Research on consumer personalized customization mode under the scenario of intelligent manufacturing

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Abstract. The personalized customization production mode for consumers in the intelligent era under 5G intelligent manufacturing scenario was discussed. And the personalized customization system, in terms of technical framework, would include two functional modules of customization and production, as well as four operating systems of product design, recycling improvement, mirror manufacturing and additive manufacturing. The experiments of screening and sorting product color attributes would be carried out systematically to meet the unique demands for product color attributes out of consumers and ultimately to establish the variety satisfactory to consumers. And then the satisfaction evaluation and disgust point analysis for the optimized pattern obtained from the screening would need to be proceeded in order to circular improve the pattern to the critical limit. Personalized customization would certainly become the basic way of industrial production in the future as it greatly improved the utility of consumers with the cost of mass production.

Keywords: Intelligent manufacturing; Personalized customization; Consumer production

1. Introduction

From an economic point of view, the value of a product should ultimately be reflected in the utility it brings to consumers, and the degree of personalization of the product is an important embodiment of consumer utility. Therefore, consumers are always pursuing a high degree of personalization of products and want to maximize their utility through personalized customization.

However, under the traditional model, customization faces some dilemmas: consumers. On the user side, the realization of personalized customization is based on enterprises accurately capturing and analyzing the individual needs of users (Zhang et al., 2021)[1], but at present, due to technical limitations, the traditional industrial model has the defect of isolation between consumers and producers, and consumers cannot put forward personalized design requirements for products. Even if users participate in product design, users lack professional knowledge and skills, resulting in non-standardized dialogue between users and enterprises, and making it impossible for enterprises to accurately capture user needs (Tiitinen et al., 2017)[2]. Enterprises can only spend a very high cost to capture and analyze the needs of users through various channels, and finally rely on a small number of users' demand information for product design (Erevelles et al., 2010)[3]. On the process side, there is a conflict between the process standardization required by the traditional mass production process and the process dynamics required by the personalized customization process, and it is difficult for most enterprises to achieve personalized customized product production (Zheng, 2017; Hu, 2016)[4-5]. In order to adapt to the personalized customization process, enterprises will spend huge costs to flexibly transform the manufacturing end (Hu, 2016; Yan, 2020)[6-7]. So, The traditional large-scale production model is difficult to implement personalized customization, so it cannot meet the personalized customization needs of consumers, and consumer utility will undoubtedly be greatly reduced.

With the emergence and rapid development of intelligent manufacturing technology based on industrial Internet of Things, solidified physical molds will be replaced by virtual electronic molds, rigid subtractive manufacturing processes will be replaced by highly flexible additive manufacturing processes, and previously isolated consumers can be linked to intelligent manufacturing production sites through industrial Internet of Things. In this case, the cost of personalized customization will be greatly reduced, even to the cost level of mass production.

In the near future, with the continuous improvement of 5G and even 6G industrial Internet of Things technology, the intelligent manufacturing model will gradually replace the traditional large-scale production model, and consumer personalized customization will become the standard of the intelligent manufacturing model. In order to actively respond to the upcoming challenges of intelligent manufacturing personalized customization, this paper will try to explore the consumer personalized customization mode under the intelligent manufacturing scenario, in
order to deeply understand the operation logic of personalized customization in the era of intelligent manufacturing, and lay an academic foundation for future intelligent customization in advance.

2. Personalized Logical Framework

2.1 Concept connotation of personalization
Personalized customization is a non-mass production mode in which consumers participate in the personalized design and manufacturing process of products under the scenario of Industry 4.0. Specifically, personalized customization is that producers use intelligent manufacturing systems to design the unique structure of products based on consumers' personalized needs, and give consumers the power to optimize the product structure through real-time experience and circular improvement through the virtual mirror platform, until consumers are satisfied and then handed over to the physical manufacturing system for final output.

