Zeszyty Naukowe Politechniki Częstochowskiej
Budownictwo – Civil Engineering Science
ISSN 0526-5916

Zeszyty Naukowe Politechniki Częstochowskiej nr 29 (2023), 98-103
DOI: 10.17512/znb.2023.1.15

Machine learning impact on the construction industry: A review of application possibilities

Judyta Niemiro-Maźniak[1]

ABSTRACT:
The development of Artificial Intelligence (AI) technology has had a huge impact on technological progress in various industries. The complex construction industry is also a very important application area for AI, which is slowly but steadily developing. One of the main artificial intelligence tools that plays a key role in the technological development of construction is machine learning. The use of machine learning in the construction industry gives a number of possibilities, such as automatic detection of objects, defects or anomalies, construction supervision, as well as intelligent protection of structures. The paper explains the issue of machine learning, including deep learning and presents its division. Based on the literature review, examples are given of the use of deep learning in the construction industry in terms of safety on the construction site and defect detection in construction objects.

KEYWORDS:
artificial intelligence; machine learning; deep learning

1. Introduction

Over the last few decades, significant technological progress has been observed, which has a significant impact on various industries. Thanks to new technologies such as: Artificial Intelligence (AI), Building Information Modeling (BIM), Smart Vision (SV), Digital Twin (DT) and the Internet of Things (IoT), the construction industry is also slowly but steadily developing in this area [1]. Accuracy, safety, as well as productivity and efficiency of construction processes are being improved. The complexity of the construction industry means that scientists and researchers are constantly working on expanding the area of potential AI application in various construction sectors, including architectural design, structure analysis, material optimization, intelligent construction and building management, monitoring the progress of construction works, monitoring of safety, durability analysis construction, as well as compliance of construction projects with applicable regulations.

The term "artificial intelligence" was introduced by John McCarthy in 1956 at a workshop at Dartmouth College to distinguish it from the concept of cybernetics [2]. The advent of AI gave rise to an attempt to recreate the human brain's ability to reason intelligently and solve tasks and problems [3]. Initially, artificial intelligence did not enjoy much recognition, so its areas of interest and applications were limited. However, with the emergence of new, more complex and constantly evolving algorithms, AI began to gain more and more interest. One of such algorithms is neural networks, including deep learning (DL), which is a branch of machine learning (ML). Figure 1 shows deep learning in the context of artificial intelligence with its widely used algorithms: Multi-Layer Perceptron (MLP), Convolutional Neural Networks (CNN), Generative

[1] Czestochowa University of Technology, Faculty of Civil Engineering, ul. Akademicka 3, 42-218 Częstochowa, Poland, e-mail: j.niemiro-mazniak@pcz.pl, orcid id: 0000-0001-6808-7067

Adversarial Network (GAN), Recurrent Neural Network (RNN), Radial Basis Function Network RBFN and Long Short-Term Memory Network (LSTM).

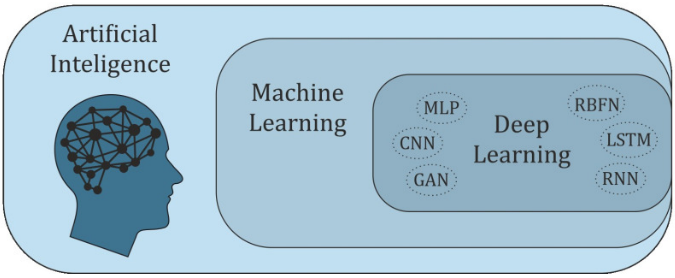

Fig. 1. Deep learning in the AI and its algorithms (own elaboration)

Machine learning has become a very important and desirable tool that supports the automation of construction processes. It is the main area of interest for AI and a key element in the creation of "smart" buildings. The ability to process large amounts of data and learn useful patterns saves time and maximizes the use of computing resources [4]. Machine learning can be used e.g. in project documentation for text mining, risk prediction [5], or in improving logistics processes. Very good results of deep learning in the field of computer vision meant that it was adopted in many construction sectors, especially in the field of: construction site safety [6-8] and structural damage detection, e.g. bridges [9, 10].

