IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

DELVE IN THE NEW ERA: ARTIFICIAL INTELLIGENCE IN STRUCTURAL ENGINEERING

1st Author :**Kailas G Nath**

Mtech in Computer Aided Structural Engineering

Mar Baselios Institute of Technology and Science

Nellimattom ,Kothamangalam,Eranakulam,Kerala,India

Abstract: Artificial Intelligence (AI) is that branch of computer science that develops machines and software with humanlike intelligence. Artificial Intelligence proves to be the most promising path to more efficient practices in civil engineering. AI can be successfully implemented as a vital game changer in the field of Structural engineering to determine engineering design parameters when testing is not possible. Even with the vast range of adaptability that AI possesses, it is never, at least in the near future that AI is to be considered to perpetually replace human involvement as it can never account for the rationality that is purely human in possession. On the contrary, the essence of it is to be touchwood to assist and help in the field of structural engineering to expand their workflow. The complex and deep-learning algorithms possessed by modern AI systems provide clear cut platforms to the engineers and is something to be put resources into.

Key Words: structural engineering, artificial intelligence, machine learning, pattern recognition, deep learning, structural maintenance

1.INTRODUCTION

AI is defined as “The field of science and engineering concerned with the computational understanding of what is commonly called intelligent behavior, and with the creation of artifacts that exhibit such behavior.” The term “AI” was introduced at a conference held in Dartmouth College in 1956.[1] It 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. Machine intelligence is a similar term as that of AI. Machine intelligence refers to machines with human-like intelligent behaviour and reasoning, while AI refers to a machine’s ability

to mimic the cognitive functions of humans to perform tasks in a smart manner.[2] The development of AI techniques can be divided into the following five periods: the incubation period (before 1956), the formation period (1956-1970), the dark period (1966-1974), the knowledge application period (1970-1988), and the integrated development period (1986-present).[3]

2.DEVELOPMENT OF ARTIFICIAL INTELLIGENCE

The term Artificial Intelligence was introduced by John McCarthy. He described it in the way that process of human thinking was manipulated mechanically by symbols.[4] There are two types of machine intelligence they includes hard computing and soft computing methods. Hard computing is based on binary logic, crisp systems, and numerical analysis. This requires a precisely stated analytical model and is capable of producing precise answers. When comparing with hard computing, soft computing can deal with ambiguous and noisy data, incorporates stochastic information, and allows parallel computations. The main constituents of soft computing include neural networks, evolutionary algorithms, probability reasoning and fuzzy-logic.[5] The applications of Artificial Neural Networks are in the field of Civil engineering designing, planning, construction, and management of infrastructures such as highways, bridges, airports, railroads, buildings, dams and to predict tender bids, construction cost, and construction budget performance. Artificial Intelligence also has role in project cash flow, maintenance construction demand and labour productivity.[6]

Among AI based computational techniques, adaptive neuro-fuzzy inference systems were suitable for modelling complex systems with known input-output data sets especially to study the behaviour of cement-based materials undergoing single, dual, or multiple damage factors. The model allows construction planners to generate and evaluate optimal construction scheduling plans that minimize both project time and cost.[7]

Machine learning is a subfield of AI which is used to design a model to learn the trends, thus focusing on prediction based on known properties learned from the training data.[8] Deep learning is a tool that concentrates on learning the representations and features of the data. It is also necessary to distinguish AI from data science and big data.[9] Data mining is a cross disciplinary field used to discover valuable insights and trends in a data set and they focus on the discovery of unknown properties in an area where there is limited knowledge. Big data refers to large or complex data sets that are difficult to represent using conventional data processing techniques [Fig 1].[10]