The core of consumers' personalized demand for product structure is the unique appeal to the product décor attributes. In detail, personalized customization is based on consumers' personalized needs for product décor attributes, through the intelligent manufacturing system to introduce consumers into the design, screening, real-time experience and cycle improvement and optimization of product décor attributes, and finally make product décor varieties that consumers are satisfied with.

2.2 Personalize the system architecture

2.2.1 Intelligent manufacturing system architecture
Personalization is highly dependent on intelligent manufacturing systems. Intelligent manufacturing system is an organic combination of industrial Internet of Things and intelligent manufacturing technology, which is roughly composed of two parts, the physical part is the intelligent manufacturing workshop, the virtual part is the workshop mirror, and the virtual and real parts are linked by the industrial Internet of Things. The process of personalization is mainly done by the consumer in the workshop mirror. The architecture of the intelligent manufacturing system in the general sense can be described by Figure 2.

2.2.2 Personalized customization system based on intelligent manufacturing

Based on the intelligent manufacturing system, the personalized customized system includes two functional modules and four major operating systems. Among them, the two major functional modules are customized modules and production modules; The four operating systems include product design system, circular improvement system, mirror manufacturing system and additive manufacturing system.

The customized module mainly undertakes the function of product design and improvement optimization, and includes product design system and circular improvement system. The product design system mainly designs initial products according to the individual needs of consumers; The circular improvement system is mainly to carry out iterative improvement of the consumer experience of the initial product until the consumer is satisfied.

The production module mainly undertakes the product manufacturing function, which includes the mirror manufacturing system and the additive manufacturing system. The mirror manufacturing system is mainly to check the producibility of product styles; Additive manufacturing systems are responsible for the final manufacture of viable product patterns. Figure 3 provides an overview of the overall architecture of a personalized system.
2.3 Personalized implementation path
The personalized operation path can be roughly divided into six steps, namely "consumer networking, product personality design, consumer experience improvement, production feasibility testing, 3D printing product electronic model, product production and delivery". The specific customization path is shown in Figure 3.

3. Screening and Sorting experiment of product décor attributes
As mentioned earlier, personalization is essentially seeking to satisfy consumers with the decor attributes of the product. In order to obtain product décor attributes that consumers are satisfied with, consumers must have the opportunity and ability to fully screen product décor attributes. To this end, the consumer design of the product décor attribute screening and sorting experiment.

3.1 Experimental variables
The general logic of the experiment is that consumers select a number of favorite decors from a certain number of product decors, and then select the top decors from the more favorite decors, and sort the final decors preferences. Accordingly, the relevant experimental variables are defined as follows:

- **Product décor alternative capacity.** Refers to the upper limit of the number of alternative decors that consumers can bear in the product décor screening experiment, which is recorded as \( Q \). Within this upper limit, consumers have the ability to identify preferred decors; Beyond this limit, it will be difficult for consumers to identify their preferred decors.

- **Product décor preference capacity.** It refers to the upper limit of the number of decors that consumers choose from the alternative product decors (\( Q \)), which is recorded as \( L \). Within this upper limit, consumers have the ability to select decors for sorting; Beyond this limit, consumers will have difficulty selecting decors to sort in.

- **Product decor sorting capacity.** It refers to the upper limit of the number of decors selected by consumers from the favorite decors (\( L \)), which is recorded as \( l \). Within this upper limit, consumers have the ability to sort decor preferences; Beyond this limit, it will be difficult for consumers to sort decor preferences.

3.2 Experimental variable interviews
Select \( n (n \in N) \) consumer individuals, based on the actual shopping experience of a certain product \( A \), ask them respond about the product décor alternative capacity (\( Q \)), product décor preference capacity (\( L \)), and product décor sorting capacity (\( l \)). The interview data are statistically averaged to obtain the initial reference values of the experimental variables, which are recorded as the initial value of product décor alternative capacity \( Q_0 \), the initial value of product décor preference capacity \( L_0 \), and the initial value of product décor sorting capacity \( l_0 \), and used this initial value to guide the following experimental design.

