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Review

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Application of artificial intelligence and machine learning for BIM: review

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Abstract. Quality control is very important aspect in Building Information Modelling (BIM) workflows. Whatever stage of the lifecycle it is important to get and to follow building indicators. The BIM it is very data consuming field and analysis of these data require advance numerical tools from image processing to big data analysis. Artificial intelligent (AI) and machine learning (ML) had proven their efficiency to deal with automate processes and extract useful sources of data in different industries. In addition to the indicators tracking, AI and ML can make a good prediction about when and where to provide maintenance and/or quality control. In this article, a review of the AI and ML application in BIM will be presented. Further suggestions and challenges will be also discussed. The aim is to provide knowledge on the needs nowadays into building and landscaping domain, and to give a wide understanding on how those technics would impact industries and future studies.

Keywords: Artificial intelligent / machine learning / building information modelling / digital twin / IoT / smart building / industry 5.0

1 Introduction

Over recent years, the addition of new technologies into different methodologies for the management of buildings and landscape projects provided great progress. Indeed, through Building Information Modelling (BIM) and Artificial Intelligence (AI), new processes have been composed using multiple inputs to add more accuracy and effectiveness into the progression and management of constructions all around the world [1–4]. The first concept of BIM came in the 1960's and AI 1950's, nowadays those process has improved and are used in many projects. Machine learning (ML) techniques, such as deep learning (DL) algorithms, can now process large amounts of data. Adapting these practices in the construction business, like in other industries, is no longer a luxury but a necessity [5–9]. The continuous advancement of technology necessitates the application of artificial intelligence in the construction business in order to uncover potential for increased efficiency through intelligent solutions. Among the main goal of this article is to analyse how BIM and Digital Twin may progress, as well as how AI development may impact them. The first will be to highlight the developments of AI incorporation into BIM and Digital Twin [1,2,10–13].

Thus, the creation of this literature review will bring information's on how those new tools influence the field of landscapes and buildings. In order to build a theoretical framework, it is deemed necessary to understand where and when BIM and AI came from, how such definitions have changed over time, and how they are now present into multiple projects in those particular domains. With this objective in mind, this introduction first discusses of theoretical principal of those two technologies. The questions about the functioning of AI, the different types of them and which ones are mainly used in the landscape and building field will be answered. The outputs from those AI will impact the use of BIM, it is then also necessary to evoke the principle of BIM the different use of it and its most widespread use. Once the notion of AI and BIM has been portrayed, we will review applications of those technologies to improve building and landscape industry [4,14–16].

Over time, architects and engineers have tended to work together, creating architectural files that include structural and mechanical engineering elements. This enhanced collaboration has had an impact on the greater

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industry, including a shift away from design-bid-build contracts and toward integrated project delivery, in which multiple disciplines often collaborate on a mutually accessible set of BIM models that are updated on a variable basis. Despite the fact that the overall concept and technology of BIM are reaching their thirty-fifth anniversary, the industry has only just begun to recognize the potential benefits of Building Information Models. As the majority of structures are built digitally, an existing building marketplace where building materials and structural components can be bought and sold locally will arise. Human-computer interaction, augmented reality, cloud computing, generative design, virtual design and construction trends to continue to have a rapid impact on BIM development.

