Preface

In recent years, artificial intelligence (AI) has drawn significant attention with respect to its applications in several scientific fields, varying from big data handling to medical diagnosis and more. A tremendous transformation has taken place with the emerging applications of AI and machine learning (ML) techniques. The use of these technologies is already present in our everyday lives with several applications, such as personalized ads, personal virtual assistants, autonomous driving, etc. AI and ML work in principle by combining large amounts of data with fast, iterative processing, and intelligent algorithms (e.g., neural networks, process mining, convolutional neural networks, deep learning, and others), allowing the machine to learn automatically from patterns or features in the data. This way, AI can provide a wide range of solutions to address many challenging problems.

As expected, AI and ML techniques have been increasingly adopted in various engineering fields, including civil engineering, which is undergoing a major transformation, driven by recent advances in these technologies. AI and ML have started revolutionizing the way we design, construct, and maintain structures and infrastructures, and are enabling engineers to make more informed decisions, leading to more efficient and sustainable practices. These techniques have proven to be beneficial in predicting and optimizing various aspects of civil engineering projects such as structural design, construction, maintenance, and management. For instance, AI and ML techniques can help predict the performance of structural systems under various loads and environmental conditions, thus aiding in the design of more efficient and resilient structures. Additionally, AI and ML techniques can be used for monitoring construction progress and identifying potential defects, thus enabling timely corrective actions. Overall, the use of AI and ML techniques in civil engineering has the potential to improve efficiency, safety, and sustainability of civil engineering projects.

This book is designed to provide an overview of the present thinking and state-of-the-art developments in the application of AI and ML techniques for civil engineering, and to explore their potential applications in various domains. It brings together leading researchers and practitioners from academia and industry to share their experiences, insights, and best practices. It is intended for a wide audience, including professionals, researchers, practitioners, and students in the civil engineering field who are interested in incorporating AI and machine learning techniques into their work or research. It can serve as a valuable reference for those seeking to keep up to date with the latest developments in this exciting field. We hope that it will inspire readers to explore new ideas and opportunities, and to contribute to the ongoing evolution of civil engineering.

Being a collection of innovative research on the methods and implementation of AI and ML in multiple facets of civil engineering, the book is divided into 13 chapters, each covering a different aspect, as described in detail in the following paragraphs.

Chapter 1 is about the application of AI techniques in Building Information Modeling (BIM). AI in BIM can be used to streamline operations, advancements and innovations that were previously based on human ability, saving costs, delays, and hazards while improving project output quality. The authors examine the technical advancements based on ML algorithms that propelled AI to the top of the BIM list.

Chapter 2 discusses the importance of detecting and assessing damage in concrete structures for safety reasons and investigates the use of Deep Learning (DL) techniques for the detection and assessment of the damaged condition of these structures. Some indicators of damage are difficult to detect automatically, but deep learning can effectively extract features from multi-source data and perform related tasks such as classification and detection. The authors highlight the potential of DL in addressing crucial problems related to damage inspection for concrete structures, including component recognition, local damage recognition, and structural anomaly analysis.

Chapter 3 discusses the use of ML applications in vibration-based Structural Health Monitoring (SHM). The chapter examines how recent advances in sensing technology and AI have led to the development of techniques based on ML for SHM. The chapter focuses on the application of ML for vibration-based SHM and outlines the fundamental principles of ML and the steps involved in vibration-based SHM for damage detection. It includes the application of ML at each step of the SHM process, identifying key milestones from existing literature and highlighting the many possibilities for successful ML applications in SHM.

Chapter 4 discusses the limitations of national and international design codes in providing oversimplified and inaccessible formulas for designing and analyzing structures. It aims to address this issue by demonstrating the use of AI and ML in developing more accurate formulas for different types of applications related to structural design. The applications discussed include predicting shear capacity, calculating the fundamental period of structures, and predicting deflection for steel I-beams with a curved design.

Chapter 5 investigates a predictive model for the shear strength of reinforced concrete (RC) roof corner joint subjected to dynamic load. Reverse cyclic loading is applied to a RC roof corner joint to determine its shear strength. The study develops a nonlinear model to calculate the joint's shear strength in opening or closing moments. Two equations are developed using a genetic algorithm to predict the joint's shear strength, taking into account material and geometric factors such as compressive strength, joint aspect ratio, and reinforcement strength. The equations are developed using data from 61 experiments and are statistically evaluated and compared to existing models. The proposed equations are shown to be accurate and suitable for real-world applications.

