PRODUCT CUSTOMIZATION AND GENERATIVE DESIGN

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Abstract

Parametric design is essentially a generative design that can be created using a computer and mathematical relationships. In a process-oriented way (instead of changing the shape), we modify the components' parameters that make up the shape, resulting in a new look. Because manipulations' consequences can be seen immediately, the development of product families and new product variants can be implemented quickly. With the help of parametric design, customizing the product and increasing customer satisfaction is more efficient, as several successful projects have already shown in automotive industry, aircraft manufacturing, architecture, jewelry manufacturing, etc.

Keywords: Generative design, Customization, Algorithm, Parametric design

1. Introduction

Studies have shown [1] that product customization is important to reach more customer satisfaction. For example, Deloitte found out that one out of five customers is willing to pay 20% more for a unique, personalized product [2]. This is why it has become a business strategy in many fields, from shoe design to vehicle features.

Parametric or generative design (also known as algorithmic design) can have a great future because by using it, the designer can provide customers with personalized, unique pieces. Generative design essentially means design using a computer and mathematical relationships. The result is generated by algorithms. Unlike the traditional design method, the design processes can be controlled step by step, and the consequences of the manipulation can be seen immediately. Thanks to the new approach, several versions of a product can be carried out extremely quickly. It is because changing a parameter transforms the whole body.

In the course of the article, the essence of generative design is described, and its features and advantages are presented by showing industrial examples.

2. Generative design

In generative design instead of the designer drawing the product he envisions, it is sufficient to specify the requirements set for the product (such as material properties, manufacturing process, cost, etc.) for the computer, and the software creates the possible solutions [3] [4].

Take an example: the designer would like to design a chair. Instead of drawing a chair and then playing with its shape, he can give the computer how much weight it can support, how much weight the chair itself should be, how much it should cost, and what material it should be made of. The computer can produce thousands, if not millions, of options that meet the criteria. From the variants, we can choose the solution that meets the most important requirement (Figure 1).
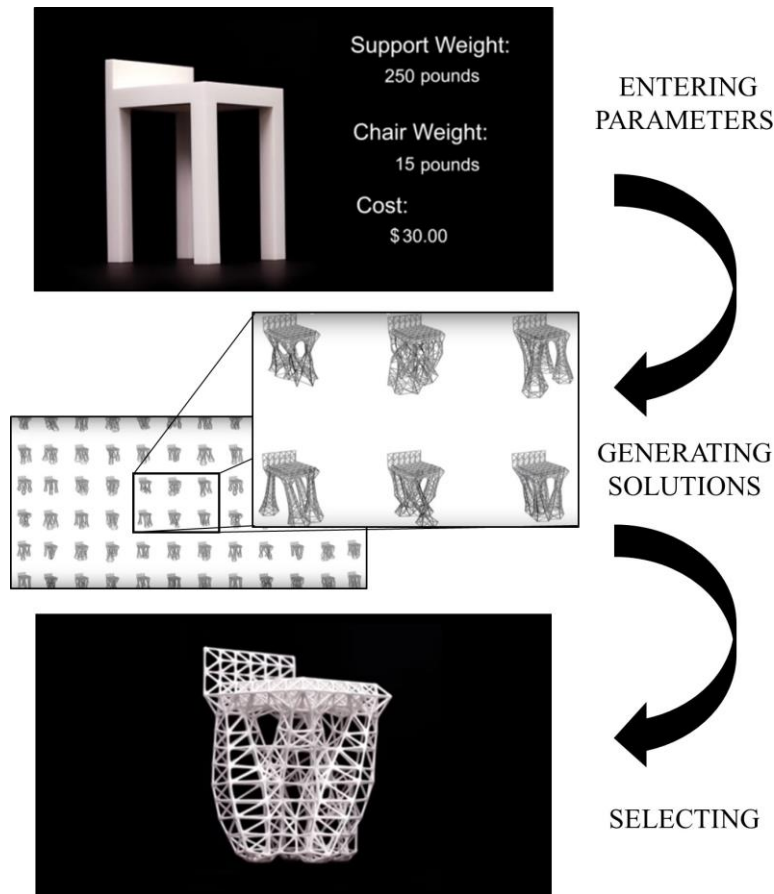
Figure 1 *Steps of the generative design based on Jeff Kowalski's performance [4]*

Generative design has several advantages, some of which are:
- Among other things, a shape may be created in a way that the designer would not have imagined,
- time can be saved because while we are able to create an idea, the computer is creating thousands,
- and combined with additive manufacturing, such a complex shape and optimized inner mesh can be created that would be impossible to achieve with traditional manufacturing methods.