Over the last few decades, many articles have been written on the application of various fields of artificial intelligence to solve problems in construction. In the article [11], a review of the existing literature from 1960-2020 was conducted in order to examine the existing applications of AI in the construction industry. 1,800 publications were assessed, of which 1,272 were considered relevant and were analysed. The literature was selected based on the description and evaluation of the sub-fields of artificial intelligence and how they can be applied to the construction industry. In this work, a clear trend of increasing the number of publications in the field of the researched subject was established. It has also been noted that in the last decade, ML has overtaken knowledge-based systems in construction applications.

ML technologies can open up a number of opportunities throughout the construction process, but their implementation requires many challenges. This is related to e.g. with difficulties in obtaining marked data, especially in a very complicated area of the construction site. This paper presents the characteristics of machine learning, including deep learning, and based on a review of the literature, examples of the use of deep learning in the construction industry have been indicated.

2. Machine learning

Machine learning is a subset of artificial intelligence. It involves the computer observing, learning and improving on a set of input data, and then, based on this, generate a model for solving problems. Learning and improvement is not programmed. Algorithms are trained to find patterns and correlations in a given, large data set, and then, as a result of this analysis, make decisions and provide appropriate predictions. Unlike traditional programming, predictive models are generated based on the data, which are used to make predictions based on invisible data [1]. ML can be divided into: supervised learning, unsupervised learning and reinforcement learning.

2.1. Supervised learning

A method of learning in which the data set on which the algorithm learns contains both the predictors and the solution to the problem, the so-called "labels". Initially, the algorithm learns from the labeled data and then uses it to create a model that can be used to predict results for the new data. The scheme of supervised learning is shown in Figure 2. The most commonly used supervised tasks are: classification (class prediction) and regression (value prediction). Commonly used examples of supervised learning algorithms include: linear regression, logistic regression, neural networks and Support Vector Machines (SVM).

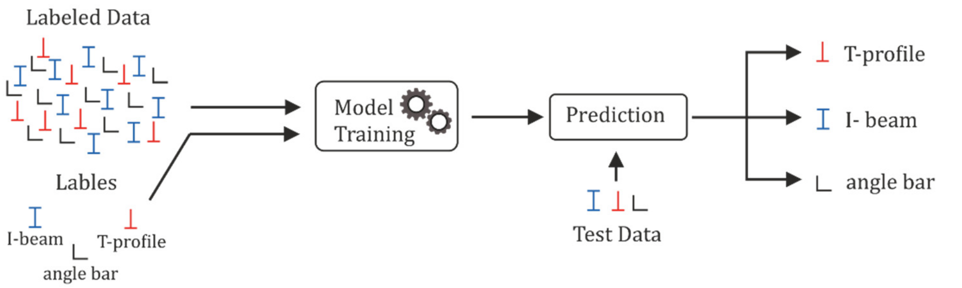

Fig. 2. Supervised learning scheme (own elaboration)

2.2. Unsupervised learning

In this method, the model algorithm starts learning from an unlabeled dataset. On their basis, it will identify hidden patterns or internal structures. Unsupervised learning algorithms can classify, group, detect, or label data points without any outside guidance. This method therefore allows you to independently identify patterns in a given set of data. Unsupervised learning is primarily used to detect various types of anomalies and new information. The unsupervised learning scheme is shown in Figure 3.

