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APPLICATION OF ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING (ML) IN CIVIL ENGINEERING: A REVIEW

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Abstract

Artificial intelligence is new technology which is extending human limits to the maximum. A few decades back things which was an imagination are now possible in the era of digitalization. Artificial intelligence can have a significant impact on the evolution of the AEC (Architecture, Engineering & Construction) sector. Among the most significant advantages that intelligent systems are able to offer to the construction sector. In this paper the review of application of AI technology in Civil and structural engineering is discussed.

Keywords— Artificial Intelligence, Machine learning, Construction Industry.

Introduction

Artificial Intelligence is new techniques that have created an impact on civil engineering. AI attempts to construct and make operations reasonably simple and precise. This technique helps to solve many complex problems and it act as an analytical tool to diagnosis the results easily. AI models in civil engineering are used in construction projects for accuracy, cheaper, and less disruption. AI can be used for the best project planning, the control of construction time and costs. The reduction of accidents at work, The increasing efficiency and productivity, The simplification of survey process, The best maintenance management. Machine learning ability is one of the intelligent systems used in civil engineering. Which is skilful systems each of them has its own explanatory solutions. AI models in civil engineering are used in construction projects for accuracy, cheaper, and less disruption. Its applications in the field of civil engineering are vast and diverse. It can be used for intelligent design, Analysis of time and cost, Management of construction process, identification and mitigation of risk, facility management and structural health monitoring.

Artificial Intelligence and its application in Civil Engineering

Shengyuan Li and Xuefeng Zhao, [1] designed a CNN through modifying AlexNet and then trained and validated using a built database with 60000 images. To improve its performance, general global transforms and edge detection detectors were applied, such as fast Haar transform (FHT), fast Fourier transform (FFT), Sobel, and Canny edge detectors. training and testing codes and their usage can be viewed from the website https://github.com/Shengyuan-Li/CNN-forCrack-Detection. the trained. model is integrated into asmartphone application named Crack Detector. Datasets as open-source can be downloaded from website https://drive.google.com/open?id1XGoHqdGWYhIaTsmuctdV9J1C eLPhZR). Author concluded that more images with more types of concrete damages under various conditions will be provided and added to the existing database to increase the adaptation and robustness of the proposed method, and comparative studies will also be performed.

Author implemented [2] a novel integrated system involving dual AI composed of a GAN and a CNN in addition to advanced ML mechanics for achieving in situ ML measurement and AI verification of structures under construction or operational multiscale structures. An integrated system with mechano luminescence (ML) and dual artificial intelligence (AI) modules with subsidiary finite element method (FEM) simulation is designed for in situ SHM and instantaneous verification.

Author [3] aims to evaluate the effect of mixture composition and age of concrete on the coefficient of variation (CV) of the rebound hammer index applied to various types of concrete. The reliability of measurements from NDT is considered a key issue that can lead to poor decisions for structural rehabilitation. In practice, compressive strength is the most assessed mechanical property to determine the onsite strength of concrete. Author concluded that pre-established ratios between NDT measurements and compressive strength were only applicable when the type of concrete was known. The use of data-driven models to predict the compressive strength of concrete can save on the cost and time required to carry out laboratory tests.

TO assign priorities for repair/replacement, [4] artificial neural network modelling is employed. Eight independent variables are employed, namely pipe, length, diameter, age, break category, soil type, pipe material, the year of Cement Mortar Lining (if implemented), and the year of Cathodic Protection (if implemented), to determine the importance of different factors influencing the pipe failure rate.

This work introduced the implementation of a machine learning-based mode [5] to detect cracks on concrete surfaces for infrastructure inspection. a dataset with 3500 images of concrete surfaces balanced between images with and without cracks was used. This dataset was divided into training and testing data at an 80/20 ratio. machine learning-based models are likely to be initially deployed as a tool that assists experts to provide a safer, faster and more productive inspection, creating new possibilities for increased effectiveness in infrastructure asset management by making unbiased, periodic structure monitoring and/or damage assessment feasible.

