On AI Promoted Apparel Mass Customization

Qian-Qian Sun, Xi-Wen Hu, Xiao-Dong Sun*

Beijing Institute of Fashion Technology, No. A2, East Yinghua Street, Chaoyang District, Beijing, China

Abstract

The traditional apparel industry faces challenges by the quarantine of global COVID-19 pandemic dramatically. The AI technics provide promising solutions for apparel industry shift from labor intensive to technic intensive for survival. However, there are many open problems on how AI could find its application in mass customization. This paper presents practicable methods, framework and the curial technologies of AI promoted apparel mass customization. The AI cloud will apply in traditional knowledge management of customers (KM) with which AI cloud been trained and make predication of trends and customer's personalization and enable personalized AI recommendations. With the AI measurement the flexible digital research development technics can automatically generate personalized patterns and virtual garment prototype based on different body shapes. By using the RFID label, the AI cloud could provide easily quality control, products tracing back in producing process and AI logistics. Those solutions and key technologies will benefit the process of apparel industry 4.0.

Keywords: AI Promoted apparel Mass Customization; The RFID Technology; AI Knowledge Management; AI pattern making; Flexible Manufacturing

1 Introduction

It is known that the traditional garment industry is labor intensive and time-consuming. The quarantine of COVID-19 pandemic has brought challenges to the traditional apparel industry. The AI promoted mass customization of garment industry is a promising solution for some of these problems, as it provides alternative online and digital production processes. The traditional garment industry requires many repeated processes of measurement, pattern making and garment fit. The traditional garment industry relies manually on measuring, pattern making and sewing sample cloth. In addition, there is a communication barrier between manufacturers, designers, and customers. Traditional garment production is not able to update the production progress in real time and is also not able to trace back the process for consumers. At the same time, product logistics mostly depend on third-party logistics companies, which have relatively higher-costs and

*Corresponding author.
Email address: sun_xiaodon@yahoo.com (Xiao-Dong Sun).

has increased apparel production costs. The emergence of Industry 4.0 provides intelligent technology solutions for the apparel industry. Industry 4.0 adopts technologies such as the Internet of Things, big data, and artificial intelligence to achieve mass customization of apparel and provide personalized services to consumers [1]. Mass customization (MC) can realize the application of advanced computer technology with the apparel industry. The MC could provide online digital customization services without the presence of the customer. It could offer personalized garment for customers at a lower cost at the same time shorten production cycles. Flexible manufacturing in Industry 4.0 will accelerate the transformation trend of mass customization of apparel. However, there are many open problems on how AI could find its application in mass customization. This paper presents the key technologies of AI promoted mass customization.

2 Methodology

The contribution of this paper is presents methods and framework for how AI could find its application in mass customization of garment industry which is AI prompted mass customization framework.

In order to know the real challenges of current mass customization in garment industry, besides survey of research documents, this paper also chose 14 the typical companies of different types in garment industry from all over China for investigation of real garment industry from year 2019-2021. To eliminate the sampling data biases, the companies were chosen from different area of China, i.e. northern China, Southeast China, and southern China. From those investigation as well as the research archives this paper generalized the traditional garment industry pattern at different stages. To solve the challenges of the traditional garment industry, the correspondent the ideal AI promoted MC solutions framework are provided and with some experimentations for verification,

This paper is organized as follows. Section 2 discusses the technologies of AI promoted mass customization of apparel in terms of the knowledge management of customers, AI measurement, AI recommendation, and flexible manufacturing for example RFID and AI logistics. It then proposes an optimized AI production method for mass customization. Section 3 provides conclusions and future research.

3 AI Promoted Mass Customization of Apparel

Generally, the garment industry include 3 stages: pre-sale, research and developent and manufacturing,delivery. This section provided full-stage intelligent framework of each stage as well as data flows through each stages.

AI Promoted Mass customization can use AI knowledge management of customers and AI recommendation to obtain customer information. Apparel pre-sales, production, and logistics use the AI cloud for data management and sharing. Consumers, manufacturers, and AI logistics interact with data to enable flexible manufacturing of apparel. Fig. 1 shows the process of AI promoted mass customization. The MC could offer customization production on customer's demand. In addition, the MC could theoretically realize zero inventories of products.

