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Application of Artificial Intelligence in Architecture, Engineering and Construction: A Literature Review

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Abstract

There is a growing adoption of Artificial Intelligence in many spheres of human endeavours including the Architecture, Engineering and Construction (AEC) sector. However, the AEC sector has been slow in developing and deploying Artificial Intelligence solutions to industry needs. To make matters worse, many industry players are not sufficiently aware of the potentials of AI, and its capacity to transform the way they work. Therefore this paper reviewed some existing literature on Artificial Intelligence in Architecture, Engineering and Construction in order to present to industry stakeholders the current uses and potentials of AI in the industry. The methodology adopted is a review of relevant literature on the subject sourced from Google scholar. The study found that AI technologies are available for use in many aspects of work in the AEC sector including material design, conceptualization and project management. The study concluded that embracing AI and keeping pace with development of AI will enhance the productivity of practitioners in the sector.

Keywords: Building, Design, Digital Twin, Engineering, Machine Learning.

Introduction

Architecture is the art and science of designing buildings and supervising and coordinating the construction of all aspects of the building in keeping with functional and aesthetic criteria. The work of the architect involves taking a client's brief, carrying out feasibility and viability studies, conceptualizing the design and producing schematic drawings. His work also extends to the production of shop drawings and contract documents in partnership with other professionals. The culmination of the architect's work is the realization of the design. In the past few decades, the architect's job has been made 'easier' by information and communication technology (ICT). Hand-drafting has been virtually replaced with computer aided drafting, and production of blueprints replaced by the printouts from digital printers and plotters.

Advancements in technology has culminated in artificial intelligence (AI) and machine learning. AI summarily, is the ability of machines or systems to accurately decipher external data, to learn from the data, and utilize the knowledge gathered to deliver on definite goals and tasks through flexible adjustment (Kaplan and Haenlein, 2019). However, the application of this technology in the AEC sector is not yet widespread (Saka et al., 2022; An et al., 2021). Many practitioners in architecture do not know sufficiently how AI can deliver in their work as architects. The motivation for this study is a desire to popularize AI usage in architecture. The study therefore aimed to collate the current published information on AI technologies deployment in the AEC sector. This is with a view to making available to stakeholders in the built industry, a document that serves as a take-off point for professionals wanting to incorporate AI in their practice.

LITERATURE REVIEW

Ai in Architecture and construction

The role of Artificial Intelligence in architecture and construction cannot be overstated. Soon, it will greatly empower architects in their day-to-day practice. However at the present, the rise in the integration of technology is growing with large firms leading the way, and the integration of building information modelling (BIM) which Artificial Intelligence influences (Chaillou, 2020). Another important aspect of Artificial Intelligence with

regards to Architecture and construction for the future is the generative design which is becoming more common in solving problems. This also includes the use Robotic AI power to augment in different complex and diverse construction projects.

One more futuristic importance of AI in architecture and construction is the influence of AI in the optimization of building performance in the reduction of energy consumption which will greatly reduce the emission of carbon monoxide into the atmosphere and as well improve the issue of global warming which this world is currently battling with (Ma et al., 2020).

The impact of AI is also evident in the productivity of the sector. Enhancement of collaboration and increase in the ability to communicate is another important delivery of AI in the built environment industry. This has fostered better communication thus reducing of the cost of construction.

Artificial intelligence in engineering

AI has become an essential tool in the field of engineering offering new opportunities for improving efficiency, reducing costs, and enhancing decision making. By leveraging the power of AI, engineers can design, and build infrastructure and systems more effectively ultimately leading to a more sustainable and resilient built environment. As AI technology continues to evolve, there are numerous opportunities for further innovation in the field of AI in engineering paving the way for a more connected and intelligent future (Bughin, *et al*., 2018).

AI engineering involves the development, implementation and optimization of AI algorithms, models and system to solve complex engineering problems and improve engineering process. AI engineering can encompass various disciplines within engineering including mechanical engineering, electrical engineering, civil engineering, aerospace engineering, metallurgical and materials engineering and more. Besides that, AI can be considered an engineering discipline in itself (Culley, 2018).

AI engineering involves tasks such as design and developing AI algorithms and models tailored to specific engineering application. The integrating of systems and processes to enhance performance, efficiency and automation is another

application of AI in engineering. Utilizing AI techniques such as machine learning, natural language processing, engineering design and operation processing and optimization algorithms to analyse data can be used to make predictions and optimize energy design and operation (Ma, 2020).