3.3 Product décor preference capacity experiment
- Preparation of product décor samples. Select \( n (n \in N) \) volunteers, use the intelligent manufacturing system to collect each volunteer's preference for the décor attribute of product \( A \), use Cartesian product algorithm to combine the preference attributes, and generate corresponding product images of the product decors that meet the
volunteers’ preferences through the virtual mirror platform for volunteers to sort.

- Product decor sorting experiment. Volunteer \( i \) (\( i \in (1,\ldots,n) \)) sort \( m \) (\( m = l + 1, l + 2,\ldots \)) decors that matched their preference and is asked to exclude the top decors. Each experiment is spaced 1 day apart and the time series of each volunteer’s experiment is recorded. Initial value of capacity sorting capacity for product decors obtained from interviews.

- Individual décor preference capacity calculation. Calculate the mutation point in the experimental time series of volunteer \( i \) (\( i \in (1,\ldots,n) \)), compare it with the initial value \( L_0 \) of product décor preference capacity obtained from interviews, and find the mutation point closest to it. The number of product decors corresponding to the mutation point is \( (L_i + 1) \), the volunteer’s décor preference capacity value is \( L_i \).

- Sample décor preference capacity calculation. The individual décor preference capacity \( L_i \) of \( n \) volunteers is averaged to obtain the consumer sample décor preference capacity \( L \).

3.4 Product decor alternative capacity experiment

- Preparation of product décor samples. Select \( n \) volunteers, and use the intelligent manufacturing system to collect each volunteer’s preference for the décor attribute of product \( A \). Then, use Cartesian product algorithm to combine the preference attributes, and generate corresponding product images of the product decors that meet the volunteers’ preferences through the virtual mirror platform for volunteers to screen.

- Product décor screening experiment. Volunteers \( i \) versus \( m \) (\( m = L + 1, L + 2,\ldots \)) products that meet their preferences are screened and asked to select the \( L \) decors they prefer. Each experiment is spaced 1 day apart and the time series of each volunteer’s experiment is recorded.

- Individual décor alternative capacity calculation. Find out the mutation point in the experimental time series of volunteer \( i \). Compare it with the initial value \( Q_i \) of the alternative capacity of the suit obtained by the interview, find out the mutation point closest to it, and find out the number of product decors corresponding to the mutation point (\( Q_i + 1 \)). So, the volunteer’s suit alternative capacity value is \( Q_i \).

- Sample decor alternative capacity calculation. The individual suit alternative capacity of \( n \) volunteers is averaged to obtain the consumer sample suit alternative capacity \( Q \).

4. Personalized customization process based on product décor library

4.1 Analysis of Consumer Preferences

The system database stores a large number of decors, in order to facilitate consumer selection, first need to analyze consumer preferences, from which to screen out decors that meet consumer preferences. For a product, the system divides its décor attributes into experiential attributes and non-experiential attributes. Experientiable attributes are attributes that can be experienced by product images. When performing consumer preference point analysis, only consumer preferences for experiential attributes are collected. In order to analyze consumer preferences more efficiently, the experientiable attributes are further divided into directly observable attributes and non-directly observable attributes, and consumer preferences are collected in turn.

4.2 Product décor library construction

Let a product have \( N \) décor attributes, where attribute \( i \) has \( M_i \) values. Through consumer preference analysis, consumers prefer the attribute \( i \) to their \( m_i \) value (\( m_i \in M_i \)). Using the Cartesian product algorithm, \( M = \prod_i M_i \) suits and their property matrix are obtained, and all suits are numbered from 1 to \( M \) in turn, and the attribute matrix of the suit \( h \) is as shown in Equation (1).

\[
a^h_i = \begin{bmatrix}
a^{h_1}_1 & a^{h_1}_2 & \cdots & a^{h_1}_M \\
a^{h_2}_1 & a^{h_2}_2 & \cdots & a^{h_2}_M \\
\vdots & \vdots & \ddots & \vdots \\
a^{h_M}_1 & a^{h_M}_2 & \cdots & a^{h_M}_M \\
\end{bmatrix}
\]

In Equation (3), the attribute vector of the suit \( h \) with respect to attribute \( i \) indicates that the suit \( h \) is the \( k \)th value in attribute \( i \). If the suit \( h \) has the \( k \)th value in attribute \( i \), then, otherwise.