2 Building information modeling (BIM)

Each word in the acronym BIM can be used as a general definition: 'Building' can be regarded as a verb rather than a noun, which can be applied to any asset in the built environment. 'Model' refers to a 'representation of a system or process' as opposed to a 3D space representation. In additional to geometric representation, we must also be able to replicate the many aspects of an asset's design such as structural, architectural, building services, etc., construction, and operation. Finally, the core concept of BIM is 'information' and particularly 'the sharing of structured information'. This comprises both geometric and non-geometric information, such as an object's source, warranty information, fire rating, and corrosion specification. BIM allows us to simulate a virtual environment to replicate the construction project. A BIM, or accurate virtual model of a building, is digitally generated using computer modelling technologies. When finished, the building information model will contain precise geometry and relevant data to support the design, procurement, fabrication, and relevant construction activities required to realize the building. The model can be utilized for after-built operations and maintenance. BIM is an advanced technology that is changing and improving the techniques used to build, manage, and finish building projects. Many early adopters believe that BIM will increase dramatically as digital technologies such as mobile, IoT, big data, data science, machine learning, and AI are improved. The key to successful BIM deployment is to guarantee that all parties are operating from the same set of assumptions. In order to specify the tools to be utilized, the techniques for information exchange, and the level of detail required for each step of project delivery, BIM does have an initial cost. In addition, individual must be trained in the new processes, as well as the company's adaptability in their design processes. ML is one of the most important technologies that will impact BIM in the near future. It is the study and the development of algorithms that can learn from and predict data without being explicitly programmed. There are three types of ML techniques: supervised, unsupervised and reinforcement learning. Supervised learning, which is commonly used in tasks such as classification and regression, involves training a machine learning model with labeled data, where the desired output or outcome is already known. In opposite, unsupervised learning involves training a machine learning model with unlabeled data, where the desired output or outcome is not known. This type of ML is commonly used in tasks such as clustering and anomaly detection. Reinforcement learning involves training a machine learning model to make decisions based on a set of rewards and penalties. This type of ML is commonly used in tasks such as game playing, robotics, and autonomous vehicles.

Like any new process, it takes time, particularly in an industry as fragmented as construction. However, the streamlined and cost-effective design process of BIM has been shown to save costs and enhance quality. This is easily accomplished with the assistance of AI and ML. The following section will examine a variety of literature on the applications of ML and modelling to improve the process in building and landscape.

3 Artificial intelligence (AI)

Artificial intelligence (AI) is nowadays an advanced technology used in a lot of different ways into multiple fields and which have realized great improvements in industrial project. Multiple tools have been created to improve BIM including the one using AI. Therefore, the concept of this technology must be well understood to rationalize their presence into landscape and building studies. AI is also refereed to ML or intelligence, as opposed to natural intelligence expressed by people and other animals, such as "problem solving" and "learning" [17–19]. AI research, in computer science, is described as study of "intelligent agents", which are devices that detect, or even understand, their surroundings and take actions to increase their chances of attaining their aims.

AI imitate the human brain development and life history, anyone can develop different types of intelligence. As an example, one might be very efficient into the coordinating their mind with their body, or giving them an ease into doing complex movements with their body, however one might also be less effective into finding the right words to what their meaning, or facing a challenge into giving a public speech. One can then condense AI as the study of machine systems that seek to simulate and apply human mind. By comparison, humans and machines do have different fields where each is better than the other one, which reinforces the importance of human interaction with AI. Humans and machines must have an information flow to create a communication. Using AI gives benefits into many fields due to its effectiveness of calculation and very accurate processing of the inputs given. Nonetheless, human intelligence is needed to give the needed inputs featuring human concepts. Thus, both intelligences have benefits described by Figure 1.

While the essential proof of principle had been established, there was still a long way to go before the final goals of natural language processing, abstract reasoning, and self-recognition could be realized. A pile of challenges were still presented with the step-by-step breakthrough of the AI technology. The largest problem was a lack of processing capability to perform anything

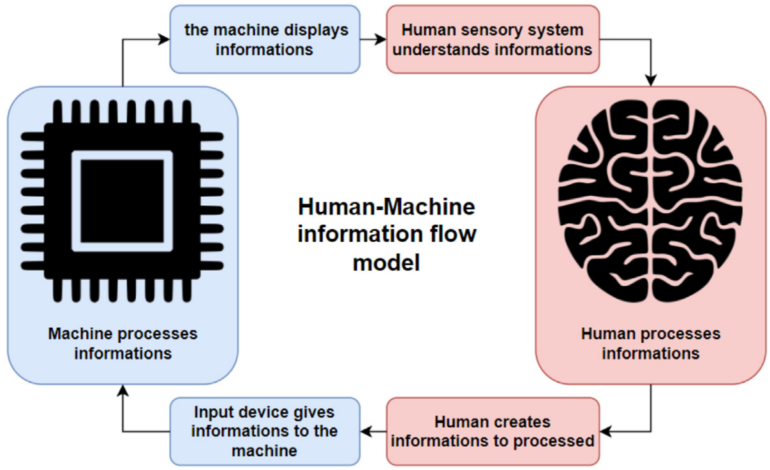

Fig. 1. Benefits of AI and human intelligence.

