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An architecture-oriented kansei engineering system for innovative long chi inkstone design

Jing Chen

Department of Product Design, School of Arts and Design, Sanming University, Sanming, 365004, China

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ABSTRACT

With more and more attention to people's psychological cognition and emotion in design, the concept of kansei engineering has been widely used in all kinds of product design. Based on the concepts and methods of kansei engineering, the research chooses the long chi inkstone as an example to seek a holistic explanation for the proposed architecture-oriented innovative system in obtaining a series of new design schemes. The system architecture integrates the design method of kansei engineering system into the structure-behavior coalescence (SBC) system architecture description language to show the behavior and components of product characteristics. A model of architecture-oriented kansei engineering long chi inkstone system specification was established. The model will clearly explain how the qualitative and quantitative methods are applied to determine the characteristics, process and kansei information of long chi inkstone design. The design specifications of long chi inkstone is described by the architecture-oriented kansei engineering system. The psychological kansei imagery of consumer groups are explored under the mode of qualitative analysis and quantitative research, and the design elements and details of physical properties of products are obtained. The aesthetic attributes of products are raised to a high level of respect for human nature and reflect its new value. The results indicate that the proposed architecture-oriented kansei engineering system in conjunction with a long chi inkstone design can help designers make the design more effectively than traditional design methods.

1. Introduction

With the rapid development of economy and society, the homogenization of the design industry is ensuing. The emotional feelings of consumers on new products become important and even play a critical role on designing better products [1]. Recently, the concept of kansei engineering that focuses on the investigation of consumer cognition in a variety of areas has been widely noted to have the capability to link between consumer requirements and design features [2]. As such, this research will show the feasibility of expanding the concept of kansei engineering in the integration of ceramic arts and commercial product design [3]. Therefore, the novelty of this research objective is to apply the concept of kansei engineering in developing an integrated system scheme and procedure for the traditional ceramic innovative product design. By developing new forms of attractive products with regional cultural characteristics, the research combines the sensual needs of consumers with the design strategies of the cultural and creative industries in the hierarchy of categories to accurately grasp consumer preferences [4], determine the correlation between design themes and guiding design elements, establish imagery space, and design products that meet market and consumer needs [5].

The design of inkstone will be used as a test bed in the development of the proposed system scheme framework. Note that the choice

E-mail address: chenjing@fjsmu.edu.cn.

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of inkstone is based on the observation of special traditional culture and its corresponding ceramic arts [6]. The research also uses architecture as a guide to build a blueprint for the specifications of the kansei engineering inkstone system [7]. Using this approach, a systematic description and guidance of the design process is realized. Taking the famous long chi inkstone of the Jiang le county as an example [8], the development research process uses the expert weighting method to demonstrate the reasonable feasibility of the method and provides a highly valuable research direction for similar product design [9].

2. Literature review

2.1. Kansei engineering in modern design

In the age of skills and information technology, sensibility has become an essential characteristic of social development and a major developmental ability that makes the human society enter into an age of human sensibility [10]. The mainstream of development trend on current market has started to be oriented to the individual needs of consumers [11]. In order to meet the needs of different consumer groups, the enterprises are gradually shifting to a combination of design and production model that customized products and services are emerged to be compatible with personalized and emotional products [12]. Especially in the face of consumers' perceptual demand, designers must deeply explore and understand users' feelings [13], and integrate products into sensory genes for special customization [14]. With a series of research methods in kansei engineering. It is particularly effective to design products that meet consumers' preferences by considering the user as the core of the product design process and reflecting their emotional feeling [15]. Kansei Engineering (KE) is also known as emotional engineering [16]. It is a comprehensive interdisciplinary discipline between design, engineering and other disciplines [17]. It uses modern technology to quantify and translate difficult-to-quantify consumer feelings and imagery into concrete design elements to help develop and design new products [18]. Kansei engineering focuses on three aspects: (1) Classification of the kansei vocabulary according to the perceptual aspects of the product and obtaining design details by establishing the kansei structure of the product [19]. (2) Establishment of kansei engineering expert systems and related design databases [20]. Including knowledge base, design color database, perceptual semantic database and imagery database. (3) Constructing kansei engineering models to show some logical relations and obtain ergonomic conclusions from kansei vocabulary [21]. These three levels show the importance of linking basic human kansei cognitive abilities with design and manufacturing engineering that will bring the people-oriented design to new level [22].

