Study on Innovative Design of Urban Intelligent Lighting Appliance (UILA) Based on Kansei Engineering

Jianxin Cheng, Junnan Ye(✉), Chaoxiang Yang, Lingyun Yao, Zhenzhen Ma, and Tengye Li

School of Art Design and Media, ECUST, M. BOX 286, NO. 130 Meilong Road, Xuhui District, Shanghai 200237, China
13901633292@163.com, yejunnan971108@qq.com, yangchaoxiang@qq.com, ylyyshly@qq.com, 1057791717@qq.com, onodesign@outlook.com

Abstract. Urban Intelligent Lighting Appliance (UILA) is a technological terminal device of smart city, which is a energy-saving lighting based on urban street LED lamp and achieves the functions of smart city in the environment of big data, including intelligent control, energy-saving lighting, charging of electrical vehicles, information distribution and exchange, intelligent transportation, WIFI, environmental monitoring, audio broadcasting, asking for help with one key and so on.

Kansei engineering aims at the development or improvement of products and services by translating the customer's psychological feelings and needs into the domain of product design, so It's essential to research innovative design of UILA based on kansei engineering.

The purpose of this research is to clarify a method to construct a support system capable of UILA modeling elements that fit the customer's Kansei, and to verify the effectiveness of this method based on Kansei engineering, for the selection of recommended design samples. To accomplish this, this paper analyse the necessity of Kansei engineering applied in the innovative design of UILA and put forward the framework of UILA innovative design based on Kansei engineering of forward quantitative inference. Then it discussed how to build the relationship between emotional images and UILA modeling elements in detail by means of the innovative design of UILA shaping, which will provide a basis for guiding UILA styling innovation and design effect evaluation. In the end, it pointed out that the expansion of applications of Kansei engineering in the field UILA products design have broad prospects and can better meet the users'perceptual needs.

Keywords: Kansei engineering · Urban Intelligent Lighting Appliance (UILA) Innovative design · Perceptual demand

1 Introduction

With the development of smart city construction around the world, more and more intelligent city research experts, intelligent street lamp industry and related technology research and development departments found that urban street lights can be important

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technological realization terminals for intelligent city project applications. Urban Intelligent Lighting Appliance (UILA) is researched and developed from the intelligent street lights of intelligent city construction projects. Urban Intelligent Lighting Appliance (UILA) is a technological terminal device of smart city, which is a energy-saving lighting based on urban street LED lamp and achieves the functions of smart city in the environment of big data, including intelligent control, energy-saving lighting, charging of electrical vehicles, information distribution and exchange, intelligent transportation, WIFI, environmental monitoring, audio broadcasting, asking for help with one key and so on [1, 2].

Currently, domestic and foreign research works on UILA mainly include: (1) In terms of related technologies and standards, the research works mainly include energy efficient control of intelligent street lights, intelligent monitoring system research and technology development. For example, Wu et al. examined the significance of IoT in the construction process of intelligent city, and built the urban street lights-based IoT basic platform by integrating intelligent sensor technology, power line carrier communication technology, cloud computing technology and other advanced technologies; [3] (2) With a view to system and management, the research works mainly include technological realization and intelligent dynamic management of intelligent urban street lighting system. For example, Elejoste et al. jointly proposed a wireless communication-based portable street light intelligent control system, which enables the dimming control of intelligent street lights by analyzing and deploying the data collected on the light sensors, thus improving the energy efficiency; [4] (3) As to practice and expansion, the research works mainly focus on intelligent control and energy efficiency of urban street lights, Singapore, France, Switzerland and other countries have placed urban street lights under automatic control by exploiting information technology.

Kansei Engineering (KE) is a set of technologies, theories and methods that quantitatively transform user's feelings or intentions towards a product into design elements [5, 6]. It refers to a set of product development technologies that are user-oriented and ergonomics-based, which in turn can turn user's ambiguous Kansei needs and images specifically to the modeling elements of a detailed product design [7]. Generally, it can be divided into forward-inference KE system, backward-inference KE system, and mixed-type KE system [8]. Thus, the principles and methods of KE can be used to accurately capture user's perceptual intention and quickly establish the correlation between Kansei intention and modeling elements, thus providing reference and basis for designers to perform modeling innovative design and evaluation.