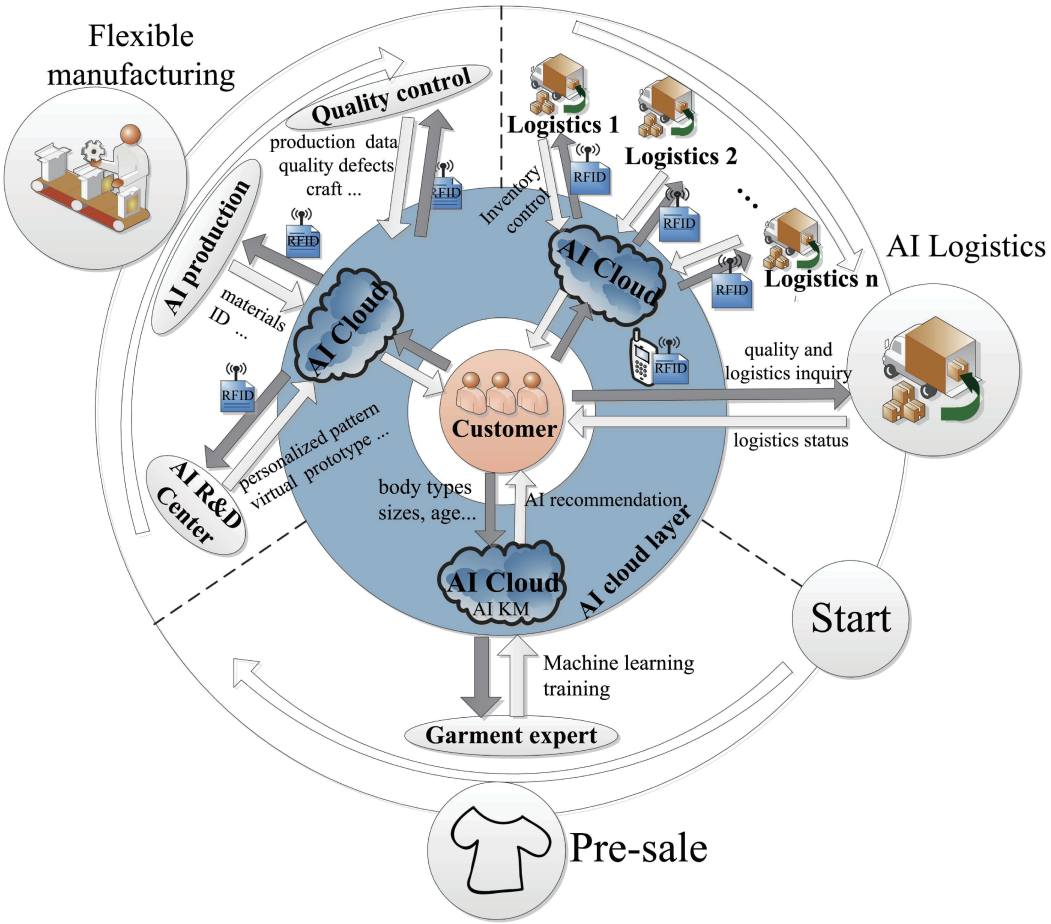
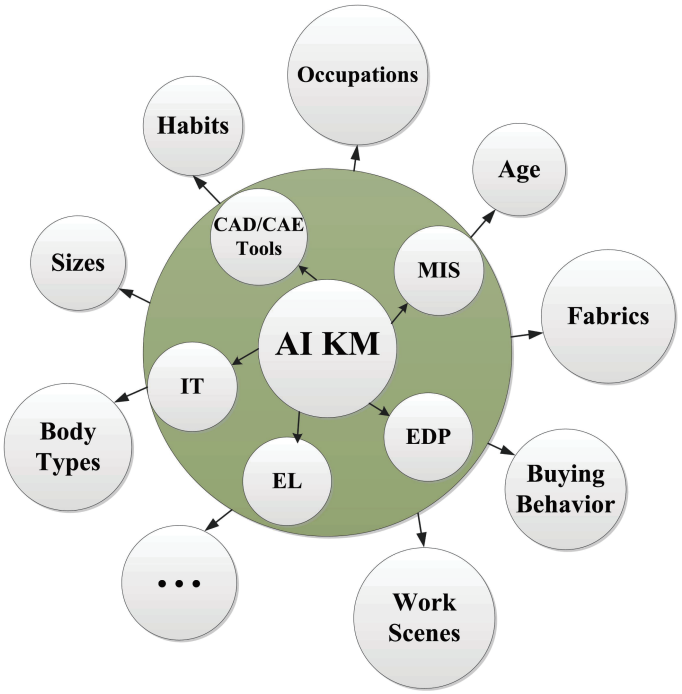


Fig. 1: The process of AI Promoted Mass customization

3.1 The AI Knowledge Management of Customers

Traditional knowledge management obtains customer's size information at stores for customization. However, it does not accumulate user information or recommend the right apparel for the user. Therefore, the AI knowledge management of customers (AI KM) is very important in mass customization. The MC can obtain precise customer requirements for personalized garment production. For enterprises, the knowledge management of customers is customer-centered, with access to all information about apparel personalization. Fig. 2 shows the AI knowledge management of customers. The AI KM with the prior knowledge of AI Expert library (AI EL) could apply deep learning technology to learn more about consumers' habits, tastes, purchase behavior, body types, sizes, fabrics, and occupations, which will offer more intelligent recommendation to customer. The AI KM combines Information Technology (IT), Electronic data processing (EDP) and CAD technology could offer intelligent digital sample cloth R&D process. The AI KM can use the AI EL to learn designer's design style, which will design personalized apparel at lower cost.

The knowledge management of customers is a prerequisite for mass customization of apparel. Fig. 3 shows the customer knowledge acquisition and AI management. Customer data is collected from offline apparel stores and online stores. The AI cloud will use the AI KM to learn customer information including age, preference, occupation, body type and size. The AI cloud could



IT: Information Technology
MIS: Management information system
EDP: Electronic data processing
EL: Expert library