The focus of research on kansei engineering may vary for different design objects [23]. The first type of approach is category classification: that is a hierarchical recursive approach to classify products according to their perceptual aspects and build a product tree perceptual structure to obtain design details [24]. The second type of method is the establishment of a kansei engineering system, to be an expert system that builds a data base through computer assistance to construct the relationship between the kansei vocabulary and the design elements [25]. The third type of method is the kansei engineering modeling system to accurately describe consumer reactions to product [26]. It is a mathematical model simulation system that deals with prediction phenomena based on perceptual semantic evaluation to find quantitative relationships between design elements and perceptual information [4,27].

2.2. Structure-behavior coalescence architecture

A system is an integrated group of components that interact with each other and their external environment [28]. Basically, these components follow the requirements of structural-behavior coalescence [7,29]. A complete system specification is used to describe the details of the system including the relationship between visual materials, the process of system operation, and the logical rules of system operation [30]. The characteristic of the SBC architecture development method (SBC-ADM) is focus on the integration of structure and behavior, covering three stages: strategic planning, management control, and job control, with a clear hierarchy [31]. SBC-ADM consists of a core "requirement core" and six layers, namely: preliminary phase, architecture vision layer, business layer, application layer, technology layer, and evolution layer. As illustrated in Fig. 1.

In this research, an architecture-oriented system specification model is built using a structure-behavior-coalescence system

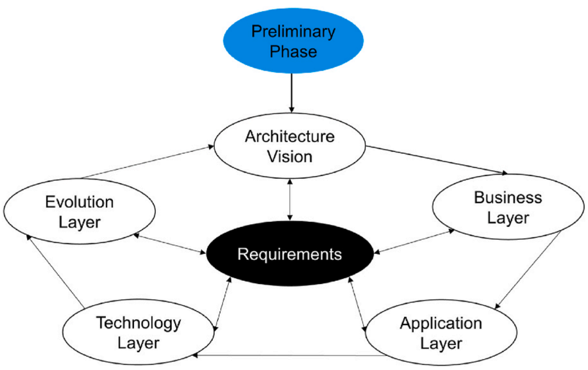


Fig. 1. SBC architecture development method.

architecture model to describe different details of the specification design diagram [32]. The system specification describes include six diagrams: Architecture Hierarchy Diagram (AHD), Framework Diagram (FD), Component Operation Diagram (COD), Component Connection Diagram (CCD), Structure-Behavior-Coalescence Diagram (SBCD) and Interaction Flow Diagram (IFD) [7,33].

The AHD shows the decomposition and combination of multiple layers of a system which can make the originally complex system simple through decomposition and combination [34]. The FD is used to explain the structure of a system composed of building blocks [7,35]. The COD is used to describe what operations are provided by the components in a system. The COD allows developers to quickly understand which operations are provided by each component or to reverse the query of which component provides an operation. The CCD is used to describe the linkage between the components of a system and to present clear structural view of the entire system style. The SBCD is used to show the interaction between the various components of a system and their impact on the external environment, allowing a quick overview of the current architecture of the system. The IFD is used to describe the interaction of each system behavior in the external environment, between the components and the components, clearly describe the sequence of each operation, can also represent the information transmitted or received by each operation. This situation allows system developers from different professional fields to build system specifications through this model to accelerate the development and completeness of the system.

3. The proposed integrative method

The SBC architecture must pass the structure-behavior coalescence architecture description language (SBC-ADL) to describe the static components and dynamic behavior of a system [7]. Understand the overall system architecture through a hierarchical approach and approach it from multiple perspectives [36]. Layering can also be cut from different attributes. Each level can be further decomposed until needed. Each class can be treated as a specific viewpoint. After the system is decomposed and combined, subsystems can be decomposed and then components can be resolved. The component element and system complement each other [37]. Using hierarchy can simplify complex kansei engineering systems and make them easier to understand [38]. In the framework diagram, the architecture of the system is explained by the combination of components, and there will be no subsystems. And use the components seen from a specific perspective as the research object. Clearly categorize the attributes and characteristics of the system [39]. Draw the interaction between users and components one by one in a simplified kansei engineering system. Integrate structure and behavior together in the system without making them independent structural and behavioral models. Use the behavior generated by interaction as the benchmark for drawing a structure behavior-coalescence diagram. After combining multiple individual behaviors, an interaction flowchart is drawn based on factors such as external environment, components, operations between components, parameters of operation output, and order of interaction between operations, demonstrating the overall behavior involved in the kansei engineering system. The first category method of hierarchical decomposition (Category Classification) is used in this research to combine the establishment of the second category of kansei engineering system with SBC-ADL for the specification of architecture-oriented kansei engineering system. As illustrated in Fig. 2.

