

A Critical Review of Generative Design Methods in Computer-aided Drafting

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Abstract

In the realm of computer-aided drafting (CAD), generative design methods have become a potential strategy for automating and enhancing the design process. These methods generate a wide range of design possibilities based on given characteristics and limitations by using algorithms and computational tools. The objective of this critical study is to assess the benefits, drawbacks, and implications of generative design techniques in CAD. A notable result of this merger is generative design methodologies, which have attracted a lot of interest in the field of CAD. These methodologies promise to transform the established design process, and use algorithms and computational tools to generate a wide range of design options. But, like with every innovation, some potential and difficulties call for a critical analysis.

Keywords: CAD, design, 2D modeling, design for manufacturing (DFM), industry

INTRODUCTION

The combination of computer-aided drafting (CAD) and generative design techniques has become a game-changing strategy in the field of contemporary design and engineering. With a focus on their synergies, drawbacks, and consequences for numerous industries, generative design techniques and computer-aided drawing are intricately intertwined in this critical review.

The Evolution of Generative Design and CAD

From experimental niche notions to commonplace design and engineering tools, generative design methodologies have seen a remarkable evolution. These techniques make use of algorithms and computing power to produce a wide range of design options depending on given characteristics and limitations. Parallel to this, advanced digital platforms have emerged for CAD, which now allows for accurate 2D and 3D modeling and visualization. By combining these two fields, designers and engineers may now investigate intricate design spaces and uncover solutions that could not have been considered otherwise [1–4].

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Importance and Use of Researching These Techniques

Due to the revolutionary potential these methods bring to the design process, efficiency, and innovation, investigating generative design methodologies in the context of CAD holds enormous importance and relevance.

EFFICIENCY AND ACCELERATED DESIGN ITERATIONS

Using generative design techniques, a large range of design options can be quickly explored. This

effectiveness speeds up the design iteration process and enables designers to quickly assess several options. The generation, analysis, and modification of design possibilities may take much longer with traditional manual design procedures. Generic techniques improve the productivity of designers and the timetable of the entire project by speeding up this cycle [5–7].

Taking on Difficult Design Challenges

Many contemporary design problems entail complicated limitations and requirements that can be challenging to handle by using only conventional techniques. By considering a wide range of options, generative design techniques excel at addressing complex design spaces. They are especially useful in sectors like design, engineering, and science because they can spot novel solutions that may not be obvious through standard methods.

ADVANCING DESIGN EDUCATION AND PROFESSIONAL SKILLS

Designers and students are required to acquire new abilities in algorithmic thinking, computational analysis, and data interpretation because of the integration of generative design methodologies. This change in skill sets improves the educational and professional environment and equips designers for a future when technology will play a bigger part in the design process.

Holistic Design Approach

Generative design techniques promote a more integrated design process in which a variety of elements, such as appearance, functionality, usability, and sustainability, are considered simultaneously. This thorough review produces designs that are well-rounded and more closely match the diverse requirements of users and stakeholders.

Considering that generative design techniques have the potential to transform design processes, encourage creativity, and offer data-driven insights, it is vital to investigate them in the context of CAD. These techniques are not only pertinent but also crucial for pushing the limits of design excellence in a variety of industries due to their effectiveness, versatility, and transformative effects.

APPLICATIONS

The generative design method was initially used in the area of architectural design, but it is now used in various applications, like industrial design, jewelry design, consumer product design, etc. Its few applications and advantages are given below.

- It has application in the conceptual or initial design phase as it provides several design shapes.
- For example, it can be used in the ornament industry mainly in jeweler design to generate several designs with less effort.
- It can be integrated with design for manufacturing (DFM) software to ensure manufacturability.
- It enables the design engineer to explore multiple ideas and make better-informed decisions during the early design stage.
- It reduces the process time, as a designer must explore the different designs by traditional methods like 2D drawing and hand sketching, etc.

The generative design method was first employed in the field of architectural design, but it is currently utilized in a variety of applications, including jewelry design, consumer product design, industrial design, and others.

Below are a few of its applications and benefits.

- Because it offers a variety of design shapes, it can be used in the conceptual or basic design phase. For instance, it can be applied to the ornament industry, specifically jewelry creation, to quickly produce many designs.
- To assure manufacturability, it can be coupled with DFM software. It allows the design engineer to consider a variety of options and come to more educated decisions at the initial design phase.

- It shortens the process time because the designer must investigate several designs using the more conventional techniques of 2D drawing and hand sketching [8].

Industries Where These Methods are Commonly Applied

Numerous industries where difficult design challenges, optimization, and innovation are crucial have found use for generative design methodologies. Here are a few examples of fields where these techniques are frequently used:

Architecture and Construction

Innovative building structures are made through generative design that is not only visually appealing but also structurally sound and resource-efficient. By producing building layouts that make use of natural lighting, ventilation, and energy sources, it can help to maximize energy efficiency and sustainable design [9].

Automotive and Aerospace

In the automotive sector, generative design can produce strong yet lightweight components, improving fuel economy and lowering pollutants. To improve performance while reducing weight, aerospace engineers employ generative methods to build intricate components like airplane frames and engine elements.

Product Design and Manufacturing

Designing consumer goods with complicated shapes and efficient material consumption is made easier with the help of generative design. Better product aesthetics and ergonomics may result from this. These techniques can improve tool routes in manufacturing, cutting costs and production times while retaining quality.