Fig. 2: The AI Knowledge Management of Customer

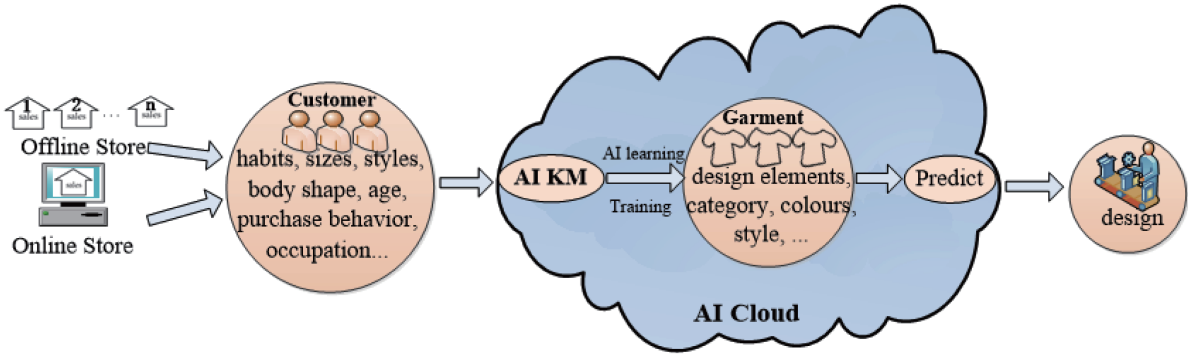
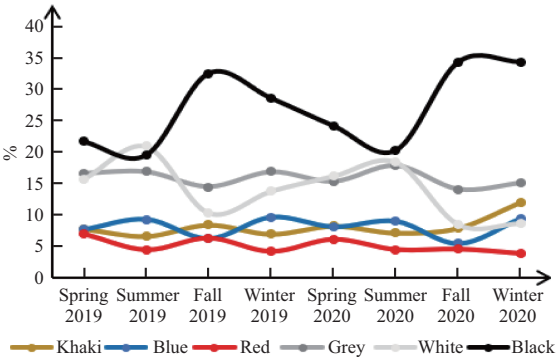


Fig. 3: The customer knowledge acquisition and AI management

predict fashion trends by machine learning the customer and apparel data. Finally, The AI cloud could feedback prediction information to the designer who create personalized garments for the customer. In order to verify the efficiency of AI cloud prototype system, color of garment in past 3 years' were provided to AI cloud prototype system and then compare it's predictions results with the true gourd data. Fig. 4 shows three years of apparel color trend predicted by the AI cloud. The AI cloud could predict future fashion trends including apparel styles, fabrics, design elements, and apparel categories. Fig. 4(a) shows the color of garment which are of black, blue, and khaki is on an upward trend red and white is on a downward trend. Therefore, The AI cloud can predict that the colors of black, blue, and khaki will be popular in the next year, and the color of garment which are of red, and white will decline. This is shown in Fig. 4(b).

Fig. 5 shows three years of apparel color trend of realistic. The black, blue, and khaki colors in apparel do increase in 2021. By comparing Fig. 4 and Fig. 5, the results of using The AI Cloud



(a) Apparel color trends in 2019-2020

(b) Apparel color prediction in 2021

Fig. 4: Three years of apparel color trend predicted by the AI Cloud

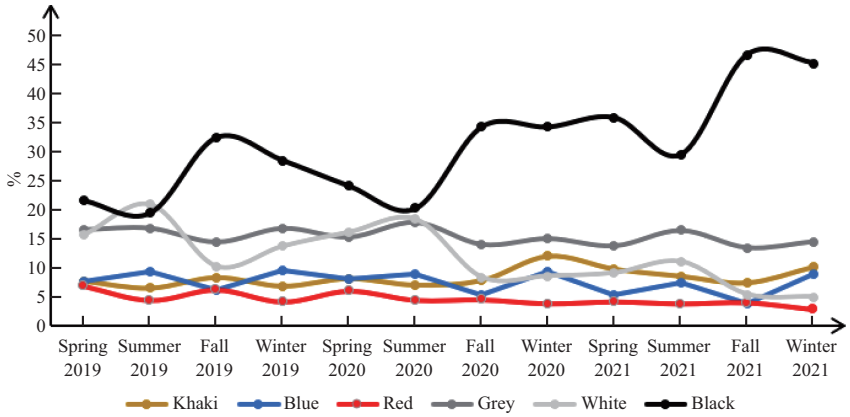


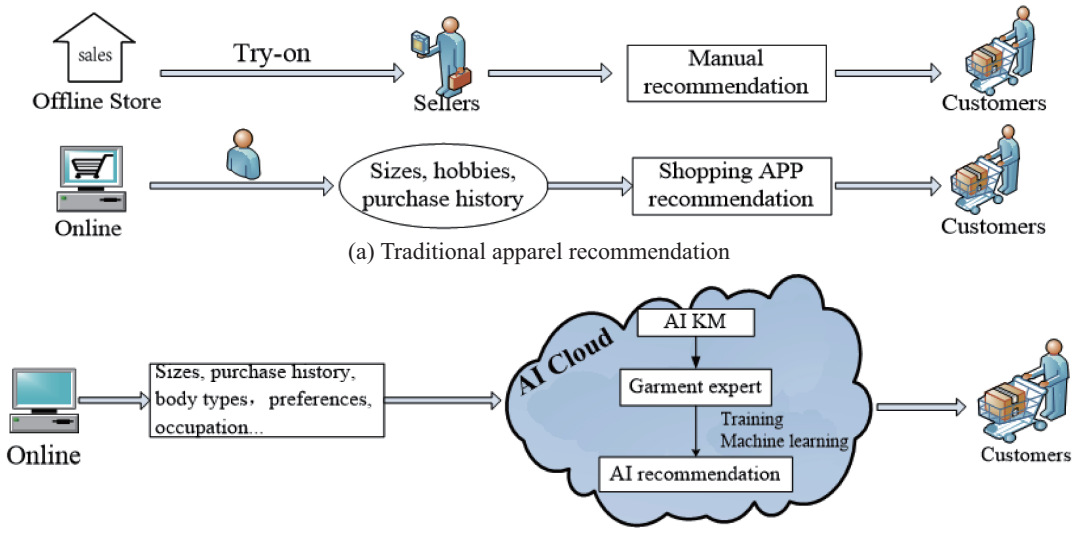
Fig. 5: Three years of apparel color trend

to predict the color trends in 2021 are successful. The AI Cloud can predict future trends from previous color trends, which will benefit to decrease the research and development time of new garment lines and increase the company's revenue and make more personalized recommendations for customers. The experiment shows that the AI Cloud prototype is valid.