The main design elements and kansei vocabulary corresponding to consumers' mental imagery are selected, and the samples and semantic difference scales are created through questionnaires and experiments [40]. Subjective perception assessment for subjects, and the relationship between them is quantified into visible physical coordinates and data [41]. Finally, with the help of expert

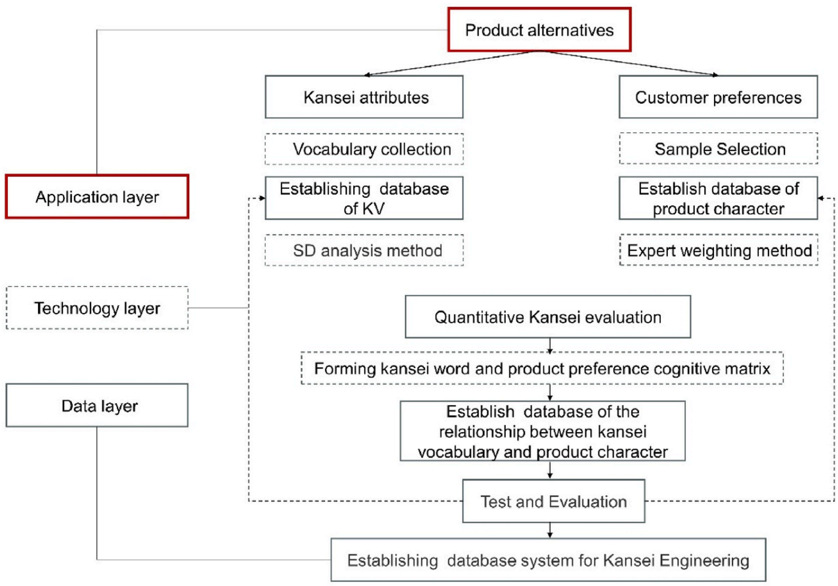


Fig. 2. Kansei engineering database system.

weighting method, establish the design elements and the kansei imagery space of long chi inkstone that satisfy the consumers' perceptual demand. In general, the expert weighting method is based on the principle of Delphi method [42]. Multiple experts give their weights and conduct the statistical analysis to determine the importance of the product elements. The relative importance ratio of variable *i* to variable *j* can be obtained by dividing the importance of each variable *i* by the importance of other variables *j*, based on the professional cognition of experts regarding the importance of each variable in the product [43]. If the relative importance ratio of the importance of variable *i* to the importance of variable $j > 1$, it can be determined that the importance of variable *i* is greater than that of variable *j*. Conversely, the importance of variable *i* is less than that of variable *j*. The advantage of the combination of the two methods is that it can quickly and concisely establish the consumer imagery space and serve as the subsequent design details associated with quantitative data to make the final design solution be in the scientific basis [44].

In conducting an architecture-oriented kansei engineering system, the research first collected various sources of kansei imagery expression regarding the targeted product design from group discussion, brainstorming and internet to investigate and analyze the consumer preferences. Some terms of kansei vocabulary that are relevant to the important preference of consumers will be selected. Let KV denote the set of names that identify kansei vocabulary, $KV = \{KV_a | \ a = 1, 2, \ldots, r\}$. A semantic differential method will then be applied in a questionnaire based on a 5-point scale of evaluation which points of 1, 2, 3, 4, and 5 correspond to very low, low, medium, high, and very high importance, respectively. Each tester will assess the identified kansei vocabulary based on his or her targeted product preference cognition such as surface texture, form structure, and material property.