useful: computers couldn't store or analyse data quickly enough. Individuals currently lived in the "Big data" era, in which people have the ability to collect massive amounts of data that are too large for a single person to process.

Rather than low capability in big data processing, AI has been already proven to be beneficial in a variety of industries, including technology, banking, marketing, and entertainment. However, to be processed by AI, a knowledge representation in algorithms must be created. We must construct a logical representation of the data depending on how we intend to analyse it, which will serve as input. Natural language is incredibly detailed, but it does not lend itself well to processing. In literature study [19–22], researchers and engineers have proposed a variety of methods in which knowledge can be represented so that it can be examined by an AI computer program as follows:

- Expert Learning Systems: These programs act as stand-ins for experts in the topic being studied.
- Semantic Networks: A method of representing knowledge that focuses on the relationships and word descriptions of items. A semantic networks or net is represented as a graph.
- Decision or Search tree: A compumerous simpler algorithms; one useful technique to illustrate this is with a tree design.
- Neural Networks: constructing a computer model of the brain's neurons and how they function.

These four techniques comprise the most important AI technologies available globally.

4 Application of AI and BIM in building and landscape

Using real-time data, AI can also add five more dimensions to a BIM, including time (4D) and cost (5D). All of these AI technologies increase data processing to produce more accurate BIM visualisation and make tool use easier. Figure 2 shows how various types of information can be used.

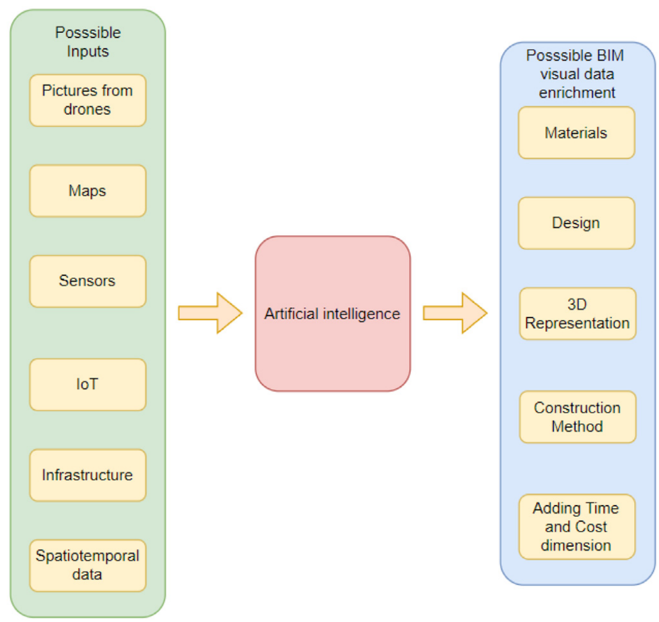

Fig. 2. Information processed by AI for BIM completion.

4.1 Applications of AI and BIM in AECO

AI can also be applied to the management of a construction project in a variety of ways. It is also possible to acquire predictions using geospatial data, real-time data, and historical data to make facility management (FM) simpler with sustainable solutions [18,23,24]. With a knowledge based expert system AI, the design of an infrastructure with the landscape in a BIM can be proceeded to acquire planning and scheduling. An AI can replicate a human expert intervention using the same knowledge representation paired with ML, recreating the human cognitive resonance on vast amounts of information. The cost record can be used to make operational and maintenance decisions. All of these instances demonstrate how AI