3.2 The AI Recommendation

Traditional recommendation uses warehouse or online app recommendations through purchase history, which is limited personalization. Garment recommendation information is provided by the customer. However, it cannot accurately recommend apparel suitable for customers. In addition, Traditional recommendation is time-consuming. Fig. 6 shows the comparison of traditional and AI recommendation. While taking multiply scales of data such as body type, size etc into consideration the AI recommendation can use the AI cloud to highly match the customer's personalized data to recommend fit apparel. The AI cloud can learn from the experience of apparel experts to make new recommendation. In addition, the AI cloud can use garment experts to train personalized styles, patterns, and make AI recommendations.

Fig. 7 shows AI recommendations in mass customization. The AI cloud can be trained by AI KM and customer information including body type, age, occupation, and preferences as well as apparel style, apparel design elements, and apparel category. It can predict apparel trends



(a) Traditional apparel recommendation

(b) AI recommendation

Fig. 6: The comparison of traditional and AI recommendation

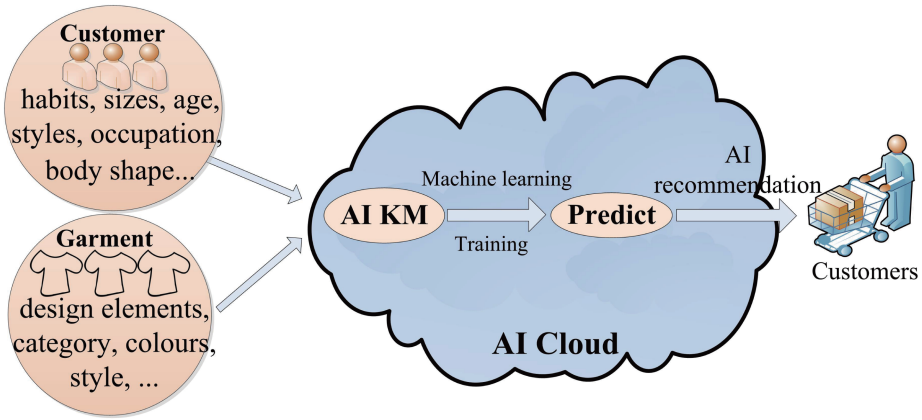


Fig. 7: AI recommendation in mass customization

and make targeted recommendations to a similar group of customers. Customers are able to experience personalized service and have high satisfaction. Companies can increase sales as well as brand influence, achieving a win-win development model for customers and companies and AI recommendations that truly meet personalization.

3.2.1 The AI Measurement

Traditional apparel measurement is done manually by measurers or consumers who fill in size information. However, the cost of manual measurement is high. Consumers generally do not know the body sizes, which will affect the entire process of apparel customization. Therefore, anthropometric methods needs to be intelligent. There are two smart measurement methods: 3D scanning and 2D image methods. The 3D scanning method can obtain accurate human body data. However, the human body scanners are usually expensive. It is inconvenient to measure at a fixed point with or without a strait jacket. The 2D image method can measure the human body quickly and inexpensively. Table 1 shows the comparison of human body measurement

methods. The comparison shows that the existing measurement methods cannot fully extract the sizes required for mass customization. Therefore, The AI measurement can use big data to analyze consumer behavior and get customer' data based on sales records and the number of online orders. The AI measurement can use the AI KM and AI recommendation to make an accurate prediction of customers' data. At the same time, the MC can keep track of changes in consumers' body types, sizes and styles and respond quickly to meet the individual needs of consumers.

Table 1: The comparison of human body measurement methods

Method	Classify	Sizes	Category	Disadvantage
Based on 3D scan	Laser [2, 3]	1-9, 11-19, 21-23, 25	Suit shirt dress pants	High noise sensitivity, large space occupation, complicated size collection
	Structured light [4, 5]	1-9, 11-19, 21-23, 25		Great light influence, immeasurable blind spot size, complicated data processing
	Depth map [6-8]	1-9, 14-17, 21-23, 25	Suit shirt pants	Low accuracy, high noise sensitivity, repeated depth map, large size error, point cloud holes, duplication
Based on 2D image	Single camera [9, 10]	1, 3-6, 9, 14-16, 22, 25	Suit shirt dress pants	Duplicate and missing point clouds, incomplete contour extraction; blind spots in measurement
	Multiple cameras [11, 12]	Camera coordinate distance		Complex equipment adjustment, disorder and missing point cloud

1-25: Bust, dress length, sleeve length, shoulder width, back length, neck circumference, upper arm circumference, cuff circumference, waist circumference, shoulder angle, shoulder slant length, chest width, back width, pants length, hips, upper length, feet mouth circumference, abdomen circumference, hip height, hip circumference, thigh circumference, inner and outer leg length, front and back girth length, back girth inclination, height.