Let PPC denote the set of names that identify product preference cognition, $PPC = \{PPC_b | \ b = 1, 2, \ldots, s\}$. The survey results will then be pooled to form a relationship matrix with rows denote kansei vocabulary and columns denote evaluated point of product preference cognition. The kansei vocabulary-product preference cognition matrix is formed. Once the matrix has been generated, a hierarchical clustering analysis in multivariate analysis will be used to categorize the kansei vocabulary into a hierarchical tree structure. Note that in this research the euclidean distance [35,45] is calculated as:

$$d_{fg} = \left(\sum_{b=1}^{s} \left(KV_{c,b} - KV_{d,b} \right)^2 \right)^{1/2}, f, g \in s, c, d \in a, b = 1, 2, \ldots, s \tag{1}$$

While the nearest neighbor method for hierarchical clustering [45,46] is denoted as HC $(KV_e, KV_f) = \min \{d_{fg}\}$.

The minimum distance between two types of kansei vocabulary is considered to be a critical distance measure and will be categorized into the number of clusters [47]. Let the set of clusters for the targeted product design be denoted as $\{C_1, C_2, \ldots, C_h\}$ and the set of kansei vocabulary for a specific cluster C_h be denoted as $[KV_{ci,ji}]$, where $i = 1, 2, \ldots, h$, and $ji = 1, 2, \ldots, F_i$. $F_1, F_2, \ldots, F_i$ represents the number of possible kansei vocabulary for the cluster $C_1, C_2, \ldots, C_h$, respectively [48]. In addition, the function of "analyze/classify/hierarchical cluster" in the statistical software SPSS v.17 is used to help manipulate the collection of numeric data and generate the hierarchical tree.

4. Case analysis

4.1. The design backgrounds

As the earliest inkstone discovered in Fujian province, long chi inkstone originated from long chi village in Jiang le county, China. Because of the excellent stone texture and unique processing form. It is listed as intangible cultural heritage. The process of making long chi inkstone varies from person to person, from place to place, and from art to art. With the development of the times, the production of modern long chi inkstone has gradually transitioned from traditional handicraft production to small-scale mechanical production. In terms of design and production, there are still more or less differences in the production of long chi inkstone due to the different understanding and innovative ideas of each person. Despite these changes, there are no practical ways and measures to talk about the development and innovation of long chi inkstone itself. For the special production process of long chi inkstone, no systematic and detailed process investigation was reported in the field of inkstone development [8,49]. Therefore, the exploration and study of its production process need to be supported by the analysis of other inkstone varieties and investigation in depth in the field to provide support for the subsequent study with actual data and processes. The rheology of traditional ancient inkstone forms is organized as illustrated in Fig. 3.

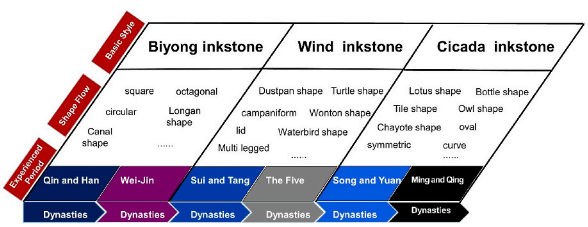


Fig. 3. Formation and rheology of traditional inkstones.

4.2. System and system purpose

Build a kansei engineering system associated with the behavior and components of design specifications, and develop a long chi inkstone kansei design system specification model for architecture through an overall explanation of the system. In this model, a combination of rational and emotional design methods is used to elucidate the characteristics and structure of long chi inkstone products, as well as the perceptual information they contain. Exploring the psychological perception imagery of consumer in a quantitative analysis mode. The Specific objectives are expressed as follows.

(1) Use the spot investigation of the history to understand the cultural background of the area regarding humanities and environment of characteristic area.
(2) Collect relevant information, to analyze and integrate in depth the functions, shape appearance, materials, decorative themes and technical processing of inkstone.
(3) Use modern kansei engineering methods, to explore the innovative design approach of the inkstone in Jiang le county in terms of style, form, craftsmanship, and decoration. The expansion of other properties of the inkstone is also analyzed.
(4) Identify the kansei imagination of different consumer groups on the innovative design of inkstone by means of questionnaires, and grasp the future trend of innovative design of inkstone as a whole.
(5) Review relevant policy reports and historical documents to grasp the strategies for the development of long chi inkstone.

