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A Study on 3D Printer Design for Clothing Printing: Focusing on Knitted Wearable Clothing Output

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Abstract

This study is a design study related to the application of 3D printer technology for garment printing. Knitting, which used to be a home industry in the early days, originally comes from hand-knitting. This evolved with various personal devices as a small job for the self-sufficiency of early European housewives. In addition, since the Industrial Revolution, mechanical production entered the mass production mass supply system, and various apparel products were provided to consumers in accordance with mass standardized dimensions. This is similar to the development process in Korea. In addition, it has formed a considerable market with the situation that it can produce and supply apparel products at low labor costs of first-generation Namdaemun and Dongdaemun merchants. As the production shifted to the Southeast Asian region due to the increase in labor costs in the domestically developed social situation, the production of garment products in Korea is now almost 5%. As a result, apparel-related production facilities and related companies are constantly moving to other countries to move production facilities sensitively due to rising labor costs. Recently, smart factory automation has been planned to explore new possibilities. In addition, in recent years, with the evolved appearance of consumers, the appropriate supply of the right amount of production has appeared, and the 3D printer applied to personal garment output has attracted considerable interest in the customized market. Therefore, in order to become a new hope and a small addition to various clothing workers, this study conducted related research on the following 3D printers for clothing output and attempted to proceed with a new design.

Keywords: *3D Printer, Clothing Printing, Knitting Machine, Product Design.*

1. Introduction

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In the domestic apparel industry, with the Industrial Revolution, production had a process of products being sold in the market as soon as the fabrics had been made in large quantities, cut, sewn, and finished. In Korea, in the 1970s, in order to resolve the considerable production issues, the process was carried out mainly by merchants in the Namdaemun Dongdaemun market. We made a situation. As a result, in order to contract and produce huge quantities for the first generation, the company rapidly produced fabrics from all over the country, hand-cut and hand-sewn, which involved a considerable amount of work ranging from finishing to finishing. In the meantime, the company is currently producing a large amount of apparel products produced in foreign countries, which are rarely produced in Korea, and supplying them wholesale nationwide. At the time, the first generation of apparel producers determined that they would find cheap production sites and finally arrived at the present situation. This is not just a problem at present in Korea alone; the same is true in Europe. In the midst of this change, Europe, which has been booming in the past, is now targeting the customized market, centered on the competitiveness of design and developing and commercializing new and innovative products through open source-oriented R&D and trial and error. It is becoming a major player in the industry. Currently, we are living in the era of the Fourth Industrial Revolution, with innovative new products a fact of modern commercial life. Innovation refers to the emergence and leadership of competitive small-scale innovative products in the customized market that deliver the right quantity within the mass production and mass supply paradigm current since the Industrial Revolution. The purpose of this study is to add to the domestic market's difficulties caused by local production elsewhere in Southeast Asia, a problem in our garment industry today. Eventually, small business owners could utilize a 3D printer for clothing output, and if they were able to produce their own new apparel products, they would be able to change the local situation of currently importing and supplying large quantities while complaining. In addition, design and development of a 3D printer application for garment output was conducted to examine the competitiveness that can emerge with new technology required for product designers. In addition, domestic product designers, as with Europe and the United States, are currently difficult areas and are difficult to see, but by advancing and understanding these areas more effectively, they provide more consumers with more initiatives in actual product design than in the past. In addition, as a research method, we reviewed the development process of the garment production method and the development process of personal production facilities in the literature research phase, and also the case of R&D, which is a global issue. In addition, as a piece of empirical research, we have reorganized old knitting machines like open source like in Europe, and produced knitwear with a 3D printing technique. We also looked at the problems that emerged during production, defined the concept, and tried to incorporate it into the design of a new 3D printer for apparel. As a result, we designed the garment-manufacturing 3D printer and produced the prototype as a 3D model.