Ziyue Zeng,[6] proposed A deep convolutional neural network and trained using a data set consisting of 380 groups of concrete mixes. The accuracy and reliability of the model are validated by comparing with three models – SVM, ANN, and AdaBoost – using a data set prepared experimentally. The results show that the proposed model achieves high coefficients of determination (0.973 for the training set and 0.967 for the test set), demonstrating its excellent accuracy and generalization ability. first structural engineering applications of ML was carried out in 1989 using artificial neural network (ANN).

In this paper [7] an ambitious and comprehensive review on the applications of ML for structural engineering has been presented. First structural engineering applications of ML was carried out in 1989 using artificial neural network (ANN). ML has emerged as a promising predictive tool for a broad range of structural engineering applications, and thus it can be potential replacements for commonly used empirical models. Structural engineering applications of ML algorithms (i.e., structural analysis and design, SHM and damage detection, behaviour and capacity of structural members and systems, fire resistance of structures, and property and mix design of concrete).

Author applied to design [8] is found in the increased diversity of outputs produced. ML algorithms have been shown to increase the design diversity by recombining the features that characterize individual designs producing solutions beyond those which would have been imagined by human engineers. In this paper AI applied to design of building Structure. Artificial intelligence in design by three ways: 1) AI as a framework in which to explore ideas about design; 2) AI as provider of a schema to model human design; and 3) AI as a means to allow the development of tools for human designers. It has been shown that ML tools have now started to appear that allow engineers to access complex multi-dimensional spaces beyond the ability of human intelligence alone. ML algorithms have been shown to increase the design diversity by recombining the features that characterize individual designs producing solutions beyond those which would have been imagined by human engineers.

Author discussed different applications of AI [9] in structural or civil engineering, steps involved in the development of these systems, different types of AI methods, AI in structural engineering, and finally their shortcomings and solutions to overcome. Researchers have dealt with mainly 3 types of AI methods in structural engineering: Picture Recognition (PR); Machine Learning (ML); Deep Learning (DL). Internet of Things (IoT) for the Structural Health Monitoring system (SHM) Machine learning is being used for: damage detection - Machine Learning is used for locating the damage in structure, amount of damage that occurs, material stability, etc.by using visual or sensor data. SHM – By using a sensor and giving the input to sensor like mode shape, stress and tension, spectrum, damping, cracking, wind profile, etc. and as output we get acceleration and displacement, temperature, humidity. From these an engineer can predict weather a damage might be caused or it has already damaged, then we have to retrofit it. ML systems can give warnings for required repairs or evacuations.

The CNN networks [10] are trained using a large number of datasets for various types of damage and anomaly detection and post-disaster reconnaissance. The trained networks are then utilized to analyze newer data to detect the type and severity of the damage, enhancing the capabilities of non-contact sensors in developing autonomous SHM systems. 2D CNN algorithms were mostly explored for 2D images in various SHM applications to detect defects and anomalies autonomously. With increasing computational capabilities in the era of big data, high-performance computing, parallel processing, and cloud computing, CNN techniques have witnessed significant developments in remote and autonomous SHM of critical civil infrastructure. Smart and autonomous monitoring systems of future urban cities will result in internet-of-things (IoT)-enhanced big data for large-scale structures. This data will include either time-series measurements obtained from long-term embedded sensors within the structures or a large number of images obtained from sophisticated vision measurement systems such as drones and robots.

Author presents a discussion on crack detection through [11] a manual process, image processing techniques, and machine learning methods along with their limitations. Structural images are used for various purposes, e.g., automatic locating of cracks, classifying the cracks, and measuring crack properties to monitor the structure for proper caring. This paper provides review of CNN architectures with their effectiveness in crack detection concerning hardware, software, dataset, architecture, mode of training, loss function, and results and overall performance. Structure crack detection is challenging due to lighting conditions, complex background, illumination effect, and low contrast between crack and non-crack regions. Deep learning has solved these challenges by automatically extracting the crack and non-crack features from the images and detecting the crack. It is anticipated that deep learning algorithms will surely replace the conventional methods of detecting cracks.

Author used [12] some AI theories to assess the seismic performance of school buildings, including: gray theory, artificial neural network and support vector machine. He developed five resampling techniques and three classifiers based on machine learning to evaluate seismic capability for school buildings.