4.3. Summary of system specification

The architecture hierarchy diagram of the long chi inkstone kansei engineering system is illustrated in Fig. 4. A multi-layer decomposition and combination of the inkstone kansei engineering system is shown that the steps of redesign are unfolded in a hierarchical manner making the complex system simple through decomposition and combination. The proposed system should also be better guiding the various aspects of the design.

In Fig. 4, the system includes three layers: application layer, data layer and technology layer. The main component in the application layer is long chi inkstone, while the data layer involves the data base of long chi inkstone kansei engineering system. As to the application layer, its main component is the long chi inkstone. Note that the data base of long chi inkstone kansei engineering system contains six subcomponents. They are.

(1) Collection of inkstone kansei vocabulary
(2) Collection of inkstone picture samples
(3) Establishment of inkstone semantic imagery space
(4) Selection of inkstone design elements
(5) Survey of inkstone kansei imagery degree
(6) Relationship between inkstone design elements and imagery

The final sample was selected by using the expert weighting method associated with the SD semantic scale [50]. Evaluate the importance of design elements and the significance of each design element in long chi inkstone through regression analysis [51].

Fig. 5 illustrated the Structure Behavior Coalescence Diagram of the long chi inkstone kansei engineering system. The SBCD of the long chi inkstone kansei engineering system illustrated provides a quick overview of the details of the current architecture in the

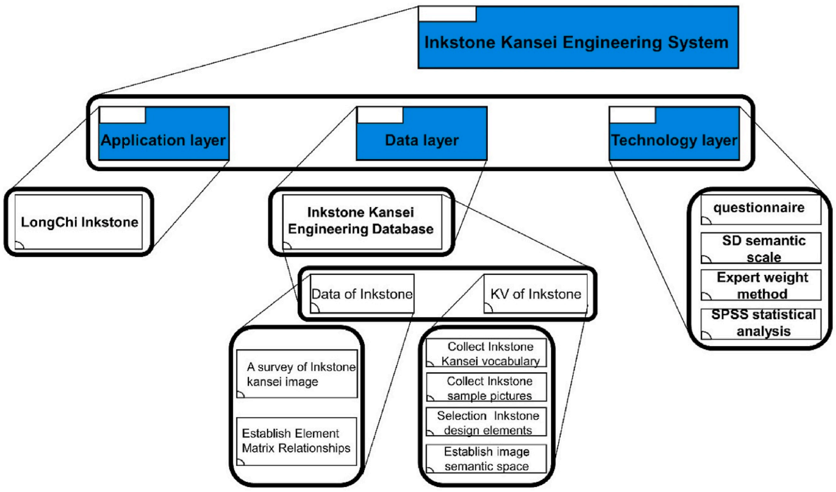


Fig. 4. AHD of long chi inkstone kansei engineering system.

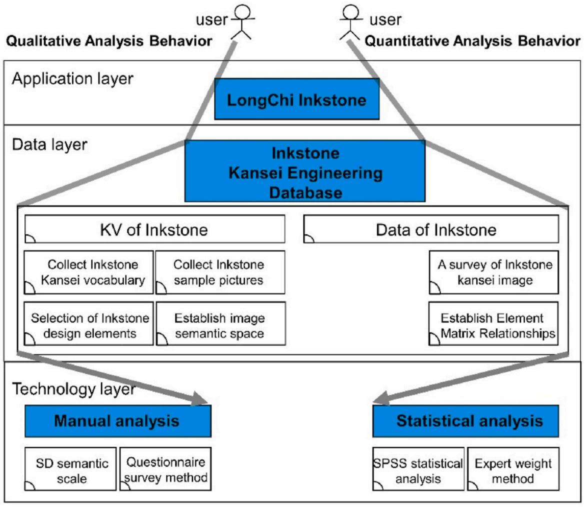


Fig. 5. SBCD of long chi inkstone kansei engineering system.

system. It also clearly shows the interactions between subcomponents and two major behaviors of qualitative and quantitative analyses in this system associated with the external environment that leads to draw design conclusions with the help of manual and statistical analysis. The design solution generated by this process avoids as much as possible a design discontinuity.