2. Development of an Apparel Manufacturing Method

2.1 Advances in the production of knitwear

The history of knitting started around 500–400 BC, with housewives knitting in the early family, and it started at home as a chore. It originated from small craftsmanship and gradually developed into mass-produced industry through the mechanical production of the Industrial Revolution. A typical example is a Chemnitz-based manual circular knitting machine. In 1880, a passive-power knitting machine appeared for the production of stockings with toes and heels. This has led to a situation in which mechanical production is known to be difficult. In 1890, the first simple hand-made flatbed knitting machine for home use in the cottage industry appeared, leading to the production of this machine in small factories [1]. Since Brother knitting machines have been evolving into a technology that can be used in the home, electronic technology has developed along with the design of the square interface [2]. Table 1 shows Brother knitting machine history.

Table 1. Brother knitting machine history

MODEL	YEAR	MODEL	YEAR	MODEL	YEAR
KH-500	1955	KH-800	1971	KH-910	1976
KH-511	1960	KH-810	1973	KH-930	1980
KH-561	1964	KH-820	1974	KH-940	1988
KH-581	1966	KH-830	1976	KH-965	1992
KH-588	1969	KH-840	1978	KH-970	1996
		KH-890	1979		
Non punch-card machines		**Punch-card machines**		**Electronic knitting machines**	

Knitting machines were the first personal manufacturing tools used in homes. As shown in the above chart, manufacture of the Brother knitting machine, which had been developed and produced since 1955, stopped in 1996. However, the devices that were applied at the time are still in use today, and some of the unwieldy interfaces have been improved to apply electronic control methods and to make them easier to use. An example is the modification of the KH-930 model. It is a hackato to physically improve the convenience of the interface of the current KH-930 model, and it is currently providing a new interface by developing a new program using Arduino board and Python which are cheap and easy to apply. Also, due to the nature of open source, many adventurers have been inspired by Travis Goodspeed and Fabienne Serriere. The development of the Knitic program by Varvara & Mar has been created through open source and has attracted considerable interest.

2.2 Knitting technique

Knitting is a handicraft industry with a lot of handwork. The problem that has to be processed is a field that takes a lot of time to produce and shows a problem, and requires a lot of patience for those who are interested. However, these inconveniences are addressed by Oiko-nomic Threads, a joint project of Marinos Koutsomichalis, Maria Varela, and Afroditi Psarra, that shows the possibility of applying new techniques by controlling algorithms of knitting machines and developing techniques with open data. It is a project to research and develop a feasible approach with the support of the Center for Innovation of the Center for Creativity-Oriented Production and Approach (CIMPA) Framework [3]. An example is Ayab, which involves a knitting technique that adapts existing electronic knitting machines to technology to improve its convenience in use. Ayab has been in the spotlight in the R&D of the automatic control of patterns by a computer using the manual electronic control method in the Brother knitting air [4]. Also in Japan, the Glitchknit project yielded similar significant results. In order to control the knitting machine with a computer, this project created an environment in which an image pattern can be outputted to a knitted fabric using an open source board, and the developed content was used to create a glitch knitted fabric, which is a representation of a new pattern [5]. Stoll also created a new paradigm called Unmade that can serve the needs of a diversified consumer class with software utilizing an online platform [6]. This is creating a new business in which the seller becomes a producer while also producing a small quantity of various kinds of products different from the existing mass production system. Stoll was founded in 1878 by Heinrich Stoll, a German manufacturer of industrial knitting machines. His company has been in the forefront of research and development of knitting machines for 145 years. It is targeting the market [7]**.** In 1919, the first model was used to automate the entire needle of the knitting machine