After using Cartesian product algorithm to combine attributes to obtain the above \( M \) product decors, the corresponding mirror products are generated through the virtual mirror platform to build a product library that meets consumer preferences.

4.3 Product decor area division

In order to further reduce the number of alternative decors extracted from the product library, the decors in the product library can be divided into regions, and the decors of each region can be selected in turn.

1) Similarity Algorithm

The division of product decors into areas is to classify product decors according to certain standards. Specifically, the similarity classification standard is adopted, and the product decors with high similarity are divided into a region as a category. The similarity algorithm is: for product decors \( r \) and decors \( s \), the attribute vectors of the \( i \)th attribute of the two are as shown in equation (2).
Then the similarity between suit \( r \) and suit \( s \) can be calculated by equation (3).

\[
h(r,s) = \frac{\sum_{i=1}^{N} (a_i^r)^* a_i^s}{Q_r + Q_s - \sum_{i=1}^{N} (a_i^r)^* a_i^s}
\]

Where the suit \( r \) and suit \( s \) have the same value with respect to attribute \( \sum_{i=1}^{N} (a_i^r)^* a_i^s = 1 \), otherwise \( \sum_{i=1}^{N} (a_i^r)^* a_i^s = 0 \). Indicates the number of suits \( r \) and suit \( s \) that share properties. \( Q_r \) and \( Q_s \) are the number of attributes of suit \( r \) and suit \( s \), respectively, and are calculated as in equation (4).

\[
Q_r = \sum_{i=1}^{N} \text{sum}(a_i^r), Q_s = \sum_{i=1}^{N} \text{sum}(a_i^s)
\]

### 4.4 Product Decors Screening

After all decors are divided into regions, the decors of each region are provided to consumers in turn, and the most preferred decors of consumers are obtained through layer by layer screening. The screening process is shown in Figure 5. \( M \) is the total number of decors in the product décor library that meets consumer preferences.

The system provides \( Q \) product decors in each region to consumers for screening, and selects \( L \) favorite decors from each region.

The system summarizes the selected product decors, and if the number of remaining unselected decors is greater than \( Q \), the remaining decors are divided into regions and return to step ①; Otherwise, go to the next step.

The consumer again selects the \( L \) decors that he prefers from the remaining decors.

The consumer sorts the \( L \) suits in step ③ and excludes the first \( L \) suits.

### 4.5 Consumer Disgust Point Analysis

When consumers feel disgust with certain attributes, there is a need for aversion attribute improvement. Therefore, after consumer screening, the system collects consumer disgust points and makes product personalization improvements based on the disgust points.

1. Collect consumers' preference attributes and disgust attributes regarding the decors of the top \( L \) products. Modeled on consumer preference analysis, collect consumers' preference attributes and disgust attributes about the top \( L \) products from the aspects of directly observable attributes and non-directly observable attributes.

2. Analyze and summarize consumer disgust points. Organize the preference attributes and disgust attributes and summarize consumer disgust points.

### 4.6 Personalization improvements based on disgust points

#### 4.6.1 Satisfaction Evaluation Rules

After consumer screening, the system collects ten attributes that consumers consider important and defines these attributes as satisfaction evaluation indicators. After the indicators are set, the ten-point scoring rule is adopted to let consumers score the satisfaction of these indicators, and the system calculates the satisfaction value according to the consumer's rating of each indicator. For consumers to score the index \( i \) \( \pi_i \), the system formalizes the score of the index according to equation (5).

\[
s_i = \frac{\pi_i}{10} \times 100\%  \tag{5}
\]

#### 4.6.2 Indicator weight assignment

Using the Likert 7-level scale, consumers are required to score the importance of each evaluation index, and for each indicator. The higher the score, the higher the degree of importance that consumers think of the indicator. According to the consumer score, the importance score of each evaluation index \( i (i=1, 2, \ldots, 10) \) was obtained. The weights of each indicator are calculated as in Equation (6).
\[ \omega_i = \frac{y_i}{\sum_{i=1}^{10} y_i} \]  

(6)

1) Personalization Improvement Process

After screening out the top L product decors, consumers improve the product based on the disgust point to achieve personalized customization.

