Chapter 17
Structural Systems Powered by AI and Machine Learning Technologies

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ABSTRACT

This chapter investigates the use of artificial intelligence (AI) and machine learning (ML) technologies in structural engineering, with an emphasis on their applications in automating design processes, optimizing structural configurations, and evaluating performance measures. It demonstrates the effectiveness of AI-powered algorithms in creating design alternatives, anticipating structural behavior, and improving sustainability. The chapter also includes a framework for comparing the performance of various structural designs, taking into account safety, cost-effectiveness, and environmental impact. It provides case studies and practical examples that show how AI/ML-driven autonomous design may achieve greater structural performance while using fewer resources. The chapter stresses the potential of AI and ML to revolutionize structural engineering by allowing engineers to design more sustainable and high-performing buildings, so contributing to a more ecologically aware and economically viable built environment.

INTRODUCTION

As architects confront the difficulty of optimizing buildings for safety and sustainability while adhering to severe budget limits, the discipline of structural engineering is seeing an increase in demand for novel solutions that emphasize sustainability and performance efficiency. Traditional structural design methods take time and rely primarily on human knowledge. AI and machine learning advancements have transformed this procedure. This chapter looks at how intelligent structural engineering may be combined with optimization approaches, performance comparison methodologies, and sustainable design principles, all of which are driven by AI and ML technologies (L. Sun et al., 2020a).

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This chapter investigates the use of AI and ML in structural engineering, with an emphasis on automation, optimization, and performance measures. It also explores sustainable design ideas and how they might be combined with AI and machine learning to develop more ecologically aware architecture. It demonstrates the advantages of AI/ML-driven autonomous design, enhancing structural performance and resource usage, using case studies and practical examples. The chapter also discusses the problems and ethical concerns related with the integration of AI and ML in structural engineering (Möhring et al., 2020).

Artificial intelligence and machine learning are reshaping structural engineering by introducing new tools and approaches for structure design, analysis, and upkeep. AI and machine learning algorithms can examine large datasets and uncover patterns that people cannot, result in better predictive modeling and risk assessment. Engineers may use artificial intelligence (AI) to examine historical data, such as construction failures and maintenance records, to detect possible concerns and offer design changes, thereby enhancing the safety and durability of buildings (Shea & Smith, 2005).

AI-powered design optimization tools assist engineers in constructing efficient and cost-effective structures by recommending new solutions that take into account criteria such as materials, load distribution, and environmental variables, decreasing costs and minimizing environmental impact. AI and machine learning are improving real-time monitoring and maintenance of structures, allowing for early diagnosis of deterioration and lowering maintenance costs. This proactive strategy protects the safety and longevity of the building. AI-driven simulations, such as complicated finite element analysis and computational fluid dynamics, may increase structural analysis accuracy and efficiency, allowing for more robust and trustworthy structure design under varying circumstances (Liu et al., 2004). AI and machine learning (ML) integration with Building Information Modeling (BIM) improves collaborative decision-making, stakeholder communication, project management, and design, construction, and maintenance results. These technologies are becoming more important in structural engineering, ushering in a new age of creativity and efficiency. Artificial intelligence and machine learning allow structural engineers to construct detailed designs that maximize cost, energy efficiency, and material utilization. ML algorithms are capable of adapting to local environmental circumstances, guaranteeing that constructions can endure earthquakes and harsh weather occurrences. AI can also access complicated data from building sensors and provide real-time feedback on structural health (Salehi & Burgueo, 2018).

AI and machine learning are critical for risk assessment, discovering possible flaws in new initiatives, and reducing structural failures. They also contribute to the advancement of sustainable building practices by improving building designs for energy efficiency and sustainability. AI algorithms can detect renewable energy sources and optimize HVAC systems for energy efficiency (L. Sun et al., 2020b). By examining their performance and environmental effect, ML promotes the adoption of sustainable materials. AI and machine learning are also hastening innovation in materials science and building practices. They may aid engineers in the development of novel composite materials with increased strength and durability (Huang & Fu, 2019). Furthermore, AI can enhance building operations, increasing productivity and decreasing waste. AI can identify areas for process scalability by analyzing construction data, resulting in cost savings and more sustainable practices (Pan & Zhang, 2021).AI and ML are increasingly being used in urban infrastructure design and maintenance, enabling predictive maintenance systems for critical components such as bridges and tunnels. These smart city projects enhance traffic flow, manage utilities, and react to crises, ensuring that urban settings run smoothly (Guo et al., 2021).

By enhancing safety, efficiency, and sustainability, artificial intelligence and machine learning are changing structural engineering. These technologies allow data-driven choices, optimize designs, and