through the control of the chain. In 1958, the LIUM flat knitting machine was developed to stabilize the electric field entirely by purl stitch transfer. The company introduced the V220 model based on the Type 220 model, and the world's first workstation in 1979 to produce patterns. It shows how competing in the current large apparel market is applying the advanced method of CMS to production [8]. In addition, Shima Seiki of Japan, the founder of Masahiro Shima, studied glove knitting machines in difficult times of war and researched and developed inventions such as double loop stitch sewing machines and elastic thread insert stabilized gloves. Shimaseki began business in 1962, manufacturing a knitting machine for manufacturing gloves automatically. Later, in 1978, a computer-controlled knitting machine was developed for the SNC model to develop a machine that could be used for the automation process, which is cheaper and doubles the performance. Later, in 1981, the company developed the Simatronic Design System (Simatronic Design System) SDS-1000. After developing the second generation knitting machine SES in 1987, the company became a CAD/CAM manufacturer by completing a system called P-CAM that cuts fabrics using a computer application. Oriental Magic launched a system that could produce a single sweater in 30 minutes. Since then, a new manufacturing technique, Slide Needle, has been introduced and put into production. Since then, it has introduced its network management system (Shima KnitPLM), with 18 models including the Mach2XS, and is currently researching and distributing new types of design system [9].

2.3 Open source knitting

Open source knitting is characterized by inexpensive production in a market that can only be implemented with significant capital in the current commercial market. An example of this is Open Knit. This is the result of the development of hardware and software with the advice and attention of interested professionals around the world. In the case of Open Knit, there are two types of hardware and software. In the case of hardware, by developing a model that can be developed inexpensively by applying the 3D printing technique to the existing (expensive) knitting machine, sharing the design data of the hardware used to solve the various problems that appear and developing a more complementary model. Open knit is famous. In the case of Orton Knit, the Arduino Leonardo board, synonymous with open source, is used [10]. The development and development of a shield for a PCB for a separate drive is made public, sharing the problems presented by interested innovators, improving them, and continuing to upgrade. In addition, Open Knit has developed a commercial knitting machine called Kniterate [11], which is not developed anymore and cannot be compared with a small industrial knitting machine afterwards. The second model is in preparation. It is the first open source desktop version that allows you to easily pick and use clothing online just by controlling the size of the clothes and various numerical values. The software also developed a program called Knitic by Varvara & Mar, and since then, he has been interested in using Arduino-based boards and opening a separate PCB shield to improve the existing Brother knitting machine. This program is a Java-based program called Processing, and it is designed to input the length and neck length, allocating the numerical values of each part by simply inserting the figures into the silhouette of separate clothes, and putting various patterns into the clothes. They also showcased their interest in the circular Knitic with new hardware, firmware, and wiring [12].

2.4 Development example of clothing 3D printer design

Joshua Harris, an industrial designer, presented a design concept in 2013 that allows 3D Clothing printers to be used at home by 2050. The key point of this concept is that you can print out the material you need to print at home, as well as the material cartridge and clothing data. As a result, there will be a significant change in

the process of mass production of apparel companies in the future. Not all of the garments will change, but the traditional one-way mass production of the product should be tailored to the consumer's body size. This means a significant reduction in the amount of significant additional expenses such as tariffs, logistics costs, and transportation costs which currently have to be paid. In this respect, it is highly likely to be introduced in the near future, and is currently trying to preempt new paradigms for knitting companies in Europe and Japan [13]. The PETE concept, which entered the finals at the Electrolux Design Lab 2014, is also drawing considerable attention by demonstrating the concept design of a recycled 3D clothing printer [14] for homes, designed by Hungarian designer Kovacs Apor. This is a concept of a 3D printer for clothes printing, which outputs clothes by crushing and melting the raw material of PET, when the discarded PET bottle is placed in a 3D printer for clothes output. This raises considerable interest in that the recycled materials can be recycled at any time while alleviating the seriousness of environmental problems. The user interface is also simple. Industrial garments occupy a significant area and must have considerable design and technology, but PETE can print clothes using the 3D printing method simply by selecting the UI displayed on the screen. In addition, many attempts have been made with initial 3D printing in mind in terms of the flexibility of flexible materials. Among current innovators is Daniel Peleg, who showed his first 3D printing collection in 2015. It seemed like a new attempt by creating the stiffness of the fabric and natural moisturizing with the idea of the connection of the sculptures and the elasticity of the material that appeared directly from 3D printing in the early days. In addition, customized development of Adidas's new sneakers is applied, and new carbon material is used to demonstrate new functionality with parametric design techniques that cannot be realized in the actual manufacturing process of the mid-shield of shoes, and customized quantity production through current 3D output is spreading as a technique. In the case of Reebok, the liquid mixing ratio and elasticity, which are difficult to apply in the existing production method, are developed using the liquid 3D printing technique. Significant attention is being drawn to creating strategic design concepts and styles that also reduce the labor costs required. Damien Ludi and Colin Peillex developed the Rocking Knit, which utilizes rocking movements in a sitting rocking chair, to make a circular knitting machine that makes a hat by using the chair as the driving force of a circular knitting machine. This concept has been developed. Dave Cole, with the title of "The Knitting Machine," produced the American flag with two large forklifts at the Massachusetts Museum of Contemporary Art (MASS MoCA). A huge American flag was made from acrylic felt, as if hand-knitted, using an aluminum telephone pole attached to an excavator, showing new possibilities. Software for Crochet is currently open with the development of a program called Crochet Chart. This suggests knitting guidelines for the design of crochet patterns.

