UDC 67

RESEARCH ON APPEARANCE ELEMENT DESIGN OF PROTECTIVE DOOR FOR INTELLIGENT EQUIPMENT

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Abstract: The appearance design of intelligent equipment provides added value for the brand. This project analyzes the design elements of protective doors of intelligent equipment and generates a design scheme that meets the perceptual needs of users. BP neural network was used to assist product design, and guided by consumers' perceptual needs, semantic scale training network was analyzed to form protective door design elements, and design elements combination scheme was generated to assist design. By analyzing the correlation between design elements and the evaluation of target image, the correlation between design elements and the comprehensive evaluation of modeling is obtained indirectly, which can be used as a reference to ensure the comprehensive evaluation of expected modeling and the evaluation of target image in design activities.

Key words: Product design; Intelligent equipment; Kansei Engineering; Artificial neural network; The perceptual intention

0 Introduction

Intelligent equipment refers to the manufacturing equipment with the functions of perception, analysis, reasoning, decision-making and control [1] . Nowadays, the technology of intelligent equipment is becoming mature, but the appearance is heavy and boring, lacking of aesthetics. As a product, intelligent equipment not only needs to have practical functions, but also its aesthetic attributes play an important role, harmonious and beautiful design can provide a more harmonious use of the experience, can also become a brand to occupy the consumer market a powerful weapon.

Nowadays, the appearance design of intelligent equipment is gradually concerned by the industry, such as Japan's Yamazaki, Germany's Trumpf, DMGMORI and other international first-line brands, have invested huge efforts in the field of appearance design. The shape of its products fully integrated into the elements of brand recognition, forming a series of standardized design style. Some achievements have been made in the field of appearance design of intelligent equipment in China. For example, Kunming machine tool TK6920B CNC floor milling and boring machine (Figure 1 left) won the red-dot award, bunde laser maglev laser cutting machine (Figure 1 middle) won the IF design competition

product design award.

In this paper, the intelligent equipment special plane protective door is taken as the design object, and the technology of BP neural network is used to carry on the semantic analysis of the design elements, and the output of the combination scheme which accords with the perceptual semantic is used to assist the design, the final presentation illustrates the design results.

1. Background

1.1 Current status of intelligent equipment design

The appearance esthetics elements of intelligent equipment are composed of form, function, symbol and environment. The attention to design can bring the brand value beyond the product itself, such as the promotion of the core value of the brand, the construction of the brand image, the effect is not only to improve product efficiency, but also to build a good brand image in the consumer group and expand the influence. With the emphasis of intelligent equipment brand on design, many excellent design cases have appeared in the market.

For example, the appearance design of the products under the German express group are integrated into the dark blue rectangle this brand identity image, such as the TRULASER 1000 laser cutting machine in Figure 1 (right), body shape, decorative elements, protective door design, etc. , both echo with the brand image. Not only the product, but also the building design of the headquarters is a cube in the same style, and the official web design also makes use of rectangular elements. Tongkuai is a successful case that integrates the elements of corporate identity and makes the brand image deeply popular. The leading brands in the industry, such as Japan's Mazark, Germany's DMG, also formed a brand-specific design style, such as Mazark will be orange elements into the design, giving the product a sense of vitality, dMG, on the other hand, entrusts its products with a sense of technology through its design. Because of its excellent performance, aesthetics and usability, DMG's products are the best-selling in Germany.