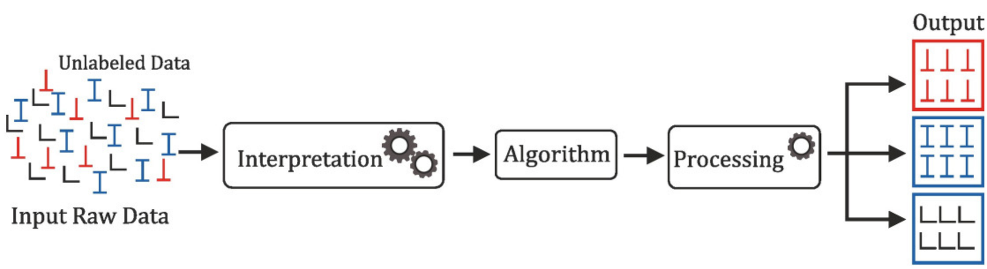

Fig. 3. Unsupervised learning scheme (own elaboration)

2.3. Reinforcement learning

A method of learning, called a reinforcement learning agents. You can train an agent to observe the environment and take repetitive actions. He receives rewards for desirable behavior. This enhances the agent's ability to learn by taking action. The goal is to get the best strategy ("policy"). This is achieved by winning as many rewards as possible over time. In conclusion, in the case of reinforcement learning, we need an agent and an environment to solve a problem, and connect these two elements with a feedback loop. By connecting an agent to an environment, we are actually giving it a set of specific actions that affect the environment in which they are embedded. By connecting the environment to the agent, we constantly send it two signals: an updated state and a reward. The reinforcement learning scheme is shown in Figure 4.

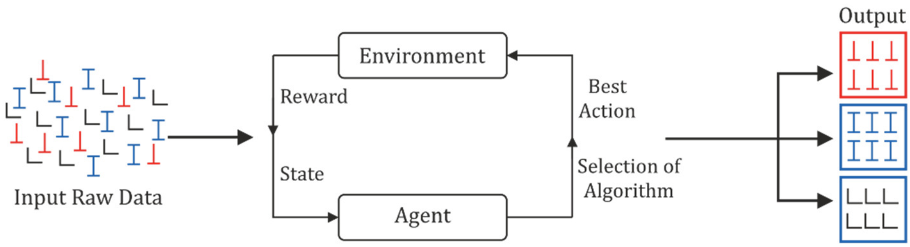

Fig. 4. Reinforcement learning scheme (own elaboration)

3. Deep learning

Deep learning is a subfield of machine learning (Fig. 1), based on artificial neural networks and other related ML algorithms. The learning process is deep because the structure of the network consists of more than one hidden layer, input and output. Thus, the computational path consists of several stages. Deep learning algorithms, due to long computational paths, are used for data with larger dimensions: images, audio or video. Commonly used DL algorithms in construction are: Feedforward neural net-works (FNN), Convolutional Neural Network (CNN), Generative Adversarial Network (GAN), Variational Autoencoder (VAE), Recurrent Neural Network (RNN).

4. Application of deep learning in construction

The review of the literature indicates the wide application of deep learning in image processing. In the construction sector, the use of deep learning methods can be distinguished, primarily in the field of: object detection, damage detection, anomalies in objects, activity detection and image segmentation.

4.1. Object detection

Safety on the construction site is one of the most important tasks facing the construction industry. Much work is devoted to the use of deep learning to minimize the risks that occur on construction sites. Examples include works [12, 13]. In the article [12] in order to avoid accidents and strengthen the supervision of construction workers, it was proposed to use the DL method for automatic non-hardhat-use person (NHU) detection technology. It has been proposed to use a very precise, widely applicable Faster R-CNN method. More than 100,000 frames of photos from video recordings of employees were randomly selected from various construction sites over a year. Various visual conditions of construction sites were analysed. Image frames were classified according to their visual conditions. Image frames were entered into Faster R-CNN according to different visual categories. The experiment showed that the high repeatability and speed of this method makes it possible to effectively detect non-hardhat-use employees in different construction site conditions. Using this method can make it easier to control and improve safety on the construction site. Also in [13], the focus was on the use of deep learning to detect personal protective equipment (PPE) on a construction site in real time. Three DL methods, built on the You-Only-Look-Once (YOLO) architecture, are presented to check whether an employee displayed in real time is wearing a hard hat, a vest, or both. The first approach is to detect employees, hard hats and vests by the algorithm. Then a machine learning model, e.g. a decision tree or neural networks, verifies the correctness of wearing vests and helmets by employees. The second approach is to simultaneously detect all employees and verify PPE compliance using a single convolutional neural network (CNN). A third approach is to detect only workers, who are then framed and classified with CNN-based classifiers for the presence of protective clothing. Research has shown that the second approach is the most efficient and is suitable for real-world use.

