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Emerging artificial intelligence methods in structural engineering

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Abstract : *Artificial intelligence (AI) is proving to be an efficient alternative approach to classical modeling techniques. AI refers to the branch of computer science that develops machines and software with human-like intelligence. Many problems in civil and structural engineering are affected by uncertainties that cannot be solved with traditional methods. AI aids to solve such complex problems. In addition, AI-based solutions are good alternatives to determine engineering design parameters when testing is not possible, thus resulting in significant savings in terms of human time and effort spent in experiments AI is also able to make the process of decision making faster, decrease error rates, and increase computational efficiency. Among the different AI techniques, machine learning (ML), pattern recognition (PR), and deep learning (DL) have acquired considerable attention and are establishing themselves as a new class of intelligent methods for use in structural engineering. The objective of this review paper is to summarize recently developed techniques with regards to the applications of the noted AI methods in structural engineering over the last decade. First, a general introduction to AI is presented and the importance of AI in the field is described. Thereafter, a review of recent applications of ML, PR, and DL in structural engineering is provided, and the capability of such methods to address the restrictions of conventional models are discussed. Further, the advantages of employing such intelligent methods are discussed in detail. Finally, potential research avenues and emerging trends for employing ML, PR, and DL are presented.*

Keywords - *structural engineering, artificial intelligence, machine learning, pattern recognition, deep learning, soft computing*

I. Introduction

Civil engineering is fraught with problems that defy solution via traditional computational techniques. However, they can often be solved by an expert with proper training. Classical artificial intelligence (AI) has targeted this class of problems by capturing the essence of human cognition at the highest level. The term "AI" was introduced at a workshop held in Dartmouth college in 1956 [1]. AI is a computational method attempting to simulate human cognition capability through symbol manipulation and symbolically structured knowledge bases to solve engineering problems that defy solution using conventional methods. AI has been developed based on the interaction of various disciplines; namely, computer science, information theory, cybernetics, linguistic, and neurophysiology.

Several terms referring to artificial intelligence can be found in the literature, and they need to

be identified to further elaborate on the state of the art. One of those terms is machine intelligence (MI). AI and MI are almost identical terms [2,3] and are often used interchangeably. MI is often considered a synonym of AI; yet it deals with different types of intelligent problems, e.g., clustering, classifications, computer vision, etc. In general, MI refers to machines with human-like intelligent behavior and reasoning, while AI refers to a machine's ability to mimic the cognitive functions of humans to perform tasks in a smart manner. Another important term is cognitive computing (CC), which is inspired by human mind's capabilities [4]. Cognitive systems are able to solve problems in a form mimicking humans thinking and reasoning. Such systems are based on the ability of machines to measure, reason, and adapt using learned experience[4,5]. The main characteristics of CC systems are their ability to interpret big data, dynamic training and adaptive learning, probabilistic discovery of relevant patterns.

II. OVERVIEW OF ARTIFICIAL INTELLIGENCE

In general, there are two types of machine intelligence: hard computing and soft computing methods. Hard computing, which is based on binary logic, crisp systems, and numerical analysis, requires a precisely stated analytical model and is capable of producing precise answers. Soft computing differs from conventional computing in that, unlike hard computing, it can deal with ambiguous and noisy data, incorporates stochastic information, and allows parallel computations. Soft computing is based on fuzzy logic, neural nets, and probabilistic reasoning; where the methods are able to evolve their own programs and yield approximate answers [12].

Soft computing is commonly considered a synonym of computational intelligence (CI). In fact, CI or soft computing can be expressed by the capability of a computer to learn a specific task from sample data or experimental observation. Mathematical or conventional modelling are useless in many complex real-life problems due to factors such as: complexity of the processes for mathematical reasoning, uncertainties during the process, and the stochastic nature of the process. The set of nature-inspired computational techniques defining CI provides solutions for such problems [13]. CI uses a combination of supplementary techniques such as artificial neural networks, fuzzy logic, learning theory, evolutionary computing, and probabilistic methods, and is capable of solving and approximating nonlinear problems while introducing human knowledge into the areas of computing.

III. EMERGING AI METHODS

As previously discussed, pattern recognition, machine learning, and deep learning are among the new artificial intelligence methods that are increasingly emerging as reliable and efficient tools in the field of structural engineering. This section provides technical background on the noted methods and insight regarding the use of such algorithms for structural engineering problems.

IV. SHM Systems with IoT

The durability of civil infrastructures has nowadays become a big issue given the number of structures that need to be repaired, and concerns on the efficiency of traditional techniques used to manage maintenance and repair actions. This situation is creating a paradigm shift toward cuttingedge technologies such as the Internet of Things (Iot) [258]. The IoT refers to a system in which WSNs mounted with intelligent software and local computing power could be effectively used for the monitoring of structures. IoT aims to increase machine-to-machine communication thru wireless integrated sensors with the goal of monitoring devices remotely and efficiently. In this new paradigm, smart devices collect data, transmit information, and process information collaboratively using cloud computing techniques. Software is also needed to extract useful information from the large amount of data that is generated.

v Conclusion

The durability of civil infrastructures aims to increase machine-to-machine communication thru wireless integrated sensors with the goal of monitoring devices remotely and efficiently which can be achieved by this method. the advantages of employing such intelligent methods are discussed in detail .

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