Industrial Equipment and Machinery

For industrial machinery and equipment, generative design is utilized to develop specialized and optimized parts that adhere to strict operating limitations and performance specifications.

Energy and Renewable Resources

To improve the performance and efficiency of renewable energy structures like wind turbine blades and solar panel arrays, generative design techniques are used in the energy sector. One of the main benefits of employing generative design techniques in the field of CAD is efficiency and rapid design iterations. These advantages have the power to transform the design process and foster creativity.

Rapid Exploration of Design Space

Based on predetermined parameters and limitations, algorithms are used in generative design methodologies to produce a wide range of design choices. This makes it possible for designers to quickly explore a huge design space that would be difficult to do manually. Designers can cover a significantly wider variety of possibilities in a fraction of the time it would take using conventional approaches by automating the development of various options.

Quick Iterations and Assessment

With generative design, designers may quickly test the viability of numerous design iterations. Because the process is automated, designers can quickly develop, assess, and alter designs. The ongoing improvement and optimization of design solutions are made possible by this iterative cycle [10].

Efficient Problem Solving

The term generative design techniques can effectively produce solutions that satisfy certain requirements and restrictions when faced with difficult design challenges. Designers can specify the goals and constraints, and the algorithm will look for solutions that satisfy them. This effectiveness is especially valuable in fields like product development and production where time is of importance.

COMPARING MANUAL DESIGN APPROACHES TO GENERATIVE DESIGN

In the field of CAD, comparing generative design with traditional design procedures highlights the various benefits and restrictions of each strategy. Although each approach has advantages, they are best suited for different stages of the design process. While traditional design procedures place a higher value on human intuition, creativity, and a comprehensive understanding of design, generative design methods stress efficiency, data-driven insights, and quick exploration. Both strategies have a place in the design spectrum, and when they work together, they can provide creative, well-rounded solutions. The decision between the two is based on the requirements, objectives, and creative inclinations of the project.

Generative Design

Advantages

1. *Efficiency and speed:* Automated design exploration using generative design methodologies produces many options quickly. When time is an important consideration, this efficiency is especially advantageous.
2. *Handling complexity:* These methods excel at handling complicated design difficulties, considering several characteristics and restrictions at once, which may be overwhelming or time-consuming for manual designers.
3. *Data-driven insights:* Generative design makes use of data analysis to identify connections and trends in design that might not be immediately obvious through manual approaches.
4. *Multidisciplinary optimization:* These techniques can balance numerous elements, including material utilization, structural integrity, and performance, to optimize designs across multiple criteria.
5. *Innovation and creativity:* Generative design frees designers to concentrate on creative aspects and investigate unorthodox design concepts by automating regular chores.

Manual Design Processes

Advantages

1. *Human intuition:* Manual design methods rely on the intuition and creativity of the designer, allowing the implementation of individualized artistic and esthetic preferences.
2. *Holistic design approach:* Designers can combine their knowledge and experience to explore a wider context, considering not just user preferences and human issues but also technical limitations.
3. *Problem-solving flexibility:* Manual designers have the freedom to change their strategy and consider novel ideas that may not be produced by algorithms.
4. *Iterative decision-making:* Designers can alter parameters and designs depending on their insights and judgments at each level of the design process.

The incorporation of generative design techniques into CAD emphasizes the growing demand for designers and CAD professionals to develop their algorithmic design and computational thinking abilities. These abilities are crucial for utilizing the full potential of generative design and remaining competitive in the sector as technology continues to play a bigger part in the design process.

Harnessing Generative Design Tools

Algorithms are used in generative design methodologies to automate the generation and assessment of design choices. Designers must comprehend how algorithms operate, how to enter parameters, and how to interpret the results to use these tools successfully. Gaining knowledge of algorithmic design equips designers to make wise choices during the generative design process.

Enhancing Design Results

The ability to successfully manipulate variables and constraints is a result of algorithmic design expertise. This knowledge can result in optimized design outputs that satisfy requirements, whether they be maximizing structural integrity, decreasing material usage, or achieving energy efficiency. Designers can repeat and improve ideas with computational thinking to achieve better performance.

Collaboration with Engineers and Programmers

When using generative design techniques, engineers or programmers who implement the algorithms frequently work in tandem with designers. Effective communication and collaboration across disciplines are made possible by expertise in algorithmic design and computational thinking.

Getting Ready for Industry Trends

Industries are adopting automation, AI, and data-driven decision-making more and more. Professionals who develop their computational thinking and algorithmic design skills are at the forefront of these trends and are better equipped to adapt to changing employment demands.

CONCLUSION

In CAD, generative design techniques have revolutionary potential. These approaches to design, problem-solving, and innovation have the potential to change how we do these things in a variety of industries. The potential influence of generative design tools is becoming more and more obvious as technology develops. Optimization is a strength of generative design, whether the goal is to reduce material consumption, increase energy efficiency, or improve structural integrity. The ability to automatically produce designs that satisfy performance requirements may result in more practical and affordable solutions. Collaboration between designers, engineers, programmers, and other specialists is promoted via generative design. This interdisciplinary approach encourages creative solutions that draw on a variety of expertise and builds a holistic knowledge of design difficulties.

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