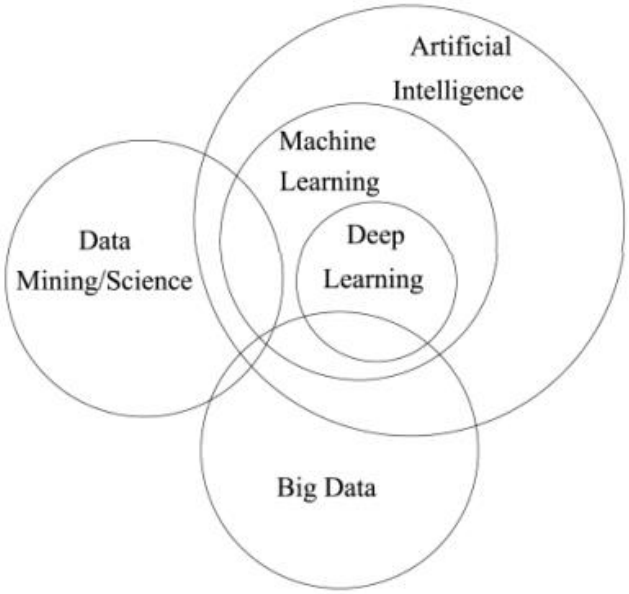

Figure 1 illustrates different intelligent techniques and their correlation.

2.1Structural System Identification

Structural System Identification (SSI) allows constructing a mathematical model of a structural system from a set of input-output measurements generated by dynamic time series signals.[11] In a study by Jiang et al. a fuzzy stochastic neural network model for nonparametric identification of civil structures using the nonlinear autoregressive moving average with exogenous inputs model through the combination of two computational intelligence techniques, i.e., fuzzy logic and neural networks.[12] The proposed model was validated using a 1:20 scaled model of a 38-storey concrete building and a benchmark 4-story 2 x 2 bay 3D steel frames.[13] Amezquita Sanchez et al introduced a new method to find the modal parameters of large structures using adroit integration of multiple signal classification and this method was applied to a 123-story super high-rise building structure, the Lotte World Tower, which is the tallest building in Korea to calculate the natural frequencies and damping ratios of the structure. He also concluded that this approach could identify the natural frequencies and damping ratios of large civil structures with high accuracy.[14]

2.2Structural Health Monitoring (SHM)

Structural Health Monitoring (SHM) is one of the subject of intensive research in structural engineering. It can be divided into two categories of image-based SHM employing the computer vision technology and vibration signal-based SHM based on the signals obtained during dynamic events. The vibration signal-based SHM involves two general approaches: parametric system identification (modal parameters identification) and non-parametric system identification. ML algorithms have been used extensively in both types of SHM.[15]

Deep learning algorithms such as Convolutional Neural Networks (CNNs) have been employed for automatic feature extraction in SHM. In these methods, feature extraction and classification steps are performed in a single step to avoid the exhaustive tests between features and classifiers [Fig 2].

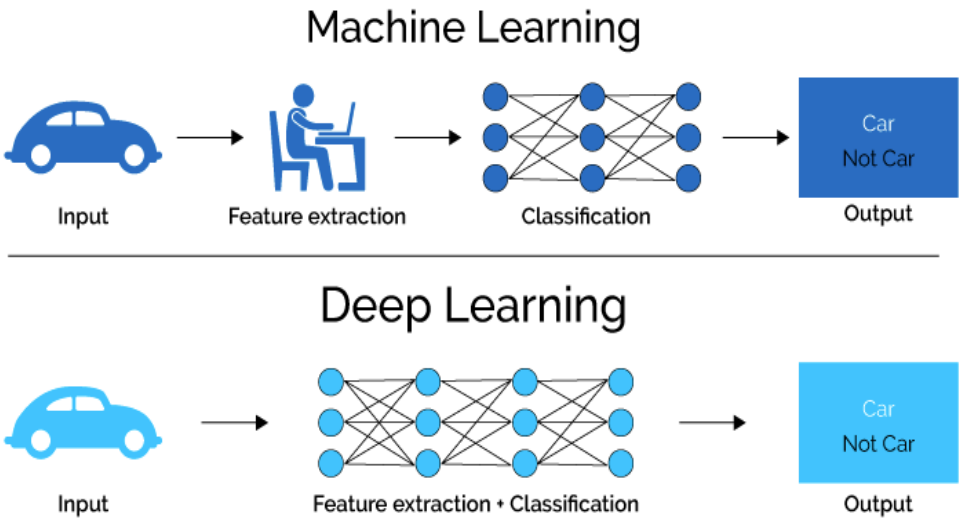

Figure 2 shows machine learning and deep learning

The effective training of supervised ML approaches requires a large set of data from healthy and damaged structures. To overcome this limitation, unsupervised ML-based methods have been proposed recently because they do not require labelling the training data from different damage scenarios.[16] In a study by Ibrahim et al, a comparison of the classification performance of three machine learning algorithms, SVM, K-Nearest Neighbor (KNN), and CNN, for evaluating the health condition of two simulated four- and eight story building structures subjected to earthquakes. They reported that CNN outperformed SVM and KNN in terms of accuracy for damage detection.[17]