This study focuses [13] on how AI and its various principles can be blended with the emerging areas of structural engineering, and how it is shaping the construction industry by employing in the major areas of monitoring of structural health, assessment of damages and construction management. Machine Learning in SHM, it deals with producing information form the earlier experiences, getting to know about the parameters of the model and then concentrating on forecasting latest and new data for input. In this paper domain application, discipline of structural Engineering, Method of AI application is discussed with the help of references. the structural problems, relates to health monitoring or damage assessment, the traditional methods are accompanied with the technological advancements in terms of sensors and algorithms for the collection of data, implementation and analysis can be possible. construction management or structural designing and analysis, emerging applications of AI in civil engineering finds a worthy result.

this study focuses [14] on the ethical aspects of their applications, like their predominant role in enhancing the construction industry, geotechnical, watershed management, and transportation fields summarizes it hallow side software approach BIM is discussed which is one of those smart sophisticated technologies which works beyond 3D modeling and building design, Building Information Modelling has significantly impacted the construction process. BIM systems now play a role in every step of the building process, from design to production to project management to handover after a job is finished. Development of Statistical Models, Data Feature Extraction, operational Evaluation, and Health Monitoring are all processes that are involved. Assessment of post-earthquake structural integrity, monitoring of structures impacted by external factors, the rise in maintenance needs rather than a decline in construction needs, the transition to performance-based design, performance improvement of an existing structure, and feedback loops to improve the future design based on experience are some of the goals of SHM. The application of AI in the fields of civil engineering is not as easy as it seemed to be and AI is used only by organizations that can afford its implementation and maintenance costs. Incorporating robots and other complex machines are expensive. Author concluded that Future applications of artificial intelligence will surely make life easier for people and might even motivate them to develop new skills.

This paper [15] reviewed the latest publications in SHM using emerging DL-based methods and provide readers with an overall understanding of various SHM applications. researchers have recently attempted to solve civil engineering problems by adapting the vision-based deep learning methods. DL-based SHM techniques have been used for: general SHM, multi-level damage detection, corrosion detection, concrete surface bug hole recognition, concrete crack detection, pavement crack detection, acoustic emissions source detection. drone were proposed tool to inspect the structures like tall buildings, bridges where inspectors do not have access to acquire image data. the nature of datasets, sizes and other characteristics are also studied from reviews.

Machine learning (ML) algorithms [16] are thus providing the necessary tools to augment the capabilities of SHM systems and provide intelligent solutions for the challenges of the past. In line with these digital advancements, considering the next-generation SHM and ML combinations, recent breakthroughs in (1) mobile device-assisted, (2) unmanned aerial vehicles, (3) virtual/augmented reality, and (4) digital twins are discussed at length. This review aims to generalize these applications harmoniously using ML and SHM frameworks

A detailed breakdown of techniques, methods, and algorithms from the literature is presented and examined, emphasizing ML and the data-centric advancements occupying the current research trends. The survey included a systematic discussion of the steps taken to implement an ML model for SHM with pathways, taxonomies, and breakdowns. Moreover, the most common algorithms proposed for context-dependent applications were overviewed. The survey revealed that the extension of ML in SHM dramatically increased the system's capabilities, providing innovative solutions for different research challenges.

Conclusion:

This paper reviews the application and development of artificial intelligence in civil engineering over the years. Artificial intelligence algorithm and neural network have been applied in the field of civil engineering for decades, widely used in structural optimization, structural state assessment and health monitoring, construction engineering, bridge engineering, geotechnical engineering, highway engineering and so on. In recent years, Big Data technologies and deep learning have been successfully applied in various aspects of civil engineering, among which the Big Data technologies have developed fastest in structural maintenance. With the rapid development of computer vision based on deep learning, the structure health monitoring based on computer vision has been greatly improved. However, deep learning has made few breakthroughs in other aspects of civil engineering. In the era of big data, deep learning becomes an efficient tool, which can fully tap into the rich information contained in big data. Therefore, the combination of big data and deep learning will become a new research direction of artificial intelligence in civil engineering.

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