3.3 Flexible Manufacturing

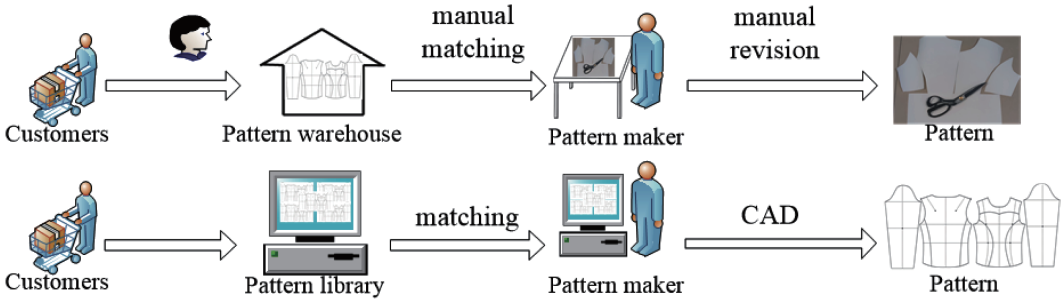
Flexible manufacturing is the key of mass customization. Traditional apparel production used manual cutting, sewing, and packaging. The traditional industrial chain has high labor costs and low efficiency and cannot achieve personalized apparel production. Flexible manufacturing can realize the transformation from factory to consumer model. QINGLIN QI [13] proposed that big data connects the information in the real and virtual world and realizes the information interaction and real-time sharing, which is conducive to the digital transformation of the manufacturing industry. The AI and big data are the key to flexible manufacturing. In the apparel industry,

the AI can be used as an intermediary between consumers, production and logistics to realize the flexible manufacturing of apparel.

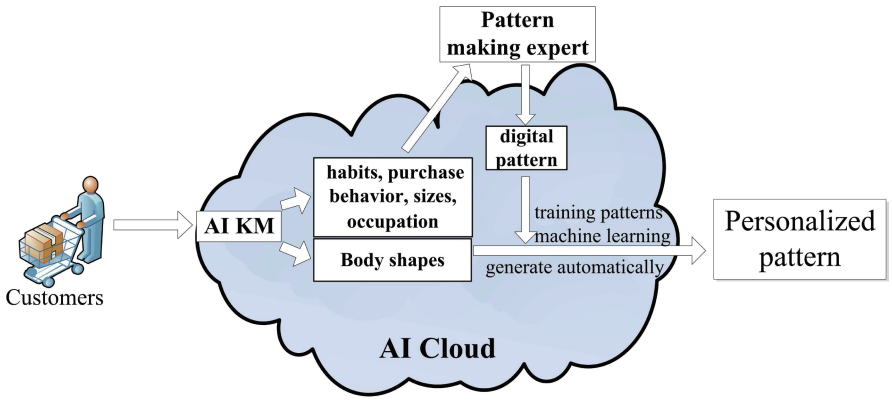
3.3.1 Flexible Digital Research and Development Technics

The AI pattern making is the key to flexible manufacturing of apparel. There are two traditional methods: manual pattern making and parametric pattern making. The manual pattern making requires the experience of pattern maker and requires repeated revisions. The patterns are placed in a specialized pattern warehouse. The second method is parametric pattern making. Parametric pattern making matched the appropriate pattern to CAD pattern making from the database. Traditional pattern making is time-consuming. In addition, traditional pattern making limited types of patterns in the existing database, which cannot provide personalized patterns of all customers. It is not really intelligent pattern making.

Fig. 8 shows the comparison of traditional pattern making and AI pattern making. The AI pattern making can use the AI KM to manage customer's information such as habits, purchase behavior, sizes, occupations etc. The development of the AI pattern making technology has been divided into two parts. In the early stages of development, the pattern-making experts use the customer data acquired to make patterns and populate the pattern database. The AI cloud can generate patterns automatically by machine learning from the patterns database. At the same time, The AI cloud can learn the pattern-making experts' pattern-making methods, styles and habits, generating automatically personalized patterns. Truly AI pattern making is the automatic generation of personalized patterns based on the body shape. At the same time, The AI cloud



(a) Traditional pattern making



(b) AI pattern making

Fig. 8: The comparison of traditional and AI pattern making

can keep the consumer's model data up to date to ensure that the pattern is personalized. Ideally, the AI pattern making would generate automatically personalized patterns based on the body shapes.

In addition, flexible manufacturing of apparel is inseparable from virtual garment prototype. Traditional garment try-on is in offline shops and time-consuming. It is a repeatedly process in garment fit. However, virtual garment prototype can realize remote contactless apparel try-on, which will reduce cost and cycle of production. It can be tried on online and quickly modified. It can also evaluate the fitness of virtual garment prototype to determine the fit of real garments. Virtual garment prototype will establish a virtual apparel library that includes all body types, fabrics and all apparel styles. And finally, virtual garment prototype will add virtual sewing process standards and establish rules for the evaluation the fit of the virtual garment prototype, which will enable the apparel industry to rapidly shift to mass customization.

3.3.2 Multiple Information Shared Via the RFID Technology

The RFID technology is the key technology of flexible manufacturing. The RFID technology can complete data collection and tracking. Traditional apparel information is recorded manually and easily lost. The garment production process is complicated and the product progress cannot be updated in real time. The RFID can quickly and accurately obtain all information about apparel customization. George Q. Huang [14] used RFID to synchronize real-time data in the manufacturing workshop to improve work efficiency. Ray Y. Zhong [15] used RFID to track and trace manufacturing objects and collect real-time production data. The garment with the smart RFID-label could offer not only tracing information of apparel design, production, and logistics for customers but also provide the easy methods for quality control and ensure the originality of apparel and realize smart apparel production in the apparel industry [16]. Mahir Oner [17] used the RFID application to track the production process of denim while managing the quality of the fabric and reducing the consumption of raw materials.

Since there are different types of data flows during each stages of MC, which are manufacturing maintenance data and manufacturing data of garment, the fast stable transfer the different data between different stages will be crucial. RFID has the stability and lower costs as short distance data transfer. Fig. 9, Fig. 10 show how the prototype system conveys the data flow under the framework presents by this paper.