Collaborating with interdisciplinary teams of engineers, data scientists, and domain experts to leverage AI technologies efficiently in engineering projects ensures the ethical and responsible use of AI in engineering application including consideration such as bias mitigating, transparency and engineering accountability. Overall, AI engineering plays a crucial role in advancing the capacity, efficiency, and innovation of engineering practices across various industries and domains (Lauren & Liz, 2002). Domains of AI utilization in the AEC industry and particularly the engineering subsector have been grouped under materials, geotechnical, hydrology, project management, transportation, energy, structural and environmental. (Momade et al., 2020)

METHODOLOGY

The research used the narrative review method. This entailed providing qualitative descriptive overview of existing knowledge of AI utilization in the AEC sector. The authors sourced and reviewed published works on the subject of artificial intelligence, machine learning and the design and built environment sectors. The authors then synthesized and interpreted the information gathered. The major database used by this article was Google Scholar. In the literature search, the researchers made use of different combinations of keywords so as to get out articles relevant to the subject. Some of these keywords include AEC, AI, architecture, engineering, construction, application etc. With a few exceptions, only literature from 10 years ago representing the most recent research findings on the subject were consulted.

RESULTS

The results of the study showed that AI has become pivotal in engineering. Some of its benefits found include enhanced efficiency, costs reduction, and optimization of decision making. Furthermore, the study found that by incorporating AI, engineers can create and construct structures and systems with greater

effectiveness culminating in a sustainable and resilient world. In addition, AI technology deployment is fostering a more connected and intelligent future. Results also showed that AI engineering interfaces with other disciplines within engineering, such as mechanical engineering, electrical engineering, civil engineering, aerospace engineering, metallurgical and materials engineering.

AI engineering or deployment delivers tasks such as design and development of AI algorithms and models tailored to specific engineering applications. AI in engineering has also been found useful in integrating systems and processes to enhance performance, efficiency and automation. Results also showed that AI can be used to analyse data for making predictions and optimizing energy design and operation. (Bughin, *et al*., 2018; Culley, 2018; Ma, 2020; Lauren & Liz, 2002; Momade et al., 2020)

In addition, the results of the review showed that AI was transforming the architecture and construction landscape particularly in the areas of generative design which is becoming more common in solving problems. Findings also showed AI was being explored for building performance in the area of reduction of energy consumption. Another area of AI utilization in architecture and construction shown by the review is in the optimization of collaboration and information sharing which is repositioning the sector for enhanced productivity. (Ma et al., 2020)

DISCUSSION

Application AI in architecture and construction

The capability of AI to transform the Architecture and Construction landscape cannot be exaggerated. It is not going to completely set the man aside as a designer because of the complex nature of the work, because man has an innovative ability to always transform his present environment (Gerber and Lin 2013). Most architectural work and construction uses the AI generative multitasking design programmes which have to do with Design and Planning. It is also used to enhance space planning which by the use of AI optimizes circulation in building as well as the floor plans and layout of Rooms (Chaillou, 2019). In study of AI tools used in the AEC industry researchers found that the most commonly used AI tools in the study area were Artificial Neural Network (ANN), Support Vector Machine

(SVM) and ANFIS, Multivariate Adaptive Regression Spline (MARS) and RF, SVM and Fuzzy Logic and LR and Particle Swarm Optimization (PSO) (Momade et al., 2020; Darko et al., 2020).

AI in Design and planning helps in the analysis of data, and within the urban areas, it also helps the planning of transport system of cities and provision of infrastructure. It is important to note that in the aspect of operations and construction AI plays an important Role by monitoring how buildings perform by predicting a maintenance checklist. Quality control and construction management are two important ways in which AI serves in construction (Lukovich T. 2023).

Another usage of AI in architecture and construction is in the improvement of sustainability and energy efficiency in buildings by the use of sustainable green building design and the application of Sustainable building material and strategies. Safety and risk management will always be useful in site monitoring, assessment and analysis of risk as well as response to emergency in an event of any disaster and AI comes in handy here.

In the aspects of collaboration as well as communication, AI improves client engagement and visualization of the design; it also improves and facilitates team work and coordination.

