

# Practical Exploration of Simulation Technology Based on Artificial Intelligence in Engineering Design

Nan Zou<sup>1, a</sup>, Qiaofeng Wang<sup>1, b</sup>, Xiaonan Li<sup>2, c</sup>

<sup>1</sup>CATARC(Tianjin) Automotive Engineering Research Institute Co., Ltd. China

<sup>2</sup>Tianjin Vocational College of Mechanics and Electricity, China

<sup>a</sup>zounan@catarc.ac.cn, <sup>b</sup>wangqiaofeng@catarc.ac.cn, <sup>c</sup>lixiaonan123@126.com

## Abstract

**This paper discusses the application and practice of the simulation technology based on artificial intelligence (AI) in the field of engineering design. By integrating AI into the traditional engineering design process, we can achieve more efficient and accurate design solutions. Taking a specific engineering design project as an example, this article shows how AI simulation technology contributes to design optimization, risk assessment and cost control. The results show that AI simulation technology can not only improve the design quality, but also shorten the design cycle, bringing revolutionary changes to the field of engineering design.**

## Keywords

**Artificial Intelligence; Simulation Technology; Engineering Design; Design Optimization; Risk Assessment.**

## 1. Introduction

In today's rapidly developing field of engineering technology, the combination of artificial intelligence and simulation technology has brought unprecedented opportunities and challenges to engineering design. Traditional design methods face the dilemma of inefficiency and difficulty in dealing with complex design problems. This paper will deeply discuss how the ai-based simulation technology can innovate the engineering design process, and promote the development of engineering design to a higher level by improving the design efficiency and accuracy. The core of this study, namely the application of AI simulation technology in engineering design, aims to attract readers to explore how this technology can be a key force driving innovation in engineering design.

## 2. Application Status of Artificial Intelligence in Engineering Design

In the field of contemporary engineering design, artificial intelligence (AI) technology has become an indispensable tool, which plays a crucial role in the generation of design solutions, effect prediction and performance analysis. In particular, AI technologies such as deep learning and computer vision enable designers to quickly identify and solve potential design problems in the early stages of a project, greatly improving the efficiency and quality of engineering design[1].

Deep learning technology, inspired by the intricate neural network structure of the human brain, has emerged as a pivotal force in transforming design processes across various industries. By simulating the way neurons interact within the human brain, deep learning algorithms can process and analyze colossal amounts of data with astonishing efficiency and accuracy[2]. This capability enables the identification of potential problems and opportunities within design

projects that human analysts might overlook due to the sheer volume and complexity of the data involved.

Deep learning's proficiency in navigating through and interpreting vast datasets offers a transformative advantage to designers and engineers, allowing for a preemptive approach to identifying and addressing potential challenges in the design process. This capability is particularly influential in fields where complexity and precision are paramount, such as architecture and product design[3].

In the realm of architecture, deep learning algorithms serve as a critical tool in enhancing the safety, sustainability, and functionality of building designs. By ingesting and analyzing a multitude of past case studies, simulations, and real-world performance data, these algorithms can identify patterns and correlations that might not be evident to human designers. For instance, deep learning can evaluate various factors such as material properties, environmental conditions, and structural loads to predict potential structural weaknesses in a building design. This analysis enables architects to make informed decisions and revise their designs proactively, potentially preventing costly and dangerous failures. Additionally, such algorithms can simulate different scenarios, such as extreme weather conditions or earthquakes, to ensure that buildings can withstand these challenges, thereby contributing to safer and more resilient infrastructure[4].

In the sphere of product design, deep learning offers significant advantages by identifying potential usability issues or design elements that may complicate manufacturing processes. By learning from historical data on similar products, including customer feedback, production logs, and warranty claims, deep learning algorithms can flag designs that are likely to encounter user dissatisfaction or high manufacturing costs. This insight allows designers to refine their products to be more intuitive and cost-effective to produce. Furthermore, these algorithms can suggest alterations or enhancements that could make the product more appealing or functional, based on trends and patterns identified in the data. This level of analysis not only improves the likelihood of a product's success in the market but also streamlines the manufacturing process, reducing waste and increasing efficiency[5].