Fig. 9 shows the data flow of the RFID technology in mass customization. The AI cloud can query and track production data from online digital R&D to workshop production. In flexible manufacturing, the AI cloud can put data about design, pattern making, virtual garment fit, production and quality control into the RFID tags for AI sorting. In AI logistics, the AI cloud can import inventory data and logistics status into RFID tags and automatically match logistics vehicles by scanning RFID tags. Customers can scan the RFID tags with smart devices and get all the information about design, production and logistics. The AI Cloud will realize information interaction among customers, manufacturing, and logistics, which can save apparel customization time and realize flexible manufacturing.

The customer could have the feedback information with the RFID tags, enabling information sharing between the customer and production. Fig. 10 shows the information flow of RFID technology in mass customization. The RFID tag is used throughout the entire process of customer orders, production and logistics. The RFID tag can generate a unique ID for the garment. While

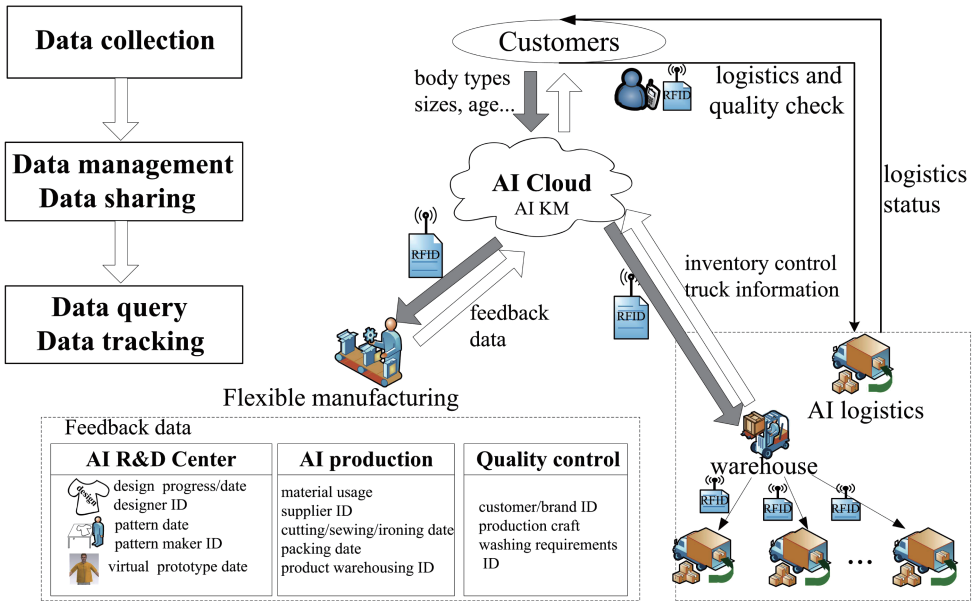


Fig. 9: The data flow of the RFID technology in mass customization [18]

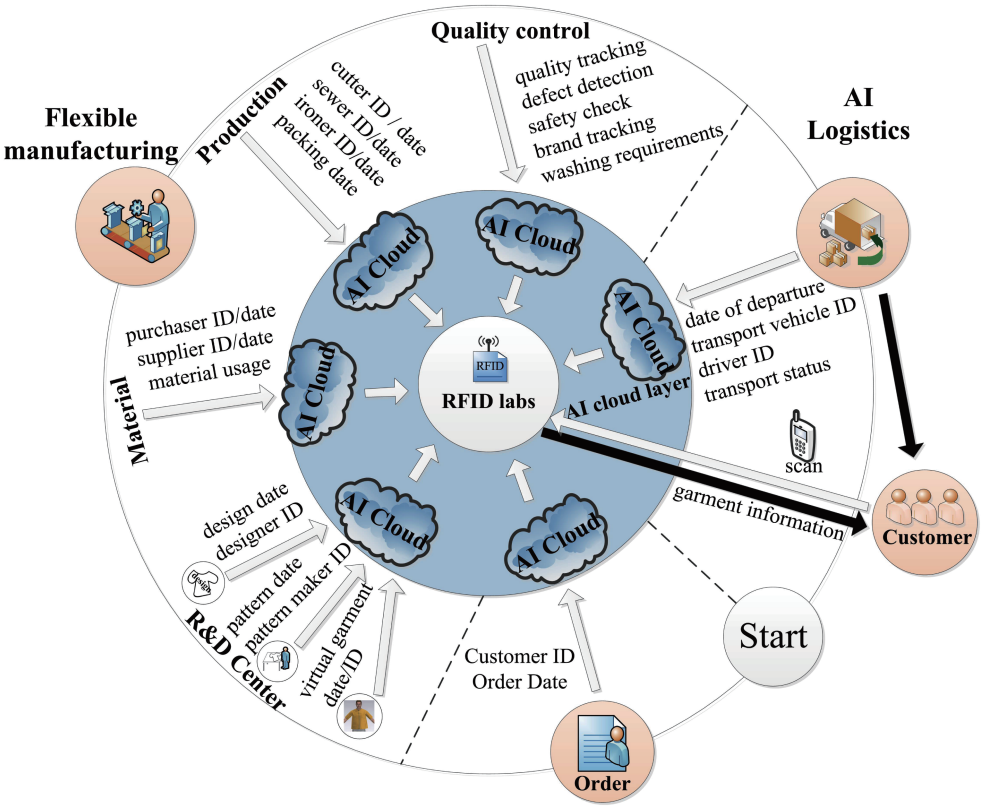


Fig. 10: The information flow of the RFID technology in mass customization

the garment go through different stages there are numerous production data generated accordingly which would store in AI cloud. The ID of RFID tag could be unique identification of the garment. With this unique identification the related data could be acquired. The AI cloud can input the customer ID and order start date into The RFID tag. The AI R&D Centre includes garment