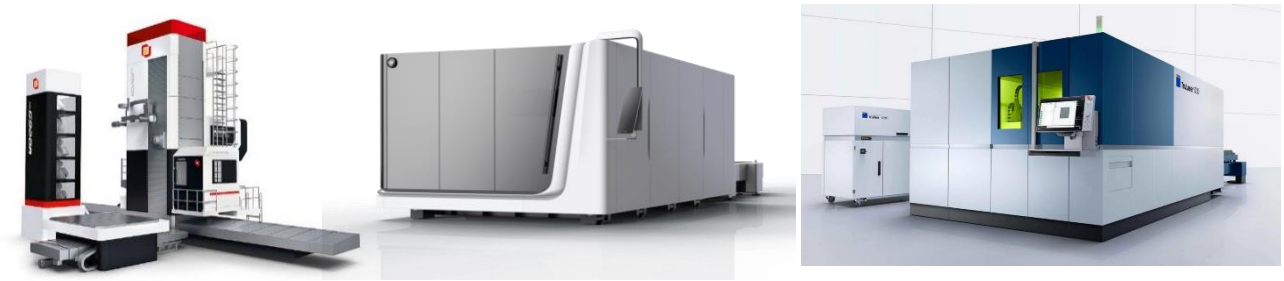

Fig.1 TK6920B CNC jig boring machine (left), Bond laser maglev laser cutting machine (middle) and TRUMPF TruLaser 1000 laser cutting machine (right)

1.2 Related sudies

The development of machine learning has brought the application direction to the design field, and artificial intelligence aided design has become a hot topic in the design field in recent five years. At present, the application of AI in the field of design

mainly exists in the following forms [3]:
(1) design reviews and recommendations. For example, a Bannersnack can rate an ad's design, while EyeEm can rate the aesthetic value of the design
(2) AI generation design, such as Alibaba Deer Class, can generate 8000 poster design per second [4], Arkie is also a poster generation program;
(3) AI tool aided design. For example, CANVA is a tool that provides support for derivative design of graphic design, while Adobe Sensi also provides a variety of AI design tools, such as one-click Cutout, multi-screen video co-editing, etc.
(4) data collection. Using AI algorithms, e-commerce can collect information about users' preferences and needs, while The Thread provides fashion matching ideas through data collection
(5) Data Processing: using neural network to deal with the data of investigation, design elements, and so on parameterized, to achieve induction and summary and even design classification and design generation.

This topic belongs to the fifth kind of applications, that is, the use of neural networks to develop semantic analysis. Relevant studies such as:
In the field of icon design, Ting-chun Tung used BP neural network to evaluate and get the best icon color matching [5], by using multiple regression equations to calculate the best combination method for aided design [6]; Wang Hongjiang et al used BP neural network for vehicle design morphology analysis calculation [7]; yin lei et al extracted the design features of vehicle headlights, the semantic eigenvalues were calculated by BP neural network, and the best matching design scheme was obtained [8] Timon et al. used implicit measurement technology and BP neural network as research tools to study the evolution mechanism of users' emotion cognition [10]. By using BP neural network, Li and others designed an evaluation method of vehicle styling to assist the detection of vehicle design level [11].

2. Methods

We use the Kansei engineering principle to transform people's vague kansei needs and images into the characteristics of the form elements of detail design At the same time, the design features of the sample of the protective door are extracted, and the training is carried out by using the normalized parameter and the neural network, then the trained network is used to traverse the combination of all the design elements to find the optimal design combination. Finally, using the design element combination to assist the design scheme generation and the results show the research framework of this topic as shown in Figure 2.