In practical terms, AI in architecture is used for the following:

i. Data collection and processing. The initial phases of design there is usually large amount of data to deal with including building regulations and by-laws, physical environment analysis, design brief, functional and space requirements, case studies, etc. AI provides serves in processing these data seamlessly.

ii. Creation of design options. AI algorithm, particularly, generative design, allows for the creation of multiple design options in record time. In particular, the text-to-image function serves to create design lay outs by merely typing in a description of desired output.

iii. Building information modeling (BIM). BIM refers to a simulation of the building design in virtual environment. AI now provides for accurate simulation of building behavior under different circumstances before they are built. This allows for important revision and adjustments that optimizes the final output.

iv. Energy performance analysis. AI makes it possible and accurately assess a building's performance in terms of energy consumption and conservation. The information so generated can then be used to improve the design relative to energy performance.

v. Structural performance analysis. This is principally the engineering domain about which the architect is expected to have basic understanding. AI is useful for structural testing, simulation and even non-destructive testing (NDT). These tests show how the building will behave under load which can be varied. This reveals what reinforcements need to be made or removed.

vi. Architectural delineation. AI makes drawing easy and fun, and can generate more realistic looking images than can sometimes be produced by hand. It also improves delivery time. AI components like Virtual Reality (VR) and Augmented Reality (AR) greatly enhances architectural visualization.

vii. AI-based Construction management: in the area of AI application in construction, AI technologies have capacity for progress monitoring, safety management, quality management, and contract management

viii. Contract management. AI has capacity develop engines that assist people make decisions based on feedbacks. This implies that AI systems can decide whether the project continues under different scenarios like public holidays or weather conditions based on information from recognized authorities

(Ceylan, 2021; Wang et al., 2020; Srivastava, 2023; Bolek et al., 2023)

Application of AI in engineering

AI stands out as an emerging trend in engineering due to its customization capacities. AI in engineering can be applied to any part of the engineering spectrum from generative AI to predictive analysis. AI in engineering refers not only to the application of artificial intelligence in different engineering context but also about an engineering discipline in itself.

In generative design, artificial intelligence leverages machine learning to learn optimization techniques to get in different design spaces. This can help engineers

to generate innovative and efficient designs that might take less time than traditional methods. These techniques are often used in mechanical engineering and can help engineers test functionality before building them (Robert et al., 2021). AI algorithms is applied in design optimization to analyse vast amount of data to optimize the design of engineering systems and components. This can lead to improved efficiency, performance, and cost effectiveness. AI powered predictive analysis can anticipate equipment failures and maintenance needs in advance. This helps engineers schedule maintenance activities more efficiently and prevent costly downtime (Ma, 2020).

AI enables the development of autonomous engineering systems such as self-driving vehicles, drones and robots, like robotics arms. This application can perform tasks in hazardous or inaccessible environment without human intervention. This has been seen in the international space station for example, where they have a mechanical arm to access the outside of spaceship. Again, AI techniques like machine learning can enhance simulation and modelling capacities. This allows engineers to simulate complex scenarios, predict outcome and optimize design more accurately (Russell & Norvig, 2020).

AI algorithms can analyse manufacturing processes in real time, identifying inefficiencies, optimizing parameters, and improving overall productivity and quality. AI powered analysis can assess and mitigate risk in engineering project by analysing historical data, identifying potential hazards, and providing commendation for risk mitigations strategies. AI can be used to accelerate the discovery and development of new materials with specific properties or performance, characteristics, which can be used in various engineering application (Culley, 2018). AI algorithms can also be used to analyse and predict the structural behaviour of complex engineering systems, such as buildings or bridges, under different loads and conditions (Lauren & Liz, 2002).

CONCLUSION

The study reviewed the place of AI in the AEC sector and synthesized information obtained into a coherent article to serve as a take-off point for industry stakeholders looking to understand how they may incorporate AI technologies in their practice. The study also provides information for practitioners in the sector seeking to

understand the potentials of AI and how it is likely to shape the future of work in the sector. The research found that AI was redefining architectural practice in several ways including form generation, façade development and project management. The field of engineering was also shown to have been enhanced by the development of AI largely in the place of material design, testing and simulation among others.

RECOMMENDATION

This research has shown that AI has come to stay. Additionally, it has shown that AI was transforming the built environment and optimizing processes. Therefore the study advises stakeholders to embrace AI technologies and utilize them ethically. The research also sues for the inclusion of AI courses in architecture and engineering curricula to help prepare the future professionals for work in a sector already being shaped by AI.

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