Deep learning can also be used to detect objects and construction equipment in a monitored location, including for analyzing the activity of earthmoving equipment, detecting the density of construction vehicles on construction sites [8], or detecting non-certified works on construction sites [6].

4.2. Object detection and image segmentation

Many factors influence wear, damage and cracks in building structures. The possibility of automatic detection of various types of defects gives the possibility of maximum exploitation of objects, as well as reducing the need for human work. Exemplary tests presenting methods of detecting defects in materials and building objects are presented in the works: [14, 15].

The work [15] presents a method of automatic detection and localization of damages in asphalt pavements caused by moisture. A modern approach to deep learning was used. Three datasets with different resolutions were created from different asphalt pavement bridges surveyed with a Ground Penetrating Radars (GPR). Mixed deep convolutional neural networks (CNN) have been proposed for feature extraction and fault recognition and detection. To prepare the input data, an incremental random sampling (IRS) algorithm was proposed to generate the appropriate GPR images to feed the CNN. The obtained results showed promising effectiveness in detecting and locating damage to asphalt pavements due to moisture.

The work [14] investigated the possibility of replacing human control in detecting glass cracks using a deep learning method based on CNN. This method was introduced to an novel modular façade-cleaning robot-using convolutional neural networks developed in TensorFlow. As part of the experiment, the robot was equipped with an on-board camera, and the learning process based on live vision was carried out using two different optimizers. Both achieved high accuracy of about 90%, so it can be concluded that this system can successfully replace a human during on-site inspection.

Deep learning is also successfully used in the area of image segmentation. In construction, image segmentation is used to segment images of object surfaces to detect possible defects and damage. It can be used to visually detect damage to the structure of bridges [9], or detect defects related to potholes in roads [16].

5. Conclusions

Machine learning has become a very important subfield of artificial intelligence, allowing systems to learn to find hidden patterns in large data sets and to predict subsequent tasks based on them. Machine learning technology is increasingly used in various industries, including construction. It significantly influences the development of automated technologies. A review of the literature indicates that research on machine learning has accelerated in recent years and is being used in many construction sectors. As machine learning has developed, deep learning has also been developed to a very high level. Currently, the deep learning method has become the main method of computer vision, replacing traditional statistical models. It is designed for image classification, object detection and image segmentation. Deep learning methods can therefore be successfully used for inspection purposes, including: automatic detection of defects and damage, recognition of dangerous behavior, detection of failure to take precautions on construction sites, or recognition of structural elements. They can also be used in the monitoring of construction facilities, analyzing the behavior and density of construction equipment on construction sites.

The review of the literature showed that machine learning, including deep learning, is an accurate method that allows for its practical application in order to increase the efficiency and safety of construction works. Further research directions may focus on fully understanding machine learning algorithms and developing deep models that would be dedicated to specific sectors in the construction industry and increasing their application capabilities.