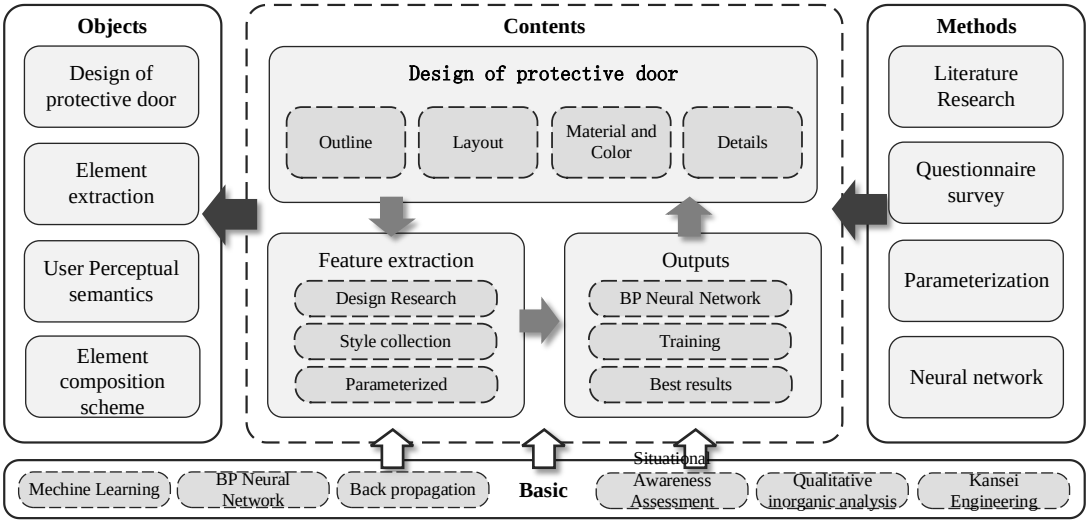

Fig.2 Research framework

2.1 Basics

2.1.1 Kansei Engineering

With the development of market economy, product competition is becoming more and more intense, and the product development model oriented by consumer demand is becoming mainstream [6]. Kansei Engineering, born in the 1970s, studies the dominance of human beings as creatures and their expression of emotions through Engineering, design, psychology, and brain science, evaluation of the relationship between product attributes and user behavior, how product characteristics affect consumer purchasing behavior, etc. [12]. The use of Kansei engineering is usually divided into three main steps: choosing design field, crossing semantic space and attribute space, and constructing the relationship between semantic space and attribute space [13]. In the field of design, firstly, we need to collect all kinds of modeling pictures of the products to be designed, and then use the collection of adjective pairs to express all the possible perceptual images, select the right subjects, then set up image kanban, and finally carry out survey and data analysis.

2.1.2 BP Neural Network

Back-propagation neural network (BPNN) was proposed by Rumelhart et al. 14 in 1986, which systematically solved the connection weight learning problem of the hidden layer of multilayer neural network. Because of the small data set, the large-scale neural network will have the problem of over-fitting, so the BP neural network is more convenient and lightweight. The structure consists of input layer, hidden layer and output layer. The network computes gradients by back-propagation and explores the optimal gradients during training to achieve better fit. BP neural network adjusts the precision of network by adjusting the weight w and the learning rate η.

2.1.3 Classification of situational awareness

The Situation Awareness Ration Technique is a post-experiment subjective assessment method, which uses a rating scale to measure the operator's situational Awareness. The scale contains 10 dimensions. In this study, the SART scale was applied to the perceptual intention analysis, and the four perceptual semantics of 25 experimental samples were scored to obtain the subjective evaluation of the

perceived design style of the protective door.

3. Experiment

3.1 Data

The first step of the experiment is to collect and preprocess the data. First of all, using "Octopus" crawler software and Python crawler program, from DMG, Mazak, Okuma, Trumpf and other smart equipment brand official website and design platform to download more than 300 classic smart equipment protective door design, from these 25 representative designs, the four dimensions of contour shape, corner design, glass shape and handle design are selected, its modeling style, color texture, space relations under the three attributes of a detailed classification (such as Table 1) .

According to the modeling analysis method of "Design feature-attribute-design element", 31 kinds of design elements under 12 kinds of attributes are determined as the basis of modeling feature parameterization. Considering that whether or not the data is normalized affects the final training effect of the neural network when using gradient descent training, the mapping values of design elements should refer to the normalization principle.

The next step is to collect emotional intention through questionnaire. The questionnaire adopts the measurement method under the Situation Awareness Rating Technique, extracts four perceptual evaluation intentions of the protective door to carry out 7 ratings, and eliminates the invalid ratings and averages each item respectively The results are preprocessed as the output layer parameters of the neural network. Table 3 shows the average of the partial intention evaluations.