Chapter 6 is about a research study that aims to develop a reliable and suitable method for calculating the fundamental period of wooden buildings, which is critical for the seismic analysis and design. An artificial neural network (ANN) model is used with the Bat algorithm to determine the fundamental period based on input parameters such as the number of stories, floor area, story height, maximum length, and maximum width. The model is trained and tested on a data set of 71 measured periods of wooden buildings. The model is evaluated against other models, including a Particle Swarm Optimization (PSO)-ANN scheme, formulas of the National Building Code of Canada, an equation from Eureqa software, and a Non-linear regression (NLR) model. The results show that the proposed model is an accurate and reliable tool for predicting the fundamental period of wooden buildings.

Chapter 7 is about the shear capacity prediction of RC elements with transverse reinforcement through a hybrid approach in which a mechanical model (the variable-angle truss model of Eurocode 2) is enhanced with two ML-calibrated corrective coefficients aimed at improving the accuracy of the numerical predictions. Genetic programming is adopted to derive closed-form expressions of the corrective coefficients, thus making the proposed formulation suitable for design purposes and usable by practitioners. The model predictive performance and the improvements over alternative code-based formulations is demonstrated through a wide database of experimental results of reinforced concrete beams and columns with plain and hollow sections failing in shear under both monotonic and cyclic loading conditions. The proposed formulation is demonstrated to be effective and accurate for practical design purposes.

Chapter 8 discusses the modelling of groundwater quantity and quality using ANNs, adaptive neuro-fuzzy inference system (ANFIS), and MODFLOW numerical-hydraulic modelling. The study focuses on the Saq Aquifer in Qassim, Saudi Arabia, and uses pumping data to determine specific storage and transmissivity parameters. The performance of the models is evaluated using Mean Square Error and Nash-Sutcliffe Efficiency of Model. The ANFIS model is found to be the most effective for modelling the aquifer, and different scenarios for sustainable groundwater pumping are examined. The research findings presented in the chapter are expected to be most helpful for water system engineers, planners, and managers in arid areas.

Chapter 9 is about the use of ANN in the reliability analysis of RC code for predicting the load carrying capacity of RC walls. The ANN-based design technique is used as an alternative to conventional design codes and physical models to estimate the ultimate load carrying capacity of RCC shear walls. A database of 95 RC wall samples has been collected from the literature. Various critical parameters have been considered, such as the length of web portion of the wall, thickness of wall boundary member, effective depth of wall, height of wall, shear span ratio, vertical steel ratio, horizontal steel ratio, yield strength of vertical and horizontal steel, compressive strength of concrete, and the ultimate load carrying capacity. The study shows that once the ANN model has been trained, it can accurately predict the response of RC members even with different geometric and material properties.

Chapter 10 examines the value proposition of ML in construction management and explores the trends in Construction 4.0. According to the study, the use of AI in construction management has long been studied as a way to improve effectiveness and efficiency while addressing common industry issues. However, the unpredictable and harsh nature of construction, combined with the high cost of technology adoption and skills gaps, have presented challenges. ML is seen as a key enabling factor for AI in construction, but it is often overlooked in discussions of the Construction 4.0 paradigm. Despite their potential, ML models are vulnerable to attacks that can decrease performance and reliability, so new models using adversarial and federated learning and the integration of blockchain are being explored for improved security and performance.

Chapter 11 is about using unsupervised learning techniques for explainable safety risk management in the construction industry. Specifically, the focus is on unsupervised ML techniques, such as clustering and dimensionality reduction, which offer advantages in analyzing and understanding complex datasets without human intervention. The chapter demonstrates the practical implementation of unsupervised ML approaches, including Principal Component Analysis (PCA) and K-means clustering, in enhancing data-centric decision-making during construction risk assessment.

Chapter 12 investigates the optimization of fuzzy logic controllers for vibration suppression of a 20-story steel structure with nonlinear behavior subjected to strong ground motions. The study considers the limitations of assuming linear behavior for structural elements and presents an enhanced optimization method using the Stochastic Paint Optimizer (SPO) with an improved method based on the Levy flight method. The fuzzy parameter optimization is conducted by the SPO and ESPO to determine the optimal rule base and membership function for fuzzy rules. The study shows that the ESPO method is capable of determining better-controlled schemes for vibration suppression of structural systems under severe seismic conditions.

To conclude, the book covers a wide range of AI- and ML-related topics which are relevant to the civil engineering industry. It also discusses the challenges and opportunities associated with the implementation of AI and ML in civil engineering, such as the need for reliable and high-quality data, the importance of interpretability and transparency, and some ethical considerations surrounding AI and ML. By exploring the latest developments and applications of AI and ML techniques in civil engineering, it is expected to have a significant impact on the field, to enhance the understanding of the subject matter, promote interdisciplinary collaboration, and inspire further research and development. The book will contribute to the advancement of the field and will help engineers to apply AI and ML techniques to solve complex problems related to infrastructure planning, design, construction, and maintenance.

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