References

[1] Sharafi P., Teodosio B., Shringi A., Mendis P., Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications, Automation in Construction 2022, 141, 104440.
[2] McCarthy J., Review of the question of artificial intelligence, Ann. Hist. Comput. 1988 (10), 224-229.
[3] Brooks R.A., Intelligence without representation, Artificial Intelligence 1991, 47, 1-3, 139-159.
[4] Xu Y., Zhou Y., Sekula P., Ding L., Machine learning in construction: From shallow to deep learning, Developments in the Built Environment 2021, 6, 100045.
[5] Poh C.Q., Ubeynarayana C.U., Goh Y.M., Safety leading indicators for construction sites: A machine learning approach, Automation in Construction 2018, 93, 375-386.
[6] Fang Q., Li H., Luo X., Ding L., Rose T.M., An W., Yu Y., A deep learning-based method for detecting non-certified work on construction sites, Advanced Engineering Informatics 2018, 35, 56-68.
[7] Fang W., Zhong B., Zhao N., Love P.E., Luo H., Xue J., Xu S., A deep learning-based approach for mitigating falls from height with computer vision: Convolutional neural network, Advanced Engineering Informatics 2019, 39, 170-177.
[8] Guo Y., Xu Y., Li S., Dense construction vehicle detection based on orientation-aware feature fusion convolutional neural network, Automation in Construction 2020, 112, 103124.
[9] Deng W., Mou Y., Kashiwa T., Escalera S., Nagai K., Nakayama K., Matsuo Y., Prendinger H., Vision based pixel-level bridge structural damage detection using a link ASPP network, Automation in Construction 2020, 110, 102973.
[10] Dorafshan S., Azari H., Evaluation of bridge decks with overlays using impact echo, a deep learning approach, Automation in Construction 2020, 113, 103133.
[11] Abioye S.O., Oyedele L.O., Akanbi L., Ajayi A., Davila Delgado J.M., Bilal M., Akinade O.O., Ahmed A., Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges, Journal of Building Engineering 2021, 44, 103299.
[12] Fang Q., Li H., Luo X., Ding L., Luo H., Rose T.M., An W., Detecting non-hardhat-use by a deep learning method from far-field surveillance videos, Automation in Construction 2018, 85, 1-9.
[13] Nath N.D., Behzadan A.H., Paal S.G., Deep learning for site safety: Real-time detection of personal protective equipment, Automation in Construction 2020, 112, 103085.
[14] Kouzehgar M., Krishnasamy Tamilselvam Y., Vega Heredia M., Rajesh Elara M., Self-reconfigurable façade-cleaning robot equipped with deep-learning-based crack detection based on convolutional neural networks, Automation in Construction 2019, 108, 102959.
[15] Zhang J., Yang X., Li W., Zhang S., Jia Y., Automatic detection of moisture damages in asphalt pavements from GPR data with deep CNN and IRS method, Automation in Construction 2020, 113, 103119.
[16] Hangbin W., Lianbi Y., Zeran X., Yayun L., Xinran A., Qichao C., Zhengning L., Bin M., Road pothole extraction and safety evaluation by integration of point cloud and images derived from mobile mapping sensors, Advanced Engineering Informatics 2019, 42.

Wpływ uczenia maszynowego na branżę budowlaną

STRESZCZENIE:
Rozwój technologii sztucznej inteligencji (AI) wywarł ogromny wpływ na postęp technologiczny w różnych gałęziach przemysłu. Złożona branża budowlana jest również bardzo istotnym obszarem zastosowania AI, która powoli, ale w sposób ciągły rozwija się. Jednym z głównych narzędzi sztucznej inteligencji odgrywający kluczową rolę w technologicznym rozwoju budownictwa jest uczenie maszynowe. Wykorzystanie uczenia maszynowego w branży budowlanej daje szereg możliwości, takich jak automatyczne wykrywanie obiektów, defektów czy anomalii, nadzór budowy, a także inteligentnego zabezpieczania konstrukcji. W pracy wyjaśniono zagadnienie uczenia maszynowego, w tym głębokiego uczenia się, oraz przedstawiono jego podział. Na podstawie przeglądu literatury wskazano przykłady zastosowania głębokiego uczenia się w branży budowlanej w aspekcie bezpieczeństwa na placu budowy oraz wykrywania defektów w obiektach budowlanych.

SŁOWA KLUCZOWE:
sztuczna inteligencja; uczenie maszynowe; głębokie uczenie