At present, most works on UILA are mainly carried out from the perspective of information and communication engineering, or computer science and technology, while few works perform design and evaluation study of UILA from the perspective of product system design, user experience, social psychology, design aesthetics or other Kansei design perspectives. In this paper, research methods for KE are mainly employed to build Kansei semantics space and modeling elements space of UILA, the correlation between Kansei semantics and UILA modeling elements is constructed through cluster analysis, Quantification Theory Type I and other mathematical statistical method, so as to provide a ground for instructing the evaluation of UILA modeling innovation and design effect.

2 Research Process and Method

According to the design flow and method in relation to forward-inference KE, provided with a rigorous and scientific data and process to the extent possible, UILA innovative design framework that is applicable to the product conceptual design phase is constructed, see Fig. 1. Coupled with the design theory and method in relation to product innovative design, an in-depth study of the KE-based UILA modeling innovation design is carried out.

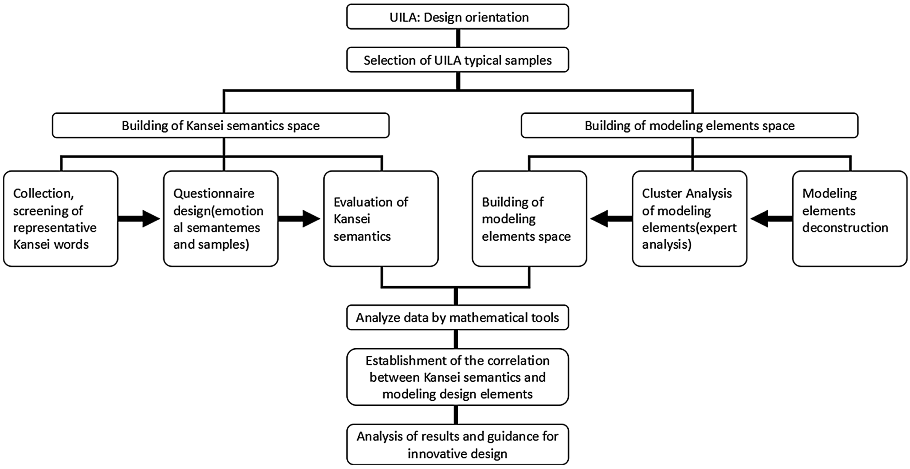


Fig. 1. UILA innovative design framework based on Kansei engineering

2.1 Selection of UILA Typical Samples

84 UILA samples are initially obtained through product brochures, user manuals of similar product, magazines and websites, 20 representative samples (see Table 1) are finally screened by multivariate analysis and cluster analysis. To avoid color factors from impacting the modeling Kansei images of UILA, all representative samples are discolored.

2.2 Building of UILA Kansei Semantics Space

2.2.1 Collection, Screening of Representative Kansei Words

Here, 202 UILA Kansei intention words are acquired through project team brainstorming, related UILA design R&D professionals, manufacturers, product manuals, magazines, websites and other channels, then initially screened, modified and classified using expert method (the expert panel is composed of UILA senior design R&D professionals and industrial design teachers) and referring to the UILA modeling features, 7 pairs of adjectives with clear intention are finally selected. See Table 2.

Table 1. Selected representative sample of UILA

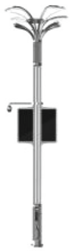
				
1	2	3	4	5
				
6	7	8	9	10
				
11	12	13	14	15
				
16	17	18	19	20

Table 2. Selected adjective couples

Simple-complicated	Intelligent-non-intelligent
Caring-distant	Fashionable-traditional
Efficient-inefficiency	Convenient-cumbersome
Environmental-wasteful	

2.2.2 Questionnaire Design

7 UILA samples that are finally selected are renumbered using semantic differential method (SD method), then made into 5-level SD scale with the said 7 pairs of Kansei adjectives (see Table 3), which are combined into a questionnaire.

