A Study on Application of Generative Design System in Manufacturing Process

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Abstract. The paradigm of manufacturing is changing with the recent era of the fourth industrial revolution. In particular, with the rapid development of artificial intelligence technology, tremendous transformation is welcomed in various areas related to manufacturing. This study concentrated on the changes in manufacturing due to the development of a generative design system. It also analyzed how designers design products through a generative design system based on artificial intelligence. The changes in the design part of the manufacturing process through the creative design are as follows: First, once the designer sets up a rough conceptual design, and then enters the conceptual design into the generative design system, the computer provides with a basic form of design. After AI presents multiple designs, designers choose the appropriate and desirable one. Next artificial intelligence puts forward an optimal material proposal considering its function and economics. And the designer reviews this alternative. After the designer's review, the computer comes up with a final proposal. Much of the design is done by artificial intelligence. This design method will be universal in the future. Therefore, this study analyzed the direction in which the generative design system would develop in the artificial intelligence era. And the results of this study are to present the theoretical basis of the future product design methodology.

1. Introduction

1.1. Research Background and Purpose
Due to the recent development of artificial intelligence technology, these technologies are being used in various fields. Artificial intelligence technology has had a lot of impact on the manufacturing industry as it fuses with digital technologies. The manufacturing industry is an area where the characteristics of the times are well-reflected. Manufacturing has grown through the Second and Third Industrial Revolution, reflecting the social phenomena of the times. The paradigm of manufacturing is also changing with the recent era of the fourth industrial revolution. This rapid development of technology is expected to lead to significant changes in various areas within the manufacturing industry. In particular, the introduction of the general design using artificial intelligence is anticipated to bring about many changes for product designers. Therefore, this study attempts to predict the direction in which the general design will be developed in the artificial intelligence era.
1.2. Literature Review
As artificial intelligence technology developing, it is also being applied in various manufacturing industries. These studies have been of great interest to various research institutes, including universities. Studies using A.I. and General Design technologies were as follows. Park Su Bin (2017) studied which kind of art had already employed A.I. technology, and how the definition of art and teaching art would be changed in the age of artificial intelligence. Then she analyzed ‘Google A.I. Experiments’ can be used for an integrated curriculum of art education tools [1]. Lee Jin Wook (2011) investigated application methods and characteristics of fractal geometry and Voronoi diagram which were the most representative principals of generative design in nature by researching the example of furniture design using these principals [2]. Ahn Seong Mo etc. (2009) verified the applicability of ecosystem to digital design generation system with a focus on the ecological approach of digital design [3]. Jeon Young Jun (2018) prepared to help understand general social trends through a case study of the past industrial revolution and analyzed the difference between the Fourth Industrial Revolution to assess current trends and technical achievements [4]. Lee Jae Young (2018) proved the efficiency of the new design. It will have a beneficial effect on the creation of aesthetic buildings. In previous studies, the generative design system was recognized as an innovative technology in the field of design. However, there is a lack of research into the relevance between the generative design system and the manufacturing sector. So this thesis investigates the application of the generative design system in the manufacturing process. These studies can be used as the theoretical basis for the manufacturing sector using artificial intelligence in the era of the Fourth Industrial Revolution.

2. Research Method
In this study, a creative design system among artificial intelligence technologies is the main research scope. Generative design systems are implemented through informational parameters and creation algorithm. In the future, artificial intelligence will help designers design their desired outcomes through this technology. Such artificial intelligence will serve to create product forms and perform human creativity, rather than simply as a tool to assist design. Recently, a creative design system based on artificial intelligence is being used in various fields of design. This thesis, in light of this, probed into the changes in manufacturing on account of the generative design. In the meanwhile, this study analyzed the application of product design through creative design. It is also intended to provide a direction for the development of generative design in manufacturing.

3. A Theoretical Study
3.1. Artificial Intelligence
Artificial intelligence is the process of solving problems through computers. Through the development of modern technology, computers go beyond solving simple problems. They, instead, take advantage of their intelligence to work out new solutions. Therefore, artificial intelligence performs learning, understanding, and reasoning through computer programs. In general, humans recognize information through the eyes and understand it through the brain. As such, information obtained through the eyes becomes knowledge. Applying this learning method to computers is called deep learning. And the way computers change information into knowledge is called algorithms [4]. The principles of artificial intelligence are as follows. First, artificial intelligence observes the environment. Through these observations, it not only collects data but also interprets data. Then it determines the reaction of the situation. Then the smart technology observes the results of the action and analyzes the data again. And it determines the next reaction. Artificial intelligence learns on its own by repeating this process. This is the basic process of artificial intelligence learning (figure 1) [4].
3.2. Artificial Intelligence Application

Artificial intelligence technology is being used in various fields. Such artificial intelligence technologies are being conducted around global conglomerates like Google and IBM. Google's artificial intelligence beat world-class Go player Lee Se-dol in Go [1]. And IBM has developed artificial intelligence 'Watson' and is being adopted in the medical field. Watson is an artificial intelligence that accurately analyzes the patient's condition and offers the best treatment. Artificial intelligence technology will improve productivity in a variety of areas. Most of them will be replaced by artificial intelligence, especially in areas where they engage in physical activity. But even in creative fields such as art and design, there are various opinions as to whether artificial intelligence can be a replacement. Recently, there has been a lot of research in the field of art using artificial intelligence. Microsoft, for example, reproduced a picture of Rembrandt with artificial intelligence. Microsoft digitized 346 Rembrandt's paintings and trained them to deep-learning artificial intelligence using digital information. After AI finished learning about Rembrandt's painting style, it ordered artificial intelligence to "draw a white male in his 30s and 40s," which completed a painting that seemed to be drawn by Rembrandt. As such, artificial intelligence is expected to be used in various fields of art and design in the future.