Beyond identifying potential issues, deep learning facilitates a more innovative and dynamic approach to design. By analyzing extensive datasets, these algorithms can uncover novel design principles and trends that may not be immediately obvious, inspiring designers to explore new concepts and solutions. This can lead to breakthroughs in design that balance aesthetics, functionality, and sustainability, pushing the boundaries of what is currently considered possible.

Moreover, the integration of deep learning into the design process promotes a more collaborative and iterative approach to development. Designers, engineers, and stakeholders can leverage the insights generated by deep learning algorithms to make data-driven decisions, ensuring that all aspects of a design are optimized for performance, user experience, and manufacturability. This collaborative environment, supported by real-time data and analytics, enhances the efficiency of the design process and reduces the time from concept to market.

As these technologies continue to advance, their potential applications within design will expand further. Deep learning could enable more personalized and adaptive designs, where products and environments dynamically adjust to meet individual user needs and preferences. In architecture, this might mean buildings that adapt to optimize energy use based on occupancy and weather conditions, while in product design, it could lead to customizable products that adjust to user feedback and usage patterns over time.

In summary, the application of deep learning in design processes heralds a new era of innovation, efficiency, and collaboration. By leveraging the ability to analyze and learn from extensive datasets, designers and engineers can anticipate potential challenges, explore novel

solutions, and bring to market products and structures that are safer, more user-friendly, and more sustainable. As these technologies evolve, their impact on the design world will undoubtedly grow, leading to more intelligent, responsive, and successful designs. Computer vision technology, a subset of deep learning, further enhances the capabilities of designers by allowing them to analyze and interpret image and video data with unprecedented depth and nuance. This technology can automatically process visual data from sketches, models, and real-world environments, providing insights into the feasibility, aesthetics, and potential risks associated with a design scheme. For instance, computer vision algorithms can analyze images of traffic flow to help urban planners design more efficient road layouts, or they can evaluate video footage of user interactions with a prototype to identify design elements that may hinder usability.

Moreover, the integration of deep learning and computer vision technologies facilitates a more iterative and dynamic design process. Designers can quickly generate multiple design variations, each optimized for different criteria such as cost, performance, or environmental impact, and then use these technologies to assess and refine them. This iterative loop, powered by rapid analysis and feedback, greatly accelerates the design process, allowing for a level of experimentation and optimization that was previously unattainable.

Beyond problem identification and solution proposal, deep learning and computer vision also offer the potential for enhancing creativity and innovation in design. By analyzing trends and patterns across vast datasets, these technologies can suggest novel design elements and combinations that may not be immediately apparent to human designers. This could lead to breakthroughs in fields ranging from fashion and industrial design to architecture and engineering, where the blend of historical data analysis and creative insight can yield truly innovative solutions.

Additionally, as these technologies continue to evolve, their integration into collaborative platforms and tools is fostering more cohesive and multidisciplinary design teams. Engineers, designers, and stakeholders can now work together more seamlessly, sharing insights and data-driven recommendations in real-time, thus ensuring that all aspects of a design are aligned with the project's overall objectives and constraints. In conclusion, deep learning and computer vision are revolutionizing the way we approach design, offering powerful tools for analyzing data, identifying potential problems, and exploring innovative solutions. By harnessing these technologies, designers can anticipate challenges, optimize designs, and push the boundaries of creativity and innovation. As these tools become more sophisticated and integrated into the design process, we can expect to see even more remarkable advancements in the designs of products, buildings, and systems that shape our world. In addition, AI simulation techniques, especially fluid dynamics simulation (CFD) and finite element analysis (FEA), provide strong support for engineering design. The CFD technology can simulate the flow of gases and liquids in the design, while the FEA technology is used to predict the reaction of the material under force<sup>[1]</sup>. These simulation techniques can predict the performance indexes of stress, deformation and fatigue under different environmental conditions, and provide scientific basis for design decisions.