Tab.1 Classification of design elements of special aircraft protective door

Features	Style（1）			Color（2）			Relationship（3）		
Feature A (Outline)	A_{11} Rectangle	A_{12} Diamond	A_{13} Trapezoid	A_{21} Black glass	A_{22} Silver-gray metal	A_{23} Paint	A_{31} Single door	A_{32} Two doors	—
Feature B (Corner)	B_{11} Right angle	B_{12} Rounded corner	B_{13} Bevel	B_{21} Matel	—	B_{23} Stroke	B_{31} Symmetry	B_{32} Non-Symmetry	—
Feature C (Glass)	C_{11} Right-angled rectangle	C_{12} Rounded rectangle	C_{13} Others	C_{21} Transparency	C_{22} Color glass	C_{23} Gray glass	C_{31} Symmetry	C_{32} None-Symmetry	—
Feature D (Handle)	D_{11} Columns	D_{12} Flat	—	D_{21} Smooth metal	D_{22} Color matel	D_{23} Mix	D_{31} Out	D_{32} Dent	D_{33} Horizonta

Tab.2 Parameters of design elements of special aircraft protective door

Num	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	D_1	D_2	D_3
01	1	0	1	0.5	0	0	0.5	0	0	0	0	0
02	0	0	1	0.5	1	0	0.5	0	0	0	0	0
						.....						
25	0	0	0	0.5	0	0.5	0.5	1	0	1	0	1

Tab.3 Image evaluation value of special aircraft protective door

Num	**Intelligent**	**Simple**	**Stable**	**Dynamic**
01	3.72	3.50	3.67	3.51
02	3.81	3.41	3.45	3.45
03	3.10	3.66	3.74	3.09
		.....		
24	3.71	3.89	3.70	3.41
25	3.89	3.84	3.69	3.39

3.2 Network training

First of all, it is the work of network construction, using the structure of input layer-hidden layer-output layer BP neural network, because the subjective perceptual image is restricted by various variables, there are uncertainties and errors, BP neural network can utilize its own good fault-tolerant ability to solve this problem [15] . The n-dimension input space is the combination of product design elements, and the m-dimension output space is the user's perceptual evaluation. The Perceptual Evaluation of the questionnaire is used as a training set, and then the mapping between design elements and perceptual semantics is established to predict the feature size of the non-training samples. The parameters of each layer are initialized, then the forward and back-propagation functions are set, the activation function is Tanh, the network learning rate is set to LR = 0.1, the number of cycles is 10000, and the network training is carried into the training set, set up 12 input nodes, 10 hidden layer nodes, 4 output layer nodes. At the same time, 12 design elements were traversed, $3^2\times2\times3\times2^2\times3^2\times2\times3^2\times2$=69984 combination results were brought into the test set for scoring prediction.

4. Data Analysis and design generation

4.1 Combination of design elements results

The 69,984 sets of data generated were imported into SPASS and ranked in descending order according to the weights of “Intelligent”, “Simple”, “Stable” and “Dynamic”, respectively, the highest score of four perceptual semantic combinations was obtained.

“Intelligent” perceptual semantic combination for the material for the black glass-based rectangular single door, glass for transparent asymmetry, with a

cylindrical protruding metal texture handle; “Simple” is the best combination of trapezoidal double-door, symmetrical right angle, glass shape for the head transparent right-angle rectangle, handle flat; “Stable” under the semantics of the best combination of trapezoidal double-door gray metal, the Edge is symmetrical right-angle, gray right-angle rectangular glass, and the best combination of“Vitality” is a diamond-shaped single-door color paint, the edge of round-angle asymmetric design, observation window is irregular stained glass, cylindrical handle.

4.2 Design result

The optimum combination scheme of design elements output from neural network is taken as a reference to carry out the design of special aircraft protective door. Taking the “Simple” semantic as an example, the right-angle rectangle, the transparent glass, the gray metal, the flat handle and so on are incorporated into the scheme, and the design effect diagram is shown in figure 3. Special aircraft protective door with black and gray tone, bright yellow embellishment handle, jump color design method plays a prominent role in warning. The material is made of metallic paint and black laminated glass, the glass part is transparent glass with slightly gray scale, and the design element combination accords with the output result of neural network. The result of this design combination is simple lines, reasonable design elements, with “Simple” aesthetic features, and gives more possibilities for the appearance design of intelligent equipment.