3. Car manufacturing

An average car consists of about 30,000 parts. Manufacturing and assembling them is a very complex process [5], so the use of generative design can be particularly advantageous in automotive manufacturing.

General Motors and Autodesk plan to create a lighter and stronger car with fewer parts with generative design. Engineers enter the parameters associated with each auto part into the program, and an algorithm creates and tests the shape that can be added to them [5]. The next benefits would have a car created in this way [5]:

- would reduce the weight of car parts,
- the components could be combined or manufactured with 3D printing,
- this can also reduce costs.

It can be seen that technology fundamentally changes the way engineering works because instead of developing geometric shapes, specifying the parameters is necessary, which generates up to millions of potential solutions [6].

Innovation in the automotive industry was also the first generatively designed chassis created by the Hack Rod team [7] (Figure 2). The team has replaced the traditional manufacturing approach using generative design, virtual reality (VR), 3D printing and the cloud-based supply chain [7].

Figure 2 *The first chassis with generative design [7]*

4. Aircraft manufacturing

Generative design is already used by Airbus, which can be considered one of the most famous aircraft manufacturers [8]. With this design method, "We can generate literally tens of thousands of design iterations, compared with the manual process which could generate maybe a dozen." [9] said David Benjamin, director of The Living, a company that collaborated with Airbus, Autodesk, and APWorks [10] to create the new cabin partition for the A320 (Figure 3).
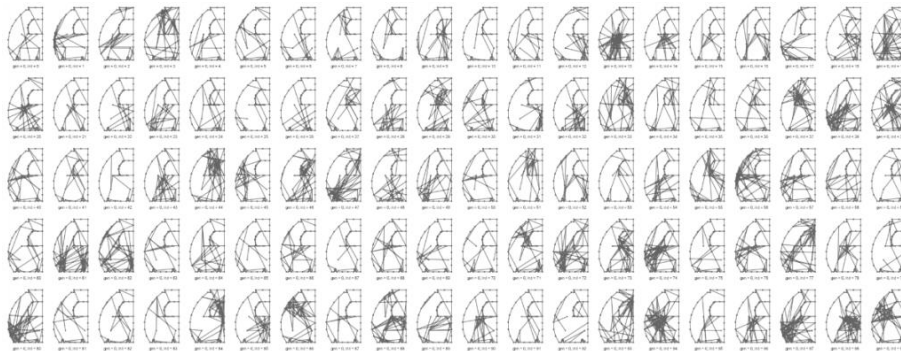

Figure 3 *Generationally designed versions for the cabin partition [9]*

The new version is 55% lighter than the original part, and also it is more resistant [11].

5. Topological optimization

Another application of generative design is topological optimization, in which we change the body's internal structure to make it lighter and more flexible.

An example of this is a running shoe developed by Under Armor (Figure 4) with a 3D printed sole. Thanks to its light and flexible design, the shoe fully adapts to the athlete's running style [12].

Figure 4 *3d-printed shoe [12]*

Another example is a skateboard created by Philipp Manger (Figure 5), which has made by its design much easier and faster [13].

Figure 5 *Skateboard created by Philipp Manger [13]*

6. Architecture

In the early 20th century, Gaudí used parametric models to design buildings, and as technology evolves, we can see more and more examples of buildings created with generative design [14] [15], for example, the Metropol Parasol shown in Figure 6 was also made on such a principle.