Although AI technology has shown great potential in improving design accuracy and efficiency, it still faces the challenges of data processing power and model accuracy when dealing with complex engineering projects. The amount of data involved in the design process is usually very large, and there are many kinds of data, including graphic data, structural parameters, environmental variables, etc., which puts forward higher requirements for the processing capacity of the AI system. At the same time, the improvement of design complexity also requires that AI models must have higher accuracy and reliability to ensure the practicality and safety of the design scheme.



**Fig 1.** Artificial intelligence simulation technology

### **3. Artificial Intelligence-based Simulation Technology Solutions and its Impact**

Faced with the challenge of the application of artificial intelligence (AI) in engineering design, the researchers have proposed innovative simulation technology solutions by adopting advanced machine learning algorithms and computational technologies. These solutions are not only aimed at improving data processing capability and model accuracy, but also aim to optimize the entire design process to improve the efficiency and security of engineering design. The incorporation of advanced machine learning algorithms like Support Vector Machines (SVM) and Artificial Neural Networks (ANN) into simulation models represents a transformative leap in the way design processes are conducted. These algorithms are adept at sifting through vast amounts of historical design data, enabling the models to discern patterns, identify crucial features of successful designs, and pinpoint recurrent issues in designs that have failed. This analysis and learning capability allows for a more informed and nuanced approach to new design schemes, offering a roadmap to circumvent previous mistakes and substantially enhance the likelihood of success in future endeavors.

The remarkable capabilities of Support Vector Machines (SVM) and Artificial Neural Networks (ANN) to digest and learn from a vast array of case studies render them indispensable tools in the modern design landscape, particularly in fields marked by intricate challenges and steep costs associated with failures, such as aerospace, automotive engineering, and sustainable energy solutions. These machine learning algorithms excel in extrapolating from historical data to predict outcomes in novel scenarios, thereby serving as a linchpin for innovation and efficiency in design processes.

In aerospace engineering, for instance, the stakes are exceptionally high, with the safety of passengers and crew hanging in the balance. SVM and ANN can scrutinize previous design iterations, flight data, and simulation results to identify design elements that might compromise aircraft safety or performance. By predicting how new designs will perform under a range of conditions, including extreme weather and mechanical stresses, these algorithms empower engineers to proactively address potential issues, leading to safer and more reliable aircraft. This predictive capability not only mitigates risks but also significantly accelerates the development cycle by reducing the need for extensive physical prototyping and testing.

Similarly, in the automotive industry, where consumer safety and product reliability are paramount, SVM and ANN can analyze vast datasets encompassing crash test results, consumer feedback, and performance metrics. This analysis enables the identification of design features that enhance safety and performance, guiding engineers towards solutions that improve vehicle reliability and efficiency. Additionally, by forecasting the outcomes of new designs, these algorithms can streamline the validation process, ensuring that new vehicles meet stringent safety standards and consumer expectations more quickly and cost-effectively.

In the realm of sustainable energy solutions, the application of SVM and ANN holds the promise of accelerating the transition to greener technologies. These algorithms can evaluate historical

performance data from renewable energy systems, such as wind turbines and solar panels, to optimize designs for maximum efficiency and durability. By predicting how these systems will perform in diverse environmental conditions, engineers can devise solutions that are not only more efficient but also more resistant to wear and degradation. This optimization is crucial for scaling up renewable energy technologies, making them more viable and cost-effective alternatives to fossil fuels.