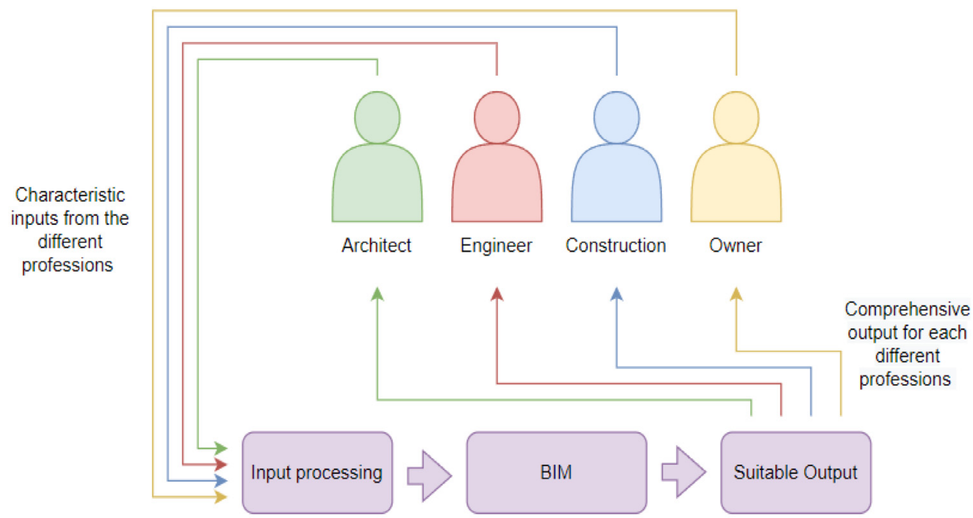

Fig. 3. AECO interaction with BIM.

may aid with decision making, prediction, and planning. Collaboration across diverse teams of Architect, Engineer, Construction, and Owner (AECO), as shown in Figure 3, is becoming easier as efficiency grows not only in adding field to BIM data, but also in using BIM in the field. As a result, AECO can manage projects more efficiently, improve buildings, and close knowledge gaps through automation processing [25].

4.2 Applications of AI in civil infrastructure

AI contributes to the development of sustainable projects by utilising energy more efficiently and decreasing waste during construction. To optimise two-dimensional cutting, a Symbiotic Organisms Search algorithm can be utilised. AI is also used to predict future needs, making buildings more efficient over time, which is in accordance with sustainable initiatives [17]. When compared to other traditional power tracing systems based on the proportional sharing principle and circuit theory, an AI-based power tracing using Evolutionary Programming provides better energy management. Wearable technology and/or the use of AI in the workplace must be applied with individuals in mind. One of the major issues with building and civil engineering structures is their cost. AI can forecast the expenses of developing [26].

Trends in AI, BIM, and Digital Twin studies demonstrate that the advancement of these domains will assist to improve the majority of construction and landscaping technologies currently in use [11,27]. Thus, providing opportunities for sustainability in terms of energy consumption and waste generation, security for residents and workers on the construction site, less expensive development and construction, and shorter project duration through optimization of planning and scheduling. The known restrictions today are the knowledge gap and information loss between AECO, as well as the ethical idea of trusting a black box learning machine system. The advancement of Building and Landscaping is dependent on the communication of all project components.

Those projects all revolve around multiple aspects and goals, including sustainability in terms of energy consumption and waste generation, security for residents and workers on the construction site, less expensive development and construction, and less time-consuming projects with optimised planning and schedules. AI integration has provided impetus to BIM and Digital Twin. With the progress of computer technology, it has been easier to deploy this technology in an effective manner, making AI more accessible to a wider audience. In terms of BIM, AI is a useful tool for both putting data into models and analysing data that comes from models [4,28,29]. The incorporation of the aforementioned new technologies into buildings simplifies data collecting, allowing ML to be even more efficient in the construction and landscape industries.