Fig.3 Design renderings

5. Conclusion

At the present time of homogenization of intelligent equipment design, the introduction of design semantics of Kansei engineering is beneficial to promote the humanization, stylization and differentiation of special aircraft design, thus endowing the brand competitiveness of intelligent equipment in the market, improve the user experience. In this paper, neural network aided design evaluation is used to obtain the user's aesthetic preference through investigation and parameterization, and at the same time extract the design elements of the special plane, through the training of BP neural network, the user's perception of the beauty of modeling is evaluated, and the design intention of different perceptual semantics is output to assist product design. Through the above-mentioned process, the project of this research generates the design scheme of the special aircraft protective door which conforms to the user's perceptual semantics.

We takes the protective door as an example to carry on the design practice. The

method of neural network aided design can be extended to the whole appearance design process of intelligent equipment, giving the design humanized experience. For the neural network model, there is still room for improvement, such as how to increase the data set to improve the reliability of prediction, how to improve the network, using more efficient and accurate neural network, such as VGG, Resnet, etc. . In addition, the application of machine learning in the field of industrial design has a huge development prospects, how to tap more artificial intelligence applications to help design activities in different degrees is the direction of future efforts.

References

[1] Bai Mingyu, Zheng Gangqiang, Liu Hao. Development status and value analysis of intelligent equipment industrial design [J].Design, 2017(09):49-51.
[2] Rao Feiyun. Research on the aesthetic innovation principle and design method of intelligent equipment [D]. Wuhan University of Technology, 2019.
[3] Ling F, Bao Y, Gong S, et al. The Brain-Machine-Ratio Model for Designer and AI Collaboration[C]//2021 IEEE 4th International Conference on Multimedia Information Processing and Retrieval (MIPR). IEEE, 2021: 308-313.
[4] Hua X S. Challenges and practices of large scale visual intelligence in the real-world[C]//Proceedings of the 26th ACM international conference on Multimedia. 2018: 364-364.
[5] Tung T C, Chen H Y. Application of back-propagation neural network-based approach to icon image design[C]//2016 International Conference on Applied System Innovation (ICASI). IEEE, 2016: 1-4.
[6] Su Jianning, Jiang Pingyu, Zhu Bin, Li Heqi. Kansei engineering and its application in product design [J]. Journal of Xi'an Jiaotong University, 2004(01):60-63.
[7] Wang Hongjiang, Wang Nan. Research on product virtual classification design based on BP neural network [J]. TVU Technology, 2012(03):45-47.
[8] Yi Lei, Huang Liqing, Li Mingzhu. Research on image modeling design of electric vehicle headlights based on artificial neural network [J].Packaging Engineering, 2021,42(20):159-166.
[9] Ma Hui. Aircraft appearance design evaluation model based on BP neural network [J]. Packaging Engineering, 2018,39(18):129-133.
[10] Ding Man, Ding Tingting, Song Meijia, Zhang Xinxin, Liu Zhen. Product color emotional design method based on implicit measurement and BP neural network [J/OL]. Computer-integrated manufacturing: 1-15[2022-05-12].
[11] Li Yanlong, Cai Qian, Sun Jiukang, Gao Xiang. Evaluation method of automobile appearance design based on BP neural network [J]. Journal of Tongji University (natural science edition), 2021,49(01):116-123.
[12] Wang Yue, Xin Xiangyang, Yu Hao, Cui Shaokang. The road to simple, the same way: the study of the source of experience design [J]. Decoration, 2020(05):92-96.
[13] Hsiao Y H, Chen M C, Liao W C. Logistics service design for cross-border E-

commerce using Kansei engineering with text-mining-based online content analysis[J]. Telematics and Informatics, 2017, 34(4): 284-302.
[14] Rumelhart D E, Hinton G E, Williams R J. Learning representations by back-propagating errors[J]. nature, 1986, 323(6088): 533-536.
[15] Zhou Meiyu, Li Qian. Application of neural network in product perceptual design [J]. Journal of Donghua University, 2011,37(04):509-513.
[16]Guo F, Qu Q X, Nagamachi M, et al. A proposal of the event-related potential method to effectively identify kansei words for assessing product design features in kansei engineering research[J]. International Journal of Industrial Ergonomics, 2020, 76: 102940.