design, pattern making and virtual pattern making. The AI cloud can put the designer ID, design date, pattern maker ID, pattern date and the date of the virtual pattern into The RFID tag. At the material preparation stage, information on buyers, suppliers and material usage is placed in The RFID tag. In addition, the information on the cutting, sewing and ironing of the garment is put into the RFID tag. Quality control is an important part of garment production. The quality inspectors can use The RFID tag for quality tracking, safety checks and defect detection. At the same time, the RFID tag can track brand information to ensure the originality of the brand. In AI Logistics, the RFID tag can enable the tracking of the date of departure, the distribution of logistics vehicles and the status of transport. Ultimately, customers can scan The RFID tag with their smartphones to get all information about the customization, production and logistics of the garments. In addition, customers can use The RFID tag to automatically identify garment fabric information for safe washing. The AI promoted mass customization requires information sharing. The RFID technology can enable the exchange of information between customer and production and can facilitate the development of intelligent mass customization of apparel.

3.4 The AI Logistics

Traditional garment logistics includes the transportation and storage of materials throughout the production process, as well as the distribution process. Traditional logistics need manual sorting and rely on warehouse to deliver apparel to customers. Traditional logistics can be transmitted to retailers or apparel stores for sales through third-party logistics companies, which increases the cycle and cost of apparel customization. Therefore, the AI logistics can deliver garments directly to consumers, reducing cycle time and cost, and improving customer satisfaction. Lee, Zhang [19] used the IoT to realize the warehousing inspection and tracking of raw materials, semi-finished products and finished products. C.K.M. Lee [20] proposed an intelligent warehouse management system, which can provide support for the smart logistics of Industry 4.0. The AI logistics generally has functions such as perception, decision-making and feedback. The perception function can use RFID tags to automatically identify apparel packaging, storage, and vehicle information. Decision-making function can achieve logistics management and distribution. The feedback function can understand the status of logistics and transportation in real time [21]. Fig. 11 shows the comparison of traditional logistics and AI logistics. The AI Logistics will use the AI cloud to obtain customer's information and production information. The AI cloud can input customer's addresses and garment quantities into RFID tags. The warehouse system can scan the RFID tags data to automatically match the logistics vehicle to the garment delivery. The AI Logistics can sort the customer's address by region. It can control the number of transport vehicles to achieve on-demand sorting, saving transport costs and lead times. The AI logistics can use the AI cloud to access warehouse management information, delivery areas and logistics status. Customers can inquire and track apparel quality and logistics by scanning RFID tags. With the application of AI logistics, The AI promoted mass customization will realize customer's personalized customization.

4 Discussion and Conclusion

The paper presents a practicable methods, framework for how AI could find its application in mass customization.

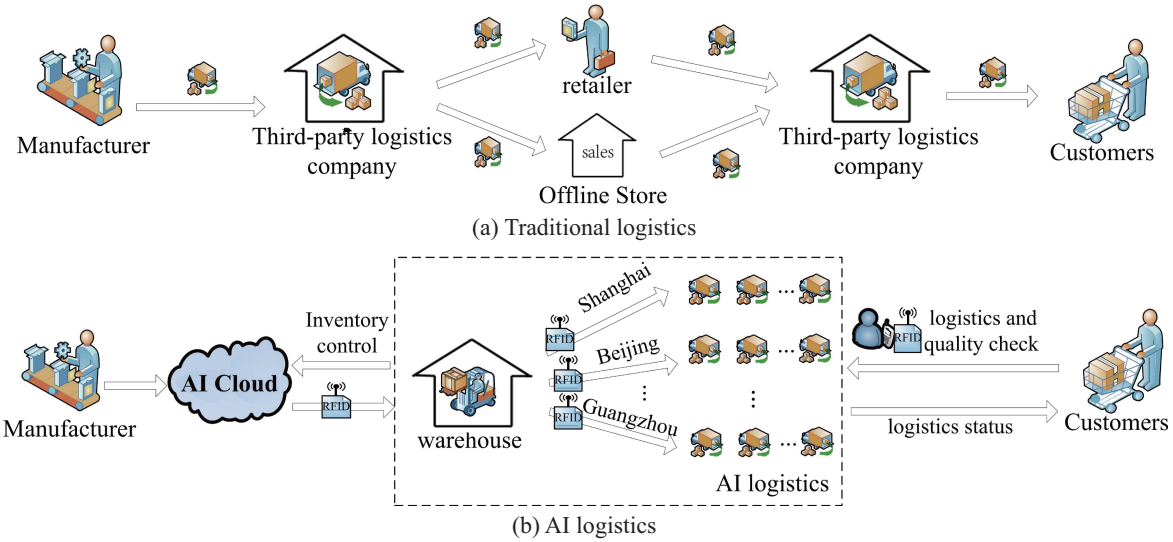


Fig. 11: The comparison of traditional logistics and AI logistics

The key technologies of AI promoted mass customization of apparel was also descripted in terms of the knowledge management of customers, AI recommendation, AI measurement and flexible digital research and develop technics, which includes AI pattern making, virtual garment prototype. The AI Cloud, AI KM and AI recommendation by deep learning of customer data including body type, occupation, and preferences, which can recommend highly personalized garment for customers. In theoretically, the AI pattern making can use the AI cloud to learn from the experience of pattern-making experts to automatically generate personalized patterns based on different body types. However, in practice due to the varieties of body shape the smart personalized non-standard body shape is an open problem. Virtual garment prototype could establish virtual fit evaluation standards, which can reduce production time and costs.