3. 3D Printer Design for Clothing Output

Before designing a 3D printer for clothing output, we researched the development cases of various knitting devices and, based on this, we have reorganized the shield to be controlled by the current open source technology and the existing Brother Kh-910 knitting machine. Also, in order to see the possibility of making garments after digital reorganization, various patterns were digitized and upgraded. After that, in order to output the garment with the reorganized knitting machine, a pattern design was applied to the surface of the garment around various design patterns, and a total of six garments were manufactured by the knitting technique. Afterwards, a knitted wearable fashion show was held at the opening ceremony of the 7th International 3D Printing Korea Expo hosted by the 3D Printing Industry Association.

3.1 Open source knitting machine for clothing output

To build an open source knitting machine, the team revamped the Brother 910 model and fitted it with an AYAB circuit board to convert it into a digital knitting machine. The mode controlled by the existing punch-card was not controlled and the actual control was tested through the Ayab board. In addition, the normal operation to each start point and limit section could be confirmed through the buzzer sounding. Figure 1(a) Shows Open source knitting machine upgrade production and Figure 1(b) Shows Ayab circuit board.

Figure 1(a). Open source knitting machine upgrade production, Figure 1(b). Ayab circuit board

3.2 Pattern research for open source knitting

Various pattern images were tested by running the Ayab program with the reorganized knitting machine, and various patterns were produced successfully. It was suggested that know-how is needed for early garment production. In addition, in the 3D printing lab, even though there was no researcher in charge of clothing design, it was surprising that it was the first time to be trained for about one hour and to produce immediately. Figure 2(a) Shows Open source knitting pattern design and Figure 2(b) Shows Image file knitting test.

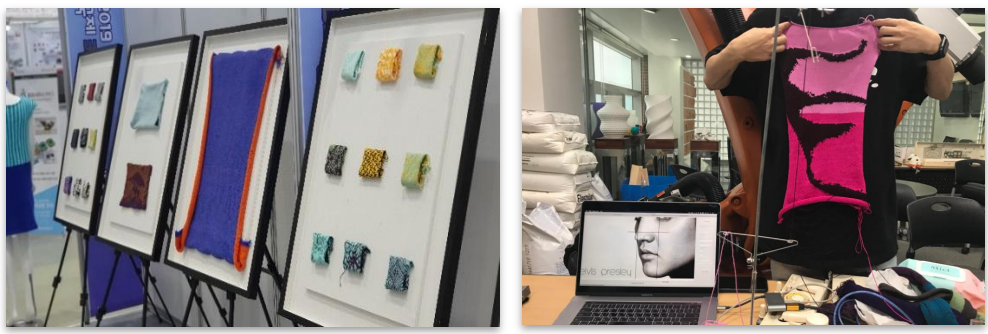

Figure 2(a). Open source knitting pattern design, Figure 2(a). Image file knitting test