3.3. Generative Design System

A generative design system is due to the development of an artificial intelligence computer system that is actively involved in the design process. A generative design system’s core technology is artificial intelligence. The generative design system has no difference from the artist's teaching methods. Through repeated learning by artificial intelligence, artistic works can be completed very quickly. So recently, various software companies are trying to develop a creative design program. A representative company of them is Autodesk, who has developed a program called Dreamcatcher that combines computer-aided design with artificial intelligence (figure 2). When a designer enters basic forms and variables together, artificial intelligence produces a product that considers various factors such as structural engineering and economic efficiency. The result of this design is a product that takes into account various factors such as economy, structure, and beauty. Also, the results created by artificial intelligence can lead to a special form that humans do not think of. If artificial intelligence technology further develops and popularizes in the future, a significant portion of the creative field will be replaced by artificial intelligence. In particular, a generative design system will bring about great variation in the manufacturing process.

![Figure 1 Artificial Intelligence Operation Principle](image-url)
4. Application of Generative Design System in Manufacturing Process

4.1. The Future of the Generative Design System
Generally, in the manufacturing process, designers needed a lot of experience and knowledge to design their products. Designers spent a lot of time collecting data on products, analyzing materials, and performing structural engineering stability, aesthetics, etc. However, if a general design system using artificial intelligence is established, anyone who understands operate the program can make the product. And the General Design System will work with designers to produce faster and better results, and it will also be able to make optimized products that take into account various constraints, appearance, and materials. After the designer enters a rough sketch into the configured computer system, artificial intelligence makes an overall consideration of various factors and produces the best results. The process of the generative design system is as follows (figure 3) [6, 7].

4.2. Manufacturing Process Using Generative Design System
The product manufacturing process consists of Propose, Plan, Design, Development, Evaluate, and Production. The manufacturing process is as follows (figure 4).

First, Propose is the process of determining the requirements of a project to develop a product. The following process is the Plan. Planning is the stage in which various data are investigated and analyzed to prepare for design. Based on the plan, the designer conducts product design. The following process is Design. Design is divided into conceptual design, basic design, detailed design, and production.
design. The design phase refers to all four of these steps. This process is a step that embodies the structure and shape of the product. The next step is to Develop, which embodies the design. At this stage, 3D programs such as sketch-ups and 3D MAX are used to refine them. The following process is to Evaluate. At this stage, the product is being modeled and evaluated. And it's a step in determining productivity while testing a product. The final step is Production. This step is the production and distribution of products on a large scale at the factory.

![Diagram of the manufacturing process using generative design system](image1)

**Figure 5** Manufacturing Process Using Generative Design System

There will be a big change in the application of the Generative Design System in the manufacturing process (figure 5). As these digital design technologies advance, a new approach will emerge in the design of the manufacturing sector. The changes in design are as follows: First, the designer sets up an approximate conceptual design. Then, when the designer enters the conceptual design into the Generative Design System, the computer provides the basic design. Designers choose the appropriate design from the basic designs presented by the Generative Design System. Based on the selected design plan, artificial intelligence then presents an optimal material proposal considering its function and economics. And the designer reviews this alternative. After the designer's review, the computer comes up with a final proposal. Most of these designs are performed by artificial intelligence. This design is called a hybrid design (figure 6) [8]. It is a design process that will take place in the future. Designers and artificial intelligence work closely together to produce results. These designs will be utilized not only in product design but also in various areas of design. And a digital platform will be formed through the Internet. So when various data are built, the design will be formed under the influence of the algorithm. Through deep learning, artificial intelligence generates huge data. Computers can review more information than humans. Much of the data accumulated in these programs will be utilized through artificial intelligence and designers will be able to make new forms of design [8].

![Diagram of hybrid design system](image2)

**Figure 6** Hybrid Design System
4.3. Development of Manufacturing Industries through a Generative Design System
With the development of the General Design System, artificial intelligence can create designs that humans never thought of. A new design can be created by calculating the curvature, the variable that has been modified in the design. With the help of artificial intelligence, the parts that are difficult and time-consuming for humans to express will be able to be solved. Besides, the Generative Design System will push beyond analog limits to break down the boundaries of expression and allow virtual space to express real space [9]. As such, in the future, various design attempts will be possible in digital space beyond the physical limitations of space. In the past, designers produced one or two design results by analyzing performance based on shape and materials. However, artificial intelligence can produce thousands of results in a short time considering various factors [5]. This design revolution in the manufacturing process will make the overall manufacturing process change.

5. Conclusion
This study reviewed changes in the manufacturing design process in the age of artificial intelligence. As these digital design technologies develop, the changes in design are as follows. After the designer has made a conceptual design, the designer enters the conceptual design in the Generative Design System. Then, based on the conceptual design, the computer provides the basic design. Then, if the designer chooses the appropriate design based on the basic design, artificial intelligence presents the optimal material proposal considering its function and economics. And the designer reviews this alternative. After the designer's review, the computer comes up with a final proposal. Much of this design is done by artificial intelligence. This is a design process that will come true in the future. The above-mentioned arguments of this thesis can be used as a theoretical basis for the manufacturing sector using artificial intelligence in preparation for the Fourth Industrial Revolution.

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