For subsequent parts, the RFID is applied to the flexible manufacturing and AI logistics, including process arrangement, quality control, customer feedback which will ensure the originality of apparel brands. At the same time, the AI Logistics could use the RFID tags for vehicle allocation and logistics tracking. The RFID tags enable the sharing information of customer, production and logistics, which benefit the development of AI Promoted mass customization. The AI Promoted mass customization could offer online and digital production processes which are a promising option for garment industry to solving the challenges that COVID-19 had brought.

5 Limitations and Future works

Although the AI R&D part of solutions for AI promoted framework has been proven to be theoretically effective. There are still limitations. The solutions framework of MC in theoretically could work for all type of body shape. In practice the algorithms of prototype system is suitable for standard body shape, it failed at some no-standard body types. So the AI promoted MC for non-standard body shapes will be an important future works.

The AI cloud of framework, in practice will have large scale of data, so how to process the massive amount of data in real time is another future works.

The ideal solution The AI logistics parts of this framework were provided, however, we hadn't have chances to have experiment to testify it. To testify the AI logistics framework with smart supply chain as well as the autonomous driving truck technology is also an important future works.

Acknowledgement

The paper was supported by project A-2020-40 Fund for great project - Mass customization of garment development for Olympic game.

References

[1] Zheng T, Ardolino M, Bacchetti A, et al. The applications of Industry 4.0 technologies in manufacturing context: a systematic literature review. International Journal of Production Research: 2020; 59(6): 1922-1954.

[2] Wu G, Zhong Y, Hu P, et al. Automatic body measurement based on slicing loops. International Journal of Clothing Science and Technology: 2018; 30(3): 380-397.

[3] Nurunnabi A, Sadahiro Y, Laefer DF. Robust statistical approaches for circle fitting in laser scanning three-dimensional point cloud data. Pattern Recognition: 2018; 81: 417-431.

[4] Yue H, Yu Y, Chen W, et al. Accurate three dimensional body scanning system based on structured light. Optics Express: 2018; 26(22): 28544-28559.

[5] Stančić I, Musić J, Zanchi V. Improved structured light 3D scanner with application to anthropometric parameter estimation. Measurement: 2013; 46(1): 716-726.

[6] Xiao HT, Xiao YP, Li WL, et al. Automatic human body feature extraction and personal size measurement. Journal of Visual Languages & Computing: 2018; 47: 9-18.

[7] Rogge S, Hentschel C. A multi-depth camera capture system for point cloud library. 2014 IEEE Fourth International Conference on Consumer Electronics Berlin (ICCE-Berlin): 2014.

[8] Ren L, Lu J, Feng J, et al. Multi-modal uniform deep learning for RGB-D person re-identification. Pattern Recognition: 2017; 72: 446-457.

[9] Shah J, Shah C, Sandhu H, et al. A Methodology For Extracting Anthropometric Measurements from 2D Images. 2019 International Conference on Advances in Computing, Communication and Control (ICAC3): 2019.

[10] Gan XY, Ibrahim H, Ramli DA. A simple vision based anthropometric estimation system using webcam. Journal of Physics: Conference Series: 2020; 1529.

[11] Pesce M, Galantucci LM, Lavecchia F. A 12-camera body scanning system based on close-range photogrammetry for precise applications. Virtual and Physical Prototyping: 2015; 11(1): 49-56.

[12] Peyer KE, Morris M, Sellers WI. Subject-specific body segment parameter estimation using 3D photogrammetry with multiple cameras. PeerJ: 2015; 3: e831.

[13] Qi Q, Tao F. Digital Twin and Big Data Towards Smart Manufacturing and Industry 4.0: 360 Degree Comparison. IEEE Access: 2018; 6: 3585-3593.

[14] Huang GQ, Zhang YF, Jiang PY. RFID-based wireless manufacturing for real-time management of job shop WIP inventories. The International Journal of Advanced Manufacturing Technology: 2008; 36(7): 752-764.

[15] Zhong RY, Dai QY, Qu T, et al. RFID-enabled real-time manufacturing execution system for mass-customization production. Robotics and Computer-Integrated Manufacturing: 2013; 29(2): 283-292.

[16] Lee CKH, Choy KL, Ho GTS, et al. A RFID-based Resource Allocation System for garment manufacturing. Expert Systems with Applications: 2013; 40(2): 784-799.

[17] Oner M, Ustundag A, Budak A. An RFID-based tracking system for denim production processes. The International Journal of Advanced Manufacturing Technology: 2017; 90(1): 591-604.

[18] Sun QQ, Sun XD. Future of the Garment Industry: AI Promoted Mass Customization. Testile Bioengineeing And Informatics Symposium Priceedings, 2021: 267-274.

[19] Lee CKM, Zhang SZ, Ng KKH. Development of an industrial Internet of things suite for smart factory towards re-industrialization. Advances in Manufacturing: 2017; 5(4): 335-343.

[20] Lee CKM, Lv Y, Ng KKH, et al. Design and application of Internet of things-based warehouse management system for smart logistics. International Journal of Production Research: 2018; 56(8): 2753-2768.

[21] Tang X. Research on Smart Logistics Model Based on Internet of Things Technology. IEEE Access: 2020; 8: 151150-151159.