3.VIBRATION CONTROL OF STRUCTURES

Vibration responses are generated by dynamic loadings such as traffic, wind and seismic activity that can negatively affect the integrity of a structure. The vibration control systems are classified under active control systems, semi active control systems, passive control systems and hybrid control systems. Computational intelligence approaches that include neural networks, fuzzy logic systems and genetic algorithms and their combination have played a significant role in the development of adaptive/intelligent control algorithms.[18] A unique aspect of this algorithm is that the structural identification and control are performed simultaneously, which makes it adaptive and more suitable for real-life structures.

It has been observed that neural network and fuzzy logic based approaches are the most commonly employed methods and their combinations provide the most powerful results. The capability to deal with non-linear properties of different dynamic systems can be achieved by using neural networks, the information uncertainty with real-world problems can be dealt with fuzzy logic approach.[19]

4.ARTIFICIAL INTELLIGENCE AS A TOOL FOR MODELING

Artificial Neural Network mimics the neural cells in human brain. Although they are a much simplified version of human brain, they can provide new directions in solving the natural tasks. ANN has the ability to learn from experience without obtaining prior knowledge about a task and is able to generalise it when presented with unseen data.[20]

Artificial Neural Networks are defined as "a massively parallel distributed processor made up of simple processing units, which has a natural propensity for storing experimental knowledge and making it available for use".[21] The neural networks have processing elements called "neurons" and the connections carry a "weight" parameter signifying the importance of link between the neurons.[22] This synaptic weights store the knowledge of the neural networks. The continuous updating of synaptic weights is undertaken by a learning algorithm known as error back – propagation.

ANN also functions as a universal function approximator as it can derive complex, non linear and unknown relationship among dependent and independent variables through a learning process.[23] Hence in the field of Civil Engineering, it can be harnessed for a variety of problems and phenomenon.[24] Despite the high advantages of the ANN, it has many disadvantages. They are ineffective in selection of initial weights and unsuitable for long term forecasting.

5.NEURAL DYNAMIC CLASSIFICATION ALGORITHM

Neural Dynamic Classification (NDC) is a new supervised classification algorithm which was developed with a goal of uncovering the most effective feature spaces and finding the optimum number of features required for accurate classification.[25] This is capable of solving highly complicated classification of problems by employing a new feature space with large margins between clusters and close proximity of the transformation functions. NDC was successfully employed for the development of an earthquake warning system and also for detection of damages in high- rise building structures.[26]

6.CONCLUSION

ANN's ability to derive enormous historical data can be coupled with the large data handling capability of the modern computers. ANN can model any functional relationship with reasonable accuracy. Machine Learning algorithms and their application in the field of Civil and Structural engineering are worth exploring. Material model based on ANN helps in explaining and deriving complex, unknown and non-linear functional relationships. This helps to simplify decision making, saves time and helps to reasonably obtain results with accuracy.

