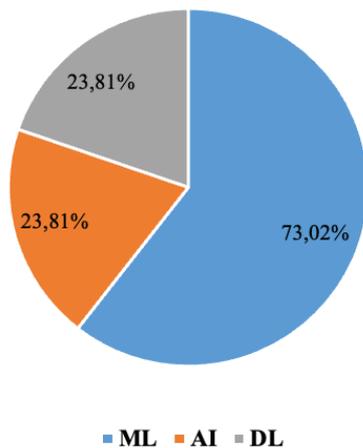


Figure 15. How wide are the AI, ML, and DL in engineering fields?

terms of sophisticated details and large amount computation resources. It's worth noting that the decision for Artificial AI, ML and DL also depends on data availability, task-specific requirements, and computational resources. It is a balance between the former factors, and the later. And finally, it is important to underscore that the percentages presented were derived from a comprehensive analysis of studies documented in Table 3, and it is acknowledged that these figures may vary from one year to the next based on evolving research and technological advancements.

While not limited to both aspects, ML approaches are extensively preferred in most of the research papers for the followings reasons. One, ML provides a range of technique that able to be used, from broad domains and research problem or application. In the second place, these methods have been developed and tested over many years, meaning that researchers now have a mature toolbox to address challenging tasks. It may also have better interpretability than ML algorithms, which is important if we use the model in domains (such as healthcare or law) that requires us to understand why a model makes specific decisions. What's more, compared to DL, sometimes ML models can work well with smaller data sets, and this in turn makes them more applicable in circumstances when the collection of data is restrictive or expensive. Altogether, the trade-off between generality and interpretability as well as the historical development of Machine Learning explains its popularity for researchers working on new applications and practical issues.

There are several exciting directions for future investigation in AI, ML and DL applications in engineering. One important avenue is to improve the interpretability and explainability of AI models – a vital aspect for increasing trust and adoption in engineering applications. Further, the

development of new architectures and algorithms focusing on engineering related problems such as real-time processing and noisy data is crucial. The synergy between AI and upcoming tech such as IoT, edge computing can bring decentralized and energy-efficient engineering solutions. In addition, ethical issues associated with the deployment of AI (e.g., mitigation of bias and privacy preservation) will continue to be prioritized. Lastly, using AI for automatic design optimization and predictive maintenance may transform the way engineering is done, providing large efficiency factors and cost reductions.

CONCLUSION

To conclude, this extensive study has revealed the widespread use of AI, ML, and DL techniques in 14 different engineering disciplines. The study began with a precise definition of AI, ML and DL in order to conduct a comprehensive survey of their diverse applications. A meticulous systematic review of the relevant studies carried-out covering key elements such as the particular technique used (AI, ML or DL), tools or software employed, methodologies adopted and short brief of their results. The yield of these attempts demonstrate that ML is the most leveraged technique, making up about 73% of the engineering research domain. All studies were thoroughly scrutinized with thoughtful commentary, enabling readers to gain fine insights into the various approaches and results in each of the sub-fields. This paper not only provides an overview of AI, ML and DL in the engineering domain but also clarifies the current dominance of ML as the most used model in state-of-the-art research projects. The results assist in developing a holistic picture of the current threshold and contribute precious wisdom to future development directions between AI and engineering fields. It was also discovered that studies using more than one intervention achieved better results.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence was not used in the preparation of the article.

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