Research Status and Development of Clothing Mass Customization

Jing Qian\textsuperscript{1}, Mengmeng Zhao\textsuperscript{1}

1. Institute of textile and clothing, Shanghai University of Engineering Sciences, Shanghai 201600, China

Corresponding author: Mengmeng Zhao, mengmengzhao@sues.edu.cn

Abstract. With the advent of the era of big data, the production and design process of clothing is becoming more and more intelligent. This paper systematically introduces the development and evolution process of clothing customization according to the time clue. The research and application status of the key technologies in the process of clothing customization are described, including the intelligent generation technology of anthropometric clothing pattern and the virtual display technology of clothing. In addition, this paper also analyses two relatively advanced operation modes of mass customization of clothing and summarizes their advantages compared with the traditional sales mode. Finally, it summarizes the development trend of key technologies and operation modes of clothing customization.

1. Introduction

Since the 21st century, the development of the Internet has brought revolutionary changes to the garment industry. On the other hand, due to the increasing demand of consumers for personalized clothing, the traditional clothing production technology has become increasingly difficult to meet the personalized needs of consumers and the rapid iteration of clothing products \cite{1}. The development of mass customization of clothing arises at the historic moment. Many garment enterprises at domestic and overseas have also made a preliminary exploration of the mode of personalized clothing customization. In such a stage, garment enterprises need to seek development or even strive for international competitive advantages, which means rapid transformation of the whole industrial chain for enterprises. The supply chain of clothing products is developing towards the direction of network, intelligence, integration and structure \cite{2}.

2. The development of garment customization

2.1 Traditional custom clothes

Clothing customization has experienced a long period of development. Its origin can be traced back to the natural economic period. In the traditional working mode of men ploughing and women weaving, clothing is customized based on individual needs. After that, due to the division of labour in the society, there gradually appeared a tailor's shop that could make clothes. As a result of class division, there are also some workers who specialize in tailoring clothes for a small number of nobles or royal dignitaries. So far, many traditional tailoring shops have been preserved both at home and abroad.

2.2 Mass-produced garments
It was not until 1845 that Elias Howe, a machinist from a textile mill in the United States, invented the world's first sewing machine. Compared with the traditional manual sewing, it greatly improves the efficiency of garment production. Subsequently, Singer company invented the sewing machine driven by electric motors, and began to produce and sell it on a mass scale. In addition, clothing paper patterns were also sold as commodities, and the mass production line of clothing began to take shape from then on. The traditional form of individual garment customization is gradually replaced.

2.3 Couture clothes
In the mid-1850s, Charles Frederick Worth, founder of the French High Fashion Association, set up his own fashion shop on the Avenue du Pall in Paris, France, to make custom dresses for the popular movie stars and duchess. This pattern of clothing production was pursued by aristocratic women at that time [3]. Since Charles Frederick Worth's first couture show in 1858, haute couture, the most lavish extravaganza in fashion, has been creeping into the public eye.

3. Research status of garment customization technology
In the early stage of clothing customization, anthropometry is needed to obtain the size data of various parts of the human body. Anthropometry methods include contact anthropometry, 3D human scanning technology and 2D image-based anthropometry. After the customer selects the final style of the garment, in order to enable consumers to see the finished product of the garment in advance, it is necessary to show the details of the fabric, accessories and style to consumers through certain technical means. In addition, the technology of rapid paper pattern generation is the key link to accelerate the garment production in the personalized mass customization of clothing.

3.1 Anthropometric technique

3.1.1 Contact anthropometry. In the early manual workshops and factories, contact anthropometry was frequently used. These methods mainly used measuring tools such as soft ruler, Martin measuring instrument, sliding meter and rangefinder to obtain the data of each part of the human body through contact measurement. However, when it is used for mass customization of clothing, the efficiency of contact measurement is not high enough, the measurement accuracy is low and it is easily affected by human factors, so it is not suitable for modern clothing customization [4].

3.1.2 Non-contact anthropometry. Three-dimensional human body scanning measurement is a kind of composite measurement technology, which is an interdisciplinary method of human body measurement, such as computer imaging, computer vision and optoelectronic information processing. It can accurately and quickly collect the user's dimensional data.

Zhang [5] discussed the acquisition of dimension data by the 3D human body scanning system and the process of establishing the database. The 3D human body scanning system was used for anthropometric measurement, and the front and rear images of the human body were combined to obtain 3D data and the system's supporting software was used to process the measured data. The Hong Ling group has also made an innovative breakthrough in anthropometry methods, changing the traditional measurement rules and developing a laser electronic volume meter. In the process of long-term tailoring, red collar finally formed its own unique method to analyze the fitness of human clothing [6]. Human body feature extraction based on two-dimensional images provides an effective method for non-contact human body size measurement, three-dimensional human body model construction and human motion recognition and other applications [7]. With the popularity of digital cameras, two-dimensional images are more convenient and cheaper to take, and are regarded as the main information carrier for human recording and understanding. Jiang et al. [8] proposed a systematic method for automatically detecting human feature points from the front and side images of the human body. Using an effective contour detection method, Freeman's eight-connected chain coding is used to represent the contour curve of human body shape. According to the specified rules, a series of feature points of the human body are
extracted by measuring the segmentation direction difference, as shown in figure 1. Simon and Francois [9] proposed a method to obtain human eigenvalues from two-dimensional contour images. This method improves the algorithm of automatic human body feature extraction based on 2d image with black background, and extracts 20 front features and 13 side features out of 45 front features and 24 side features online in parallel with anthropomorphic information.