Table 3. SD scale of sample 4

Simple	9	7	5	3	1	Complicated	
Intelligent	9	7	5	3	1	Non-intelligent	
Caring	9	7	5	3	1	Distant	
Fashionable	9	7	5	3	1	Traditional	
Efficient	9	7	5	3	1	Inefficiency	
Convenient	9	7	5	3	1	Cumbersome	
Environmental	9	7	5	3	1	Wasteful	

2.2.3 Evaluation of Kansei Semantics

In this thesis, online evaluation is used. 48 students and teachers of our industrial design program are respondents, in which the ratio of male to female is 1:1, thanks to their active teamwork, all the 48 questionnaires distributed are returned and all are valid. The average value of Kansei semantics evaluation on these UILA samples is obtained through data processing (see Table 4).

2.3 Building of UILA Modeling Elements Space

Relying on the basic principles of morphological analysis, members of the project team invite the UILA R&D professionals to analyze the modeling feature elements of UILA. In the first step, UILA modeling is used as a set of several design elements; next, the modeling is divided into a number of independent design items, i.e.: base, post, ads screen, and LED holder; finally, each design item is subdivided into a number of modeling design elements, for instance, the base can be subdivided into cylinders, geometries, and special shapes. UILA modeling elements space is thus built in this way, see Table 5.

Table 4. Average of emotional semantic evaluation

Sample	1	2	3	…	20
Simple-complicated	6.34	3.56	7.43	…	3.02
Intelligent-non-intelligent	5.46	2.25	4.35	…	4.29
Caring-distant	3.36	3.37	3.66	…	4.82
Fashionable-traditional	7.73	2.44	6.48	…	4.47
Efficient-inefficiency	4.76	1.64	5.37	…	4.29
Convenient-cumbersome	4.65	2.51	2.48	…	3.08
Environmental-wasteful	6.57	2.42	4.33	…	3.02

Table 5. Major modelling elements

Design item (a)	Shape-designing fact(b)
Foundation (a1)	Cylinder b_{11}, Geometric solid b_{12}, Irregular solid b_{13}
Lamp-post (a2)	Cylinder b_{21}, Irregular solid b_{22}
Advertisement screen (a3)	Rectangle b_{31}, Geometric b_{32}, Other b_{33}
LED lamp cap (a4)	Round b_{41}, Square b_{42}, Irregular b_{43}

2.4 Establishment of the Correlation Between Kansei Semantics and Modeling Design Elements

In the course of transform the product Kansei semantics scale into the design elements engineering scale, available methods include multiple linear regression analysis, Quantification Theory Type I, neural network algorithm, rough set analysis and other mathematical statistical methods [9]. Specifically, Quantification Theory Type I is a method used for the factor analysis and prediction problem where all independent variables are qualitative variables and benchmark variables are quantitative variables, that simulates the quantitative change of benchmark variables in the linear expression using explanatory multivariable, and examines the correlation between multiple independent variables and dependent variables to perform the multivariable analysis method of the dependent variables problem prediction [10]. Here, Quantification Theory Type I will be used to establish the correlation between Kansei semantics and UILA modeling elements, when the qualitative data for the modeling design element of the ath design item in the Nth sample is the bth class, then bs = 1; otherwise, bs = 0. Where a is the design item, b is the modeling design element, and bs (a, b) becomes the design response of the bth modeling design element in the ath design item to the Nth sample. Thus, 20 UILA modeling elements are quantified and converted into the quantitative data of 1 and 0, namely the response value for the modeling elements of each sample, so that UILA modeling design elements decomposition coding list is obtained, see Table 6.

And the average value of UILA Kansei semantics evaluation, the response value of modeling elements is taken as the dependent variable, and the independent variable respectively to establish the following multiple linear mathematical prediction model:

Table 6. UILA modeling design elements decomposition coding list

Sample	b_{11}	b_{12}	b_{13}	b_{21}	b_{22}	b_{23}	b_{31}	b_{32}	b_{33}	b_{41}	b_{42}	b_{43}
1	0	1	0	1	0	0	1	0	0	0	1	0
2	0	0	1	1	0	0	1	0	0	1	0	0
3	0	0	1	1	0	0	0	0	1	0	0	1
…	…	…	…	…	…	…	…	…	…	…	…	…
20	0	1	0	1	0	0	1	0	0	0	1	0

$$y = w_{11}b_{11} + w_{12}b_{12} + w_{13}b_{13} + w_{21}b_{21} + w_{22}b_{22} + w_{23}b_{23} + w_{31}b_{31} + w_{32}b_{32} + w_{33}b_{33} + w_{41}b_{41} + w_{42}b_{42} + w_{43}b_{43} + m \tag{1}$$

In Eq. 1, y is the average value of UILA Kansei semantics evaluation: w_{ij} is the weighting coefficient of each independent variable; b_{ij} is the response value of modeling elements (i is the design item, j is the modeling design element); m is the value of a constant term.