Figure 6 *Metropol Parasol [15]*

Another example is British Petrol Headquarters designed by Adams Kara Taylor, whose roof structure can be seen in several variations in Figure 7. During the parametric design, both aesthetic and quality aspects were taken into account. Criteria included, for example, getting as much sunlight as possible into the yard and getting into the building [16].
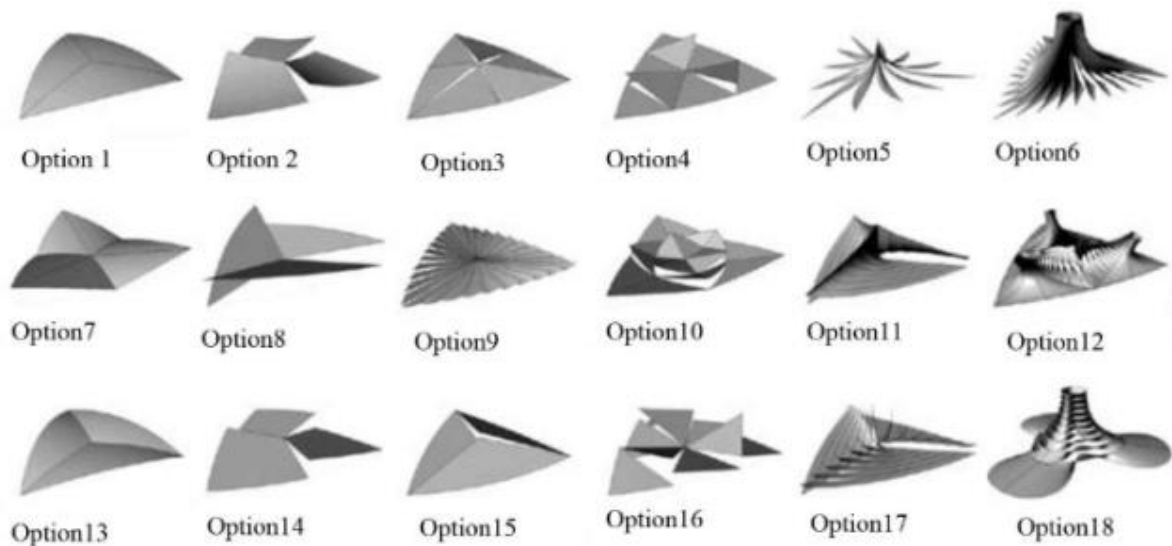

Figure 7 *British Petrol Headquarters in Sunbury by Adams Kara Taylor [17]*

7. Other industries

7.1. Jewelry

There is an application called Fusilli that generates bracelets using an algorithm (Figure 8). Combined with selective laser sintering, the program creates flexible and lightweight bracelets that cannot be implemented with traditional product design tools [18].
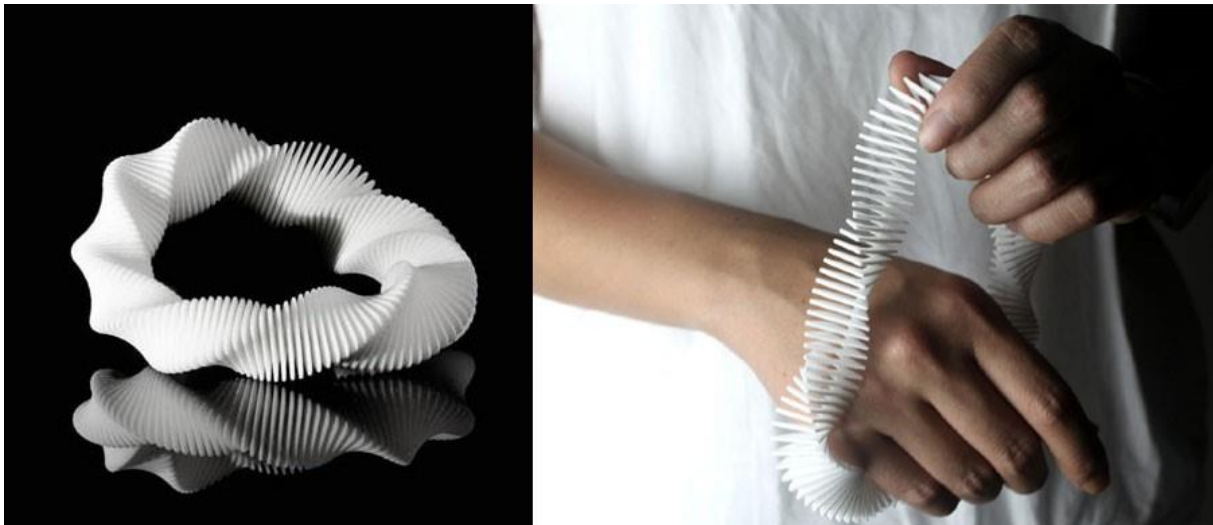

Figure 8 *Bracelet created by Fusilli App [18]*

Generative design is used in several companies to make jewelry. For example, with Kinematics, Cell Cycle, and Radiolaria applications as custom design tools, we can create our fully personalized necklaces, rings, bracelets, etc., in real-time. These applications are provided by a company called Nervous System (https://n-e-r-v-o-u-s.com/labs/). (The company researches patterns and shapes found in nature, based on which mathematical models are set up. The completed simulations can be used to create unique products. Personalized products are created by 3D printing [19].)