① Based on the product disgust point, the consumer submits a modification in the feedback box output by the system, and the system modifies the disgust attribute according to the modification opinion, and designs new attribute values.

② The system combines the attributes preferred by consumers with the newly designed attributes, and generates new decors through the virtual mirror platform.

③ According to the above consumer screening ideas, divide the new decors into areas for consumers to screen, and require the top L decors to be excluded.

④ Consumers are required to select ten attributes as satisfaction evaluation indicators, and each indicator is scored on satisfaction and importance, and the consumer satisfaction value is calculated. The satisfaction value of the i-th improvement is calculated as in Equation (7).

\[ e_i = \omega_i s_i + \omega_2 s_2 + \cdots + \omega_n s_n \]  

(7)

In Equation (9), \( e_i \) is the satisfaction value of the i-th improvement, \( s_i \) is the consumer's satisfaction score for the evaluation index i, and \( \omega_i \) is the importance weight of the index i.

⑤ Repeat the above steps until the consumer satisfaction growth rate \( \varphi \) is less than the set threshold \( \alpha \) (the threshold value is set according to the small probability event principle), and the improvement is terminated (e.g. Equation (8)).

\[ \varphi = \frac{e_{i+1} - e_i}{e_i} < \alpha \]  

(8)

⑥ Collect consumers' attribute preferences regarding the decors of the top L products, and the attributes preferred by consumers are dominant attributes.

⑦ The system combines the dominant attributes to obtain the most satisfactory products for consumers.

4.7 Personalized Product Manufacturing

4.7.1 Production Feasibility Testing

In real production, there are often many problems such as supplier restrictions, lack of raw materials in the market, so that the actual conditions of production are smaller than the conditions of the décor library. Therefore, before putting the individually designed product decors into production, the system needs to use the mirror manufacturing system to simulate the virtual manufacturing of the product, and if it passes the production feasibility test, it will be put into production; Otherwise, return to the consumer experience improvement process and let the consumer improve again until the designed decor passes the feasibility test. The feasibility test process for the production of product decors is shown in Figure 6.

![Figure 6. Product decor production feasibility test process](image)

4.7.2 Feasibility Iterative Improvement

When the product decors fail the feasibility test, the system needs to return to the consumer experience link to allow consumers to iteratively improve the decors. The iterative improvement process is shown in Figure 7.
5. Conclusions

The main findings are as follows:

- Personalized customization in the context of intelligent manufacturing is a non-mass production mode in which consumers participate in the personalized design and manufacturing process of products through intelligent manufacturing systems. It can greatly improve consumer utility at the cost level of large-scale mass production, thus becoming the standard production mode of intelligent manufacturing.

- Personalized customization is highly dependent on intelligent manufacturing systems. The personalized customization system includes two functional modules - customized module and production module, and four operating systems - product design system, circular improvement system, mirror manufacturing system and additive manufacturing system. Among them, the product design system and the circular improvement system form a customized module, which mainly undertakes the personalized design and improvement and optimization functions of the product; The mirror manufacturing system and the additive manufacturing system constitute the production module, which mainly undertakes the functions of product production testing and delivery.

- The core of personalized customization is the unique demand of consumers for the decor attributes of products. In order to meet consumers' personalized demands for product decors, it is necessary to systematically design consumers' screening and sorting experiments on product decors. The general logic of the experiment is that consumers select a number of favorite decors from a certain number of product decors, and then select the top decors from the more favorite decors, and sort the final decors preferences.

It can be expected that with the successive launch of 5G and even 6G industrial Internet of Things, consumer personalized customization based on intelligent manufacturing systems will become the basic way of industrial production in the future.

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References