Moreover, the capacity of SVM and ANN to generalize from past data to predict future outcomes enables a more iterative and responsive approach to design. Engineers can quickly test and refine their ideas, exploring a wider range of solutions and innovations with greater confidence in their potential success. This iterative process, underpinned by data-driven insights, fosters creativity and innovation, pushing the boundaries of what is possible in design and engineering. The integration of these algorithms into the design process represents a paradigm shift, moving away from traditional, often cumbersome, methods of trial and error. By leveraging the predictive power of SVM and ANN, engineers and designers are equipped with the tools necessary to make more informed decisions, optimize design processes, and reduce both the time to market and the environmental footprint of new products and technologies. As these machine learning algorithms continue to evolve and improve, their impact on the design and engineering fields will undoubtedly grow, ushering in an era of unprecedented efficiency and innovation. Moreover, the predictive power of these machine learning algorithms extends to forecasting the performance of design models under specific environmental conditions. This ability is critical in designing systems that are resilient to varying climates, operational stresses, and other external factors. For instance, in the construction of buildings or infrastructure, being able to predict how materials and structures will respond to different weather conditions or natural disasters can lead to safer, more durable designs. Furthermore, as these machine learning tools continue to evolve, they are increasingly capable of handling more complex data and delivering insights into more intricate design elements. This progression opens the door to innovations that were previously unimaginable, pushing the boundaries of what can be achieved in various engineering fields. The integration of SVM and ANN into simulation models not only aids in enhancing the accuracy of predictions but also facilitates a deeper understanding of the interplay between different design elements and their impact on overall performance.

In summary, the use of SVM and ANN in simulation models is revolutionizing the design process by enabling a data-driven approach that leverages historical insights to guide future innovations. This approach not only improves the success rate of new designs by avoiding past pitfalls but also enhances the predictability and performance of designs in specific environmental conditions, leading to more resilient and efficient solutions. As these technologies continue to advance, their integration into design and simulation workflows will undoubtedly play a pivotal role in driving forward the next wave of engineering and architectural breakthroughs. The application of cloud computing and edge computing technology is to solve the challenges of processing large-scale design data by providing powerful computing resources and data storage capabilities. Cloud computing allows designers to access computing resources on remote servers over the network, efficiently processing and analyzing complex design data without worrying about computing and storage limitations on local computers. Edge computing technology distributes the data processing tasks to the devices on the edge of the network [6], reducing the data transmission time and improving the processing efficiency. The combination of these two computing techniques greatly improves the ability of AI simulation to deal with complex engineering design problems [7]. The simulation technology based on artificial intelligence has a significant effect in the practical application. For example, in a bridge design project, by using AI simulation technology, designers can accurately predict the performance of bridge structures under different loads

and environmental conditions at the design stage. This not only provides a solid scientific basis for the design decisions, but also avoids the potential problems in the construction stage, reduces the correction cost and time, and improves the safety and economic benefits of the project.

#### 4. Conclusion

The application of the simulation technology based on artificial intelligence in the field of engineering design has significantly improved the efficiency and accuracy of the design, optimized the design process, and provided a new perspective and method for the future development direction of engineering design. Through continuous exploration and innovation, these technologies will bring a broader development prospects for the field of engineering design.

#### References

- [1] Wu Chongguang. Progress in simulation technology and its application in petrochemical engineering design [J]. Petrochemical Automation, 2001, (06): 6-9 + 0.
- [2] Business Process-Based Information Security Risk Assessment. Khanmohammadi K; Houmb S H. 4th International Conference on Network and System Security. 2010.
- [3] Li Lin, Shan Changji. Overview of the application of system simulation in engineering design [J]. Heilongjiang Science and Technology Information, 2014, (07): 1.
- [4] Integration of SERVQUAL, Analytical Kano, and QFD using fuzzy approaches to support improvement decisions in an entrepreneurial education service[J]. Lizarelli Fabiane L.; Osiro Lauro; Ganga Gilberto M.D.; Mendes Glauco H.S.; Paz Guilherme R.. Applied Soft Computing Journal, 2021.
- [5] Development of moulds for thermoforming using FFF additive manufacturing and axiomatic design[J]. Boca M A; Slatineanu L; Sover A. IOP Conference Series: Materials Science and Engineering, 2021.
- [6] Axiomatic design of matrix production systems[J]. Foith-Förster Petra; Bauernhansl Thomas. IOP Conference Series: Materials Science and Engineering, 2021.
- [7] Learning-Based Methods of Perception and Navigation for Ground Vehicles in Unstructured Environments: A Review.[J]. Guastella Dario Calogero; Muscato Giovanni. Sensors (Basel, Switzerland), 2020.