3.2 Personalized pattern generation technology
The traditional garment platemaking process is time-consuming and requires a professional knowledge of garment structure. In order to develop a suit that meets the individual needs of the customer, the pattern maker must revise the sample repeatedly until the customer is satisfied. In the mass customization of clothing, the automatic generation of personalized pattern is the key technology for the speed of garment production and the fitness of clothing, and it is also an essential tool.

Ma et al. [10] proposed a modeling method of 3D clothing patterns, in which the geometric shapes of patterns were represented by boundary and surface, figure 2. A set of developable surfaces is used to represent a pattern geometry that is easy to flatten. This method can be used to model the relationship among parametric mannequin, 3D clothing patch and two-dimensional tailoring pattern by mathematical and general methods. Object-oriented feature classes can be further developed to support intelligent mass customization of clothing products.

Liu et al. [11] proposed a "what you see is what you get" method to generate clothing pattern effectively. Compared with the existing methods, this method is more convenient and comprehensive. This method is not only suitable for tight and loose clothing, but also does not require the user to know the knowledge of plate making in advance. Compared with the previous plate making process, the design process also involves the clothing's looseness, fabric elasticity and drape.

3.3 Virtual presentation technology.
In the process of clothing customization, it is necessary to take into account the effect of displaying clothing and some details to consumers, so as to assist users to make better decisions. In the early stage, consumers need to select fabrics and accessories as well as the style structure of clothing from the material library. In this stage, consumers can make preliminary judgments based on two-dimensional images. After completing the design of the whole garment, it is necessary to present the relatively
intuitive and real garment effect and wearing effect to customers. Some enterprises and experts at home and abroad have given their solutions for virtual fitting technology.

3.3.1. Three-dimensional human modeling. In order to solve the problem of establishing a scientific database, the simulation technology can be used to try on the human body products in virtual environment innovatively, and the method can be applied to the pattern validation, and the virtual fitting can be used to develop the model for the specific human body. The mainstream method of human body modeling is to conduct modeling through 3D human body scanning technology, which can be simply divided into wire frame modeling method, solid modeling method, surface modeling method and physical modeling method [12].

As shown in figure 3, Olaru et al. [13] used the original database of three-dimensional scanning anthropometric survey of the adult female population in Romania (human body size) to conduct mathematical processing of the original data and compare it with the corresponding values given in the literature.

![Figure 3. 3D human body scan.](image)

Mao et al. [14], based on the perspective of software engineering, used CAD software based on multidisciplinary strategy to design a 3D human body model. As the initial information required for two-dimensional clothing design, the body wearing the clothing is simulated in the 3D environment, and the geometric model is built according to the shape of the body.

3.3.2 Virtual fitting technology for clothing. At present, the market there have been some relatively mature commercial software for virtual try on clothing, such as domestic dressing mirror, 3D Runway of PGM company in the USA and South Korea CLO 3D of the software can be made of 2D garment sample import, properly fixed, suture and sample set of arrangement, joint to the human body geometry model of three-dimensional, also can modify the properties of the fabrics.

Among them, CLO 3D software is a relatively mainstream commercial software, and some scholars also conduct research on intelligent design and display of clothing based on this software. As shown in Figure 11, it is the effect diagram of dynamic virtual display of clothing in CLO 3D software. Chen [15] adjusted the fabric and styling details of haute couture clothes based on the software.

Tao et al. [16] proposed a 3d collaborative design process of original customized clothing that integrates the interaction between designers and specific consumers. In practice, the proposed collaborative design process will allow the development of an online recommendation system for clothing size selection and fit estimation. In addition, it can also modify the original clothing pattern repeatedly according to the fit preference of consumers, so as to obtain the real personalized clothing. In this way, consumers will directly participate in the product design process, and obtain the desired finished products through a series of sensory evaluations on the fit of virtual clothing. As shown in figure 4, a T-shirt is designed to meet the needs of different customers.
4. Analysis of clothing customization operation mode

4.1 C2B&D Clothing customization mode
The innovative customization model driven by customers from the Internet has become more open, interconnected and shared. Clothing customization is actually a reverse customization production mode driven by customer demand, namely, C2B (Customer to Business) mode. The concept of C2B also originates from e-commerce. Compared with the B2C (Business to Customer) model, the C2B model can better satisfy consumers' pursuit of personalization [17]. Meanwhile, the Internet system also provides consumers and manufacturers with a convenient, fast and low-cost interactive channel.

In C2B&D mode, designers are involved in C2B mode. Even if the consumer makes the choice completely independently, the designer needs to be involved in the establishment of the enterprise database center stage and provide his or her own suggestions on popular elements. In the stage of consumer selection, designers can also give collocation suggestions for the color and structure of clothing [18].

4.2 Personalized clothing customization mode of C2M
C2M (Customer to Manufacturer) refers to a new e-commerce model in which consumers directly communicate their demands to the manufacturer through an Internet platform [19]. At present, this operation mode includes some shopping websites. A typical enterprise is Red Collar Group, which provides customized suits for customers through offline data collection, backstage data cloud transmission and standardized assembly line production. Compared with the C2B model, C2M can skip the external e-commerce platform, and consumers can directly communicate with manufacturers to save the cost of intermediate links.

5. Conclusion
The traditional single piece sewing has been gradually replaced by the industrialized mass clothing production mode. In recent years, the key to the transformation of clothing enterprises is to explore the clothing customization mode that can better meet the needs of consumers. The existing single customization mode cannot meet the market demand. The development of relevant technologies is not mature enough, and the operation mode of enterprises also needs to be improved continuously in the process of exploration. There are many challenges facing garment customization, but the wave of mass customization is irreversible and relevant scholars and practitioners still need to actively explore it.

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