7.2. Clothing

Kinematics Cloth is a web application (https://n-e-r-v-o-u-s.com/ kinematicsCloth/), where buyers can design clothes for themselves, modifying its 3D display. The cloth is made with 3D printing, and the customer's body scan file can be imported for design, making the garment fully personalized. You can give the cloth the shape of the base, and then further shape it, adjust the garment's length, fall, etc., using different grips in real-time. The pattern and its density can also be adjusted. The textile structure can also be specified separately, the location of which can also be specified on the clothing, we can combine it as desired (Figure 9).
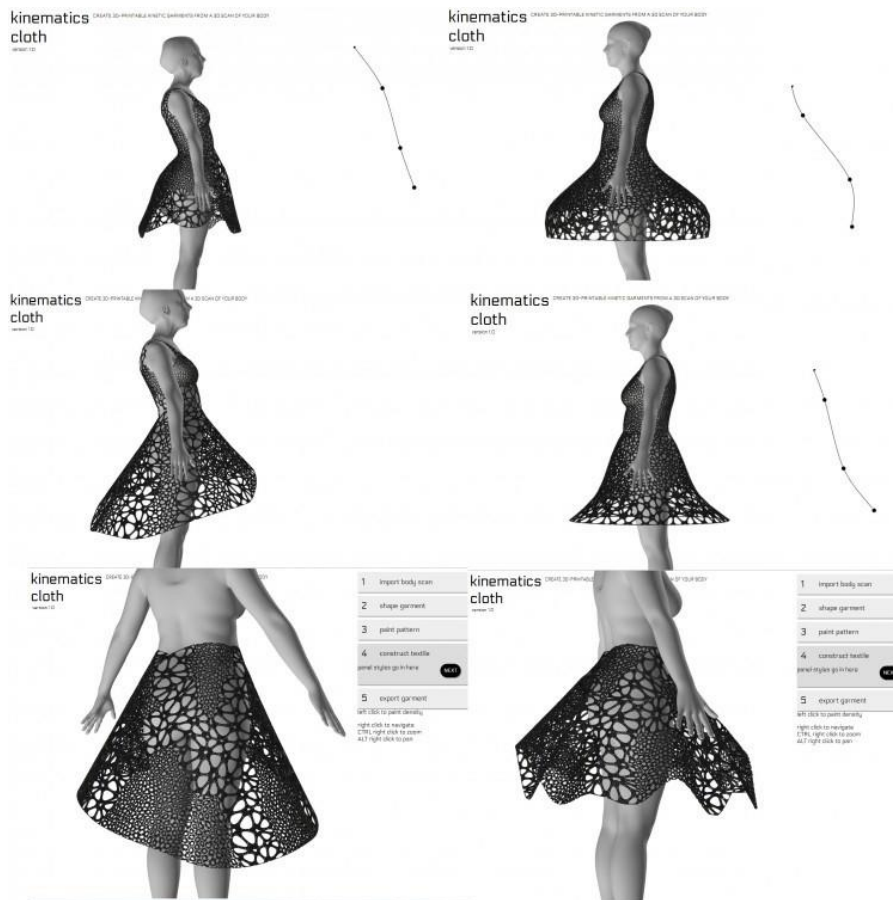
Figure 9 *Kinematics Clothing Application [20]*

7.3. Game

Also developing by the Nervous System is a game called Generative jigsaw puzzle (https://n-e-r-v-o-u-s.com/customPuzzle/), where each puzzle has a unique picture and unique pieces (Figure 10).

Figure 10 *Generative jigsaw puzzle [21]*

8. Conclusion

It can be seen that generative design is applied in many areas. In addition to mechanical design, this design approach also opens up new possibilities for architects and product designers, and nowadays, more and more advanced software support is also available.

Basically, generative or parametric design can allow the user to be the designer himself, so he can choose from infinite variations based on his taste, which could increase consumer satisfaction.

9. Acknowledgements

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