3.3 Open source knitwear production and fashion show

In addition, four non-major researchers were trained for about an hour in open source knitting and the digital program Ayab program, and produced a dress for knitting using the open source knitting machine. Overall, it took about a day to produce. Of course, current holographic techniques could not be applied and cognitive processing was necessary. However, there was no problem in making open source knitted clothing. This is an innovation. In the future, if 3D printers were made for making knitted garments applied with 3D printing techniques, We were convinced that the general public could easily apply them. In addition, they participated

in the 2019 knitwear wearable 3D printing fashion show organized by the 3D printing industry association to conduct a fashion show. Unlike when the clothes were made with DLP(Digital Light Processing) type 3D printers in 2017, models appeared very light and the weight of the clothes was very light, and if they were applied to the real apparel market, they could provide new opportunities for small businesses, it is expected. Figure 3(a) Shows 2019 3D Knit wearable fashion showroom and Figure 3(b) Shows fashion show.

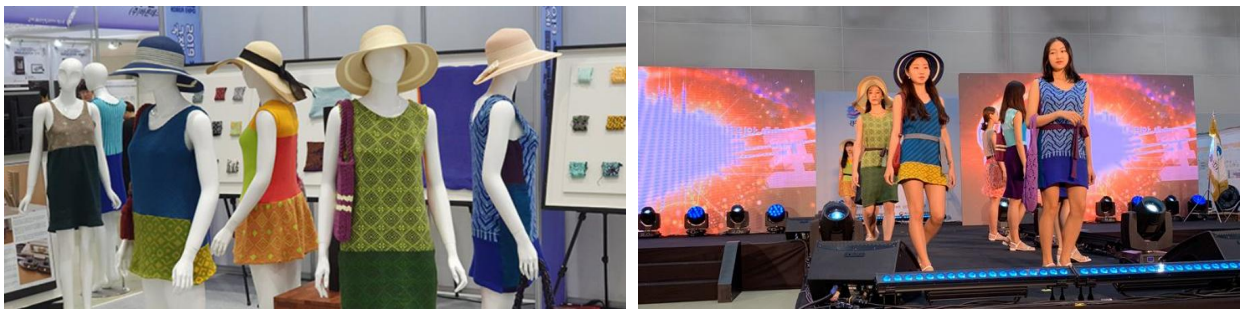

Figure 3(a). 2019 3D Knit wearable fashion showroom, Figure 3(b). show

4. Conclusion

The technology of 3D printing is affecting various industries. In the early days, it was thought that it would be an opportunity to achieve the desired purpose by printing out the objects that individuals want by reducing the mock-up cost. However, this is accompanied by the development of new technologies for 3D printing, creating considerable changes and issues in various fields. Openknit is a representative example of the apparel field. This makes significant advances for many interested innovators by developing 3D printer hardware, firmware, and software for apparel printing. In the apparel production field, there are several situations in which large companies show off large-scale production and produce fabrics quickly. However, the reality is that it does not reflect the needs of consumers in terms of diversity because it focuses only on the productivity and supply of uniform and patterned clothing because it is mass-produced. What is noteworthy here is that consumers can produce their own clothing output 3D printers and make and use customized products in small quantities required to meet individual needs. This groundbreaking and innovative product is finally creating a new paradigm that reduces the logistics costs unprecedented in the huge market and produces products that are not related to import and export tariffs, and now outputs from personal shops to provide customized clothing. Therefore, the Fourth Industrial Revolution should prepare for the customized market and also for the time when demanding various changes of producer-oriented production and producers producing and consuming appropriate quantities. In the future, researchers plan to continue research and development of low-end 3D clothing printers by developing personal digital 3D printing techniques, and to spread the technology for small business owners and meet a new paradigm of the developed consumer market.

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