3D solid design algorithms

B S Malsagov¹, M V Sygotina² and O V Yalovenko³

¹Chechen State University, 17a, Dudaev Boulevard, Groznyy, 364015, Russia
²Bratsk State University, 40, Makarenko St., Bratsk, 665709, Russia
³Irkutsk National Research Technical University, 83, Lermontov str., Irkutsk, 664074, Russia

E-mail: kafedra.bi@mail.ru

Abstract. With the development of technology, it has become possible to use artificial intelligence in design and engineering, thanks to this, they are now beginning to introduce a completely new technology called generative design. Generative design is based on the use of artificial intelligence, which is able to generate and optimize three-dimensional models that meet the specified conditions. This technology is suitable for solving complex multi-criteria tasks. This article describes the methods, functions, and tasks that generative design uses and solves.

1. Introduction
Currently, CAD/CAE/CAM is mainly used as computer-aided design systems. The CAD system is designed for the development of 3D models, design and technological documentation; CAE for engineering calculations and simulation of physical processes; CAM for the preparation of the production process. Design automation involves the systematic use of computer technology with a rational distribution of functions between the designer and the computer and a reasonable choice of methods for machine problem solving. The goals of creating computer-aided design systems are: reducing labor intensity and planning; reducing time; reducing cost, reducing production time, reducing operating costs; improving the quality and technical and economic level of design results; reducing the cost of field modeling and testing. The traditional design process requires a lot of time, experience and knowledge in various fields [1, 2, 9–11].

This is a very time-consuming process, and therefore it is possible to consider only three or four versions of the product. It often happens that the results of the design do not meet the desired parameters. Today, we need fundamentally new problem-oriented software tools developed using a single technology for specific application conditions [3]. Over the past decade, rapid advances in such areas as additive manufacturing, artificial intelligence, cloud computing, generative design tools, and 3D printing have allowed a new direction in design to develop as generative design. Generative design is already beginning to be used as the main tool for computer-aided design [12, 13].

Generative design is a design technology that, independently of the participation of engineers, is able to generate three-dimensional models that meet the specified conditions. This technology is based on the use of artificial intelligence and cloud computing [4].

2. Methodology
Generative design uses machine learning to mimic nature's evolutionary approach to design. First of all, engineers calculate the parameters (materials, dimensions, weight, strength, rigidity, production...
methods, and cost constraints) that the designed product or part will meet. After the calculations, the obtained parameters are entered into the program, then, with the help of artificial intelligence, genetic algorithms and cloud computing, the program independently generates various versions of three-dimensional models that meet the specified conditions. After that, engineers and designers consider all the options and choose the most suitable one from the received options. At each iteration, generative design works through the structure and studies each step, applying changes at each step to help create an optimized solution that meets the design goals within the specified parameters. The part is optimized by removing excess material, but it does not lose its strength characteristics. At the final stage, the resulting product or part is tested, and only then transferred to production. In Fig. 1 shows the process of creating products using generative design.

3. Results and discussion
The generative design process often results in projects that cannot be created using the traditional design process. Since genetic algorithms are often used, the shape of the resulting product is most often organic, it combines smooth lines, a distributed structure of thin and tubular structures. Organic molds are not easy to make using traditional methods, but they are ideal for 3D printing

![Image]

Figure 1. Generative design process [5]

Tasks that generative design solves. Weight reduction. As can be seen from Figure 2 (model 2), products developed using generative design can significantly reduce weight compared to traditional design methods:
1. Performance improvement. By reducing the weight of the structure, the characteristics are optimized in accordance with the specific design requirements, while using the least amount of material for this purpose. Figure 2 (model 2) shows a chair created by the generative design method. This design is 20% stronger than the one created by the traditional method (model 1);
2. Reduction of time limits. Thanks to the use of infinite calculations, you can explore many project options in a short time, and it will take a long time to create a single project using the traditional approach;
3. Lots of options. As a result of creating a variety of options, designers and engineers can choose the one that best meets the specified parameters and design;
4. Efficiency. Since modeling and testing can be incorporated into the generative design process, this saves designers and engineers time, otherwise the iterative changes typical of a more traditional design process are lost.

The development of a product under the order. Thanks to the use of generative design and additive manufacturing, complex geometry, specially designed and optimized to meet individual needs, has become much more accessible than ever before [6, 14, 15].
4. Conclusion

In recent years, generative design has been introduced in many areas of design. Combined with new production methods, generative design will allow for the near future to create high-quality products that traditional design and production technologies cannot reproduce. Products will take on new shapes and be made from unique materials as computers help engineers create previously impossible-to-understand solutions [7, 8]. The use of generative design and 3D printing techniques will make a big leap in the development of architecture, medicine, manufacturing, construction and art.

5. References

[1] Potyomkin D A, Trushko V L and Trushko O V 2018 The stress-strain behaviour of the protective pillars of a subbarrier zone using the ore deposits mining combined system *International Journal of Mechanical Engineering and Technology* 9(3) 1046–1052

[2] Trushko V L, Trushko O V and Potemkin D A 2018 Efficiency increase in mining of highgrade iron ore deposits with soft ores *International Journal of Mechanical Engineering and Technology* 9(3) 1038–1045

[3] Sidorenko A A, Belova D V and Sirenko Y G 2020 Justification for the parameters of extraction panels under the conditions of increased water inflows using computer models of rock mass *Journal of Physics: Conference Series* 1661 DOI: 10.1088/1742-6596/1661/1/012110

[4] Pearson M 2011 *Generative Art* (Manning Publications) pp 18–19

[5] Agkathidis A 2016 *Generative Design: Form Finding Techniques in Architecture* (London: Laurence King Publishing)

[6] Autodesk Solutions Retrieved from: https://www.autodesk.com/solutions/generative-design

[7] Bovkun A and Korodyuk I 2019 Analysis of the development of small innovative enterprises in the construction industry *IOP Conf. Ser.: Mater. Sci. Eng.* 667

[8] Repinskiy O D, Konyukhov V Yu, Bovkun A S and Schupletsov A F 2021 Improving the competitiveness of Russian industry in the production of measuring and analytical equipment *Journal of Physics: Conference Series* 1728
[9] Grinek A V, Timofeev S P, Kondrat'ev S I and Hurtasenko A V 2020 Method of controlling geometric accuracy for ship shafts Marine intellectual technologies 3(1) 90–96
[10] Grinyok A, Boychuk I and Perelygin D 2018 Simulation in production of open rotor propellers: From optimal surface geometry to automated control of mechanical treatment IOP Conference Series: Materials Science and Engineering 327(2) 022038
[11] Kondratyev S I and Faivisovich A V 2018 Prediction of wave load effect on crack growth in structural elements of ship Marine intellectual technologies 1(1) 140–147
[12] Chefranov A, Dukhnich E and Shapel A 2020 One-Time Involutory Matrix-Based Hill Cipher Modification International Journal of Information Assurance and Security (IJAIS) 15(4) 165–174
[13] Ignatenko A V, Frolov M M and Khudiakov S A 2020 Increasing the reliability of electronically controlled marine diesel parts Marine intellectual technologies 4(4) 45–52
[14] Sysoev I A, Kondrat'ev V V, Zimina T I and Karlina A I 2018 Simulation of the Energy States of Electrolyzers with Roasted Anodes at Elevated Currents Metallurgist 61(11-12) 943–949
[15] Kondratiev V V, Karlina A I, Guseva E A, Konstantinova M V and Gorovoy V O 2018 Structure of Enriched Ultradisperse Wastes of Silicon Production and Concretes Modified by them IOP Conference Series: Materials Science and Engineering 463(4) 042064