More specifically about the introduction of ML into the civil infrastructure, the AI can also help to improve building security by identifying threats and providing correct security system advice, which matters importantly concerning the construction issue. In the construction process, it improves efficiency, safety, quality and interior sound localisation [30–32]. For example, the application of AI, especially the computer vision could provide high security for residents and workers on the construction site by combining with advanced algorithm and unmanned aerial vehicle (UAVs) [33,34]. The assessment of the condition of civil infrastructure is conducted by utilizing data obtained from inspections or monitoring. Conventional methods used to evaluate the state of civil infrastructure often require trained inspectors to perform visual inspections and make decisions based on specific criteria. Nonetheless, these inspections are highly time-consuming, arduous, costly, and with great danger. As images capture visual information similar to that obtained by human inspectors, those problems can be well addressed by the replacement of AI. A thorough and concise review of computer vision-based civil infrastructure inspection and monitoring has been written by Spencer et al. [35].

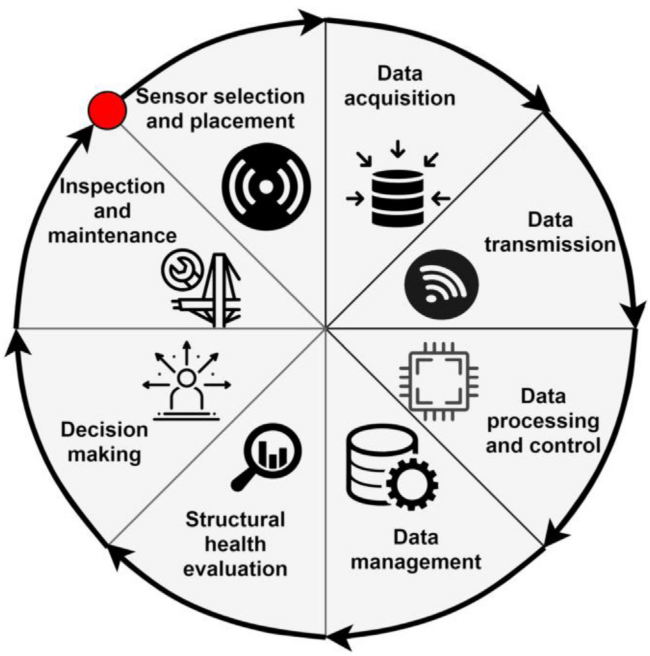

Fig. 4. Typical components of Structure Health Monitoring (SHM) [37].

Furthermore, in terms of security, an AI can not only replace the human inspectors in case of the cost and danger, but provide health advise by analysing living sites to determine whether a component of a structure is suitable or unsuitable for living at home without the assistance of a professional caregiver. This can be particularly useful for elderly individuals or those with disabilities who may require special accommodations in their living spaces. By leveraging AI-based systems, individuals can have greater independence and autonomy while still ensuring their safety and well-being.

To realize this purpose, structural health monitoring (SHM) is the key advanced technology. In general, SHM has been developed to facilitate the shift from identifying damage after the evaluation of damage in near real-time or online damage assessment. In layman's terms [36], SHM is a damage detection strategy that can observe a structure over a long period using a series of continuous measuring devices. Figure 4 can briefly represent the typical components of an SHM system. As shown, the process begins with choosing sensors and strategically placing them on the structure. Data collected by the data acquisition system is then transmitted to the processing unit, where it is stored, managed, and evaluated using various techniques and algorithms to determine the system's health status. Based on the severity and location of the identified damage and its potential for future propagation, decisions are made during the decision-making process regarding inspection and maintenance. As technology develops, the conventional damage detection techniques are gradually being replaced by state-of-the-art smart monitoring and decision-making solutions [37].

In recent years, researchers have proposed lots of methods combining with different neural networks which have demonstrated effectiveness in visual information processing, pattern detection, and prediction [36,38]. The trend shows two major AI types being employed in building projects: Artificial Neural Network (ANN) [39] and Convolution Neural Network (CNN). [40] ANN is a type of machine learning that imitates the way the human brain works by using layers of interconnected nodes to process and analyze data. CNN is a specialized type of ANN that excels in analyzing image and video data by using a process called convolution to identify patterns and features within the data. The CNN is particularly effective for image and video data, because recognition using CNNs is robust to translation with a limited number of parameters. It is why the CNN was widely utilized as a basic to optimize the performance in various of proposed methods combined with different optimization algorithms [41–43].