3 Research Result and Analysis

3.1 Research Result

The average value of the evaluation of different Kansei semantic words and the UILA modeling design elements decomposition coding list are analyzed using Quantification Theory Type I analysis tool (Japanese professor Shigenobu Aoki's VBA tool), so as to

Table 7. The QTT-I results of "convenient-cockamamie"

Items	Design elements	CS[a]	PCC[b]
Foundation (a1)	Cylinder b_{11}	0.984	0.525
	Geometric solid b_{12}	−0.141	
	Irregular solid b_{13}	−0.233	
Lamp-post (a2)	Cylinder b_{21}	−0.820	0.854
	Irregular solid b_{23}	1.522	
Advertisement screen (a3)	Rectangle b_{31}	0.505	0.687
	Geometric b_{32}	0.641	
	Other b_{33}	−0.808	
LED lamp cap(a4)	Round b_{41}	−0.610	0.664
	Square b_{42}	−0.391	
	Irregular b_{43}	0.851	
C		3.985	
R = 0.911			
R2 = 0.830			

obtain the corresponding data result. Due to limitation of length, the correlation between UILA Kansei word "convenient- cumbersome" and UILA modeling design element is mainly discussed here, see Table 7.

3.2 Analysis of Results and Guidance for Innovative Design

From the analysis result of Quantification Theory Type I of Kansei word "convenient-cumbersome", $R2 = 0.830 > 0.5$ has a strong reliability. Other analysis results are given as follows:

Partial correlation coefficient represents the degree of each design item influencing Kansei semantics, the greater value means the greater influence. From Table 7, the partial correlation coefficient of each design item is greater than 0.5, which indicates that each design item has a certain influence on Kansei word "convenient-cumbersome", the degree of such influence can be arranged in a descending order: post > ads screen > LED holder > base. If the design orientation of UILA is "convenient", we can prioritize the convenient modeling design of post.

From the weighting coefficient as shown in Table 7, for Kansei word "convenient-cumbersome", the innovative design of UILA can be cylindrical base, special shaped post, geometric or rectangular ads screen, or special shaped LED holder.

From Table 7, the predictive function of Kansei image words over the correlation between "convenient-cumbersome" and each modeling element of UILA: $y = 0.984b_{11} - 0.141b_{12} - 0.233b_{13} - 0.82b_{21} + 1.522b_{22} + 0.505b_{31} + 0.641b_{32} - 0.808b_{33} - 0.61b_{41} - 0.391b_{42} + 0.851b_{43} + 3.985$ (the coefficient of determination is 0.83); in order to validate the said function, we can reselect the samples, carry out questionnaire survey, perform T-test analysis of the data acquired from the survey and the data calculated by the said predictive function, result shows its significance level is greater than 0.05, there is no significant difference, so this result is reasonable. Similarly, this method can be used to get the predictive function that represents the correlation between other Kansei image words and each modeling element of UILA, which can judge whether the Kansei image communicated by designer through his innovation design scheme is consistent with user's perceived need, so as to provide a ground for the selection of design schemes and the subsequent in-depth design.

4 Conclusion

In this thesis, the quantitative forward-inference KE-based UILA innovative design method is proposed, and coupled with UILA modeling innovative design, the correlation between user's Kansei semantics and UILA modeling elements is established, so as to provide an innovative guidance for UILA modeling design. The proposed research method can be also used to analyze the color, material and other innovative designs of UILA for the aiding of design and the evaluation of design effect, thus aligning Kansei with rationality of UILA product. Therefore, there is a broad potential and prospect if we can extend the applications of KE in UILA product design to make up for the deficiencies of traditional design method.

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