REFERENCES

1. Pei Wang 2019. On Defining Artificial Intelligence. Journal of Artificial General Intelligence 10(2) 1-37.
2. Yang, T., Cappelle, C., Ruichek, Y., and El Bagdouri, M. (2019). \Multi-object tracking with discriminant correlation filter based deep learning tracker", Integrated Computer-Aided Engineering, 26(3).273-284.
3. Huang Y,Li J,Fu J.2019. Review on Application of Artificial Intelligence in Civil Engineering. CMES, 121(3).845-875.
4. J. McCarthy, (1980). Circumscription — A form of mathematical reasoning, Artificial Intelligence 13 (1–2).
5. Falcone, R., Lima, C., & Martinelli, E. (2020). Soft computing techniques in structural and earthquake engineering: a literature review. Engineering Structures, 207, 110269
6. Baba Shehu Waziri, Kabir Bala and Shehu Ahmadu Bustani (2017). "Artificial Neural Networks in Construction Engineering and Management." International Journal of Architecture, Engineering and Construction, 6(1), 50-60.
7. Lu, P., Chen, S., & Zheng, Y. (2012). Artificial Intelligence in Civil Engineering. Mathematical Problems in Engineering, 2012, 1–22.
8. Catbas, F. N.; Malekzadeh, M. (2016): A machine learning-based algorithm for processing massive data collected from the mechanical components of movable bridges. Automation in Construction, vol. 72, pp. 269-278.
9. Cha, Y. J.; Choi, W.; Buyukozturk, O. (2017): Deep learning-based crack damage detection using convolutional neural networks. Computer-Aided Civil and Infrastructure Engineering, vol. 32, no. 5, pp. 361-378.
10. Cai, G. W.; Mahadevan, S. (2018): Big data analytics in uncertainty quantification: application to structural diagnosis and prognosis. ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems Part A-Civil Engineering, vol. 4, no. 1.
11. Sirca, G. F., & Adeli, H. (2012). System identification in structural engineering. Scientia Iranica, 19(6), 1355–1364.
12. Adeli, H., & Jiang, X. (2006). Dynamic Fuzzy Wavelet Neural Network Model for Structural System Identification. Journal of Structural Engineering, 132(1), 102–111.
13. Jiang, X., Mahadevan, S., and Yuan, Y. (2017). \Fuzzy stochastic neural network model for structuralsystem system identi cation", Mechanical Systems and Signal Processing, 82, pp. 394-411 .
14. Amezquita-Sanchez, J.P., Park, H.S., and Adeli, H. (2017).\A novel methodology for modal parameters identification of large smart structures using MUSIC, empirical wavelet transform, and Hilbert transform", Engineering Structures, 147, pp. 148-159
15. J.P. Amezquita-Sanchez et al./Scientia Iranica, Machine learningTransactions A: Civil Engineering 27 (2020) 2645{2656

16. Raei, M.H. and Adeli, H. (2017). \A new neural dynamic classification algorithm", IEEE Transactions on Neural Networks and Learning Systems, 28(12), pp. 3074-3083
17. Ibrahim, A., Eltawil, A., Na, Y., and El-Tawil, S. (2019). \A machine learning approach for structural health monitoring using noisy data sets", IEEE Transactions on Automation Science and Engineering, 17(2), pp. 900-908
18. Chiew, F.H., Ng, C.K., Chai, K.C., and Tay, K.M. (2017).\A fuzzy adaptive resonance theory-based model for mix proportion estimation of high performance concrete", Computer-Aided Civil and Infrastructure Engineering, 32(9), pp. 772-786
19. Lu, X., Liao, W., Huang, W., Xu, Y., and Chen, X.(2020) \An improved linear quadratic regulator control method through convolutional neural network-based vibration identification", Journal of Vibration and Control .
20. G. Zhang, B.E. Patuwo and M.Y. Hu, (1998), Forecasting with Artificial Neural Networks The State of the Art, International Journal of Forecasting, 14, 35-62.
21. S. Haykin, (2009), Neural Networks A Comprehensive Foundation, 8 th Edition, Pearson Prentice Hall, India.
22. L.N. Castro, (2007), Fundamentals of Natural Computing: A Review, Physics of Life Reviews, 4, 1–36.
23. S.N. Shivanandam, S. Sumathi and S.N Deepa, (2012), Feed Forward Networks, in Introduction to Neural Networks using Matlab 6.0, 16th Reprint, Tata McGraw-Hill, India
24. A. Mukherjee and J.M. Despande, (1995), Modeling Initial Design Process using Artificial Neural Networks, Journal of Computing in Civil Engineering, 9 (3), 194–200
25. Rafei, M.H. and Adeli, H. (2017).\A new neural dynamic classification algorithm", IEEE Transactions on Neural Networks and Learning Systems, 28(12), pp. 3074-3083 .
26. Rafei, M.H. and Adeli, H. (2017). \NEEWS: A novel earthquake early warning model using neural dynamic classification and neural dynamic optimization", Soil Dynamics and Earthquake-Engineering, 100,417-427 .