These types of AI can be used to analyze sensor data collected by SHM systems in real-time, allowing for early detection of potential issues and timely maintenance and repair. In addition to detecting damage, AI can also be used to predict future issues and potential failures, allowing for proactive maintenance and replacement of components. With the integration of AI in building projects, we can expect increased efficiency [43], reduced costs, and improved safety and well-being for building occupants. As AI technology continues to evolve, it is likely that we will see further advancements in SHM systems, leading to even more accurate and reliable monitoring of building health.

4.3 Applications of BIM in building and landscapes

The BIM-based project system has also the ability to change critical information. Other technologies, such as a web-based BIM platform for accessing and exchanging crucial information in real time, could be added to increase collaboration across teams. Such concern is the required knowledge to update a BIM; if the user makes a mistake, incorrect information may be distributed to other teams. As a result, Natural Language Programming (NLP) is explored to aid in the process of incorporating new information into the model. BIM and digital twin processes are a great support facilitating process and communication among different teams in the absence of qualified individuals or a monitoring system. The increasing viability of data processing as it is gradually integrated into the BIM process suggests that it will increase collaborative working. With the advancement of technology, restrictions and knowledge gaps should be reduced.

A greater integration of technologies such as IoT, VR, AI, and cloud storage can provide a better knowledge of the opportunities for improvement in geospatial data management and Smart Building [19,44]. New technologies and their automations make BIM development and its integration easier to implement. They include a wide range of methodologies and approaches, leveraging contributions from several research domains such as Civil Engineering, Engineering Informatics, Computational Science, and Engineering. Combining multiple technologies can result in cheaper energy and financial costs, as well as time saving [45]. BIM technology employs advanced computer technology to improve the design level of the construction industry while cutting construction costs and energy usage. It requires more calculation power, which comes at a cost. The initial expense is advantageous for the industry, especially in the long run, because it has managed to limit cost variation in future stages of the construction while reduce unnecessary costs, which shorten the project schedule.

BIM and Digital Twin also help team management, planning, and scheduling. Even when written instructions are imposed, information modelling can be processed with semantic-based concepts, which may help gain time and accuracy. NLP can be used to accomplish the same purpose. It would be easier to include new parameters and rules into the BIM. A Digital Twin can be created from an Asset Information Model (AIM). The use of digital twin information in the design and implementation of a data-driven planning and control workflow for building and civil infrastructure design and construction is another effective method of planning and scheduling a building project. Both concepts are extremely effective in construction projects, but they may also be used in other constructions such as railway or manufacturing and assembly. However, in order to achieve an efficient result, data collecting, and interpretation must be thoroughly understood.

Enriching BIM can be through photographs from on-land cameras and aerial photography. Then ML recognises patterns in photographs to identify construction materials. Furthermore, if the user has the option of selecting the training method, the system can be versatile. Drones can also review mission plans in order to enable interior computer vision-based building progress tracking. Geospatial data, real-time data, and historical data can all be used to create 3D models of buildings (or even entire cities). Thermal image analysis can aid in architecture identification. Computer vision can also enable new construction methods such as 3D printing.

5 Conclusion

This short review underlines the goal of BIM and the incorporation of AI into it. It is now at the heart of building and landscaping projects. The incorporation of AI into the BIM and Digital Twin processes aids in the development of the construction industry. The employment of "problem solving" and "learning" systems provides high accuracy in pattern detection and prediction when dealing with large amounts of data. In computer science, AI research is defined as the study of "intelligent agents," which are systems that sense, or even understand, their surroundings and take measures to maximise their chances of success. As computer technology has advanced, it has been easier to implement AI in an effective manner, making AI more accessible to a wider audience.

Today, the known constraints include the knowledge gap and information loss between AECO, as well as the ethical concept of trusting a black box learning machine system. AI, BIM, and Digital Twin research shows that advancements in these disciplines will help to improve the bulk of construction and landscaping technologies now in use.

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