4.4. Systematic information

The research uses practical experiments to understand the relationship between consumer imagery of inkstone and its morphology. The experiment is divided into four stages.

(1) Morphological analysis of the existing long chi inkstone samples
(2) Collection of adjectival vocabulary of long chi inkstone kansei imagery
(3) Conduction of consumer imagery experiments on collected long chi inkstone samples
(4) Analysis of the experimental results and summary of relationship between imagery and morphology.

4.4.1. Selection of the adjectival repertoire of kansei imagery for long chi inkstone

In the first stage of experiment, the research selects the descriptive terms of related to the design imagery from the collection of inkstone pictures, the Internet, magazines, information and related literature, and the psychological feelings of consumers. The collected perceptual semantics were transformed into kansei vocabularies that could express the psychological feelings of consumers and the stylistic imagery of long chi inkstones. Figs. 6–9 illustrates the conceptual framework of deduction process for the inkstone

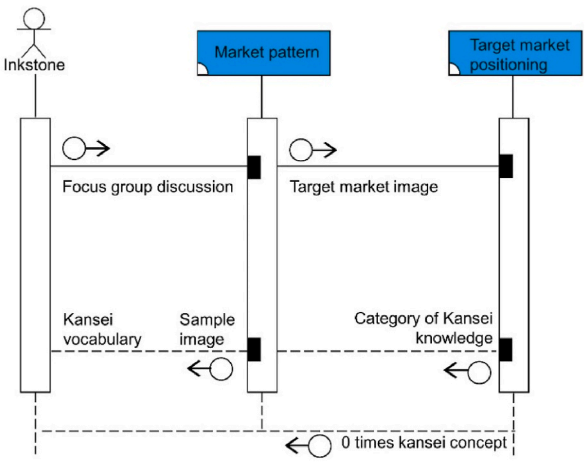


Fig. 6. IFD of 0 times kansei inkstone.

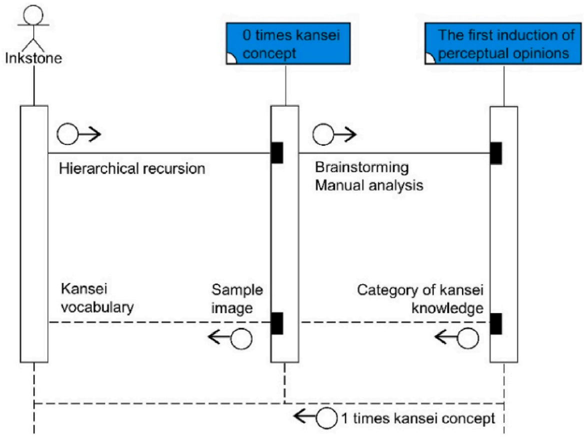


Fig. 7. IFD of 1 times kansei inkstone.

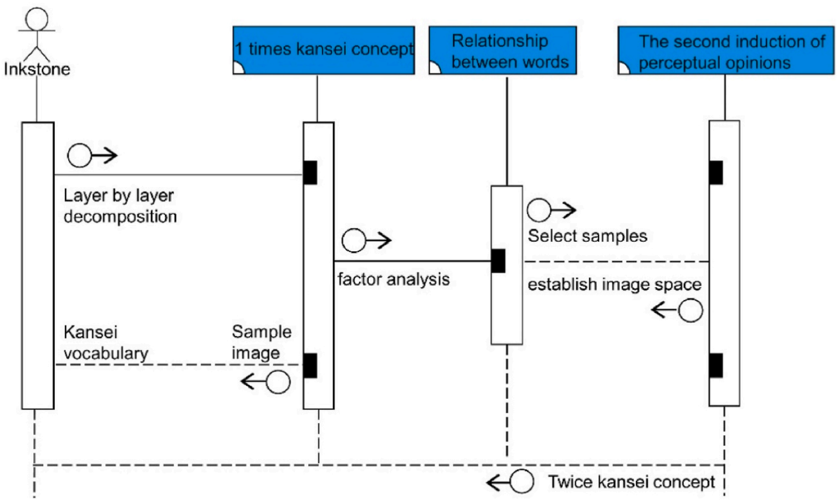


Fig. 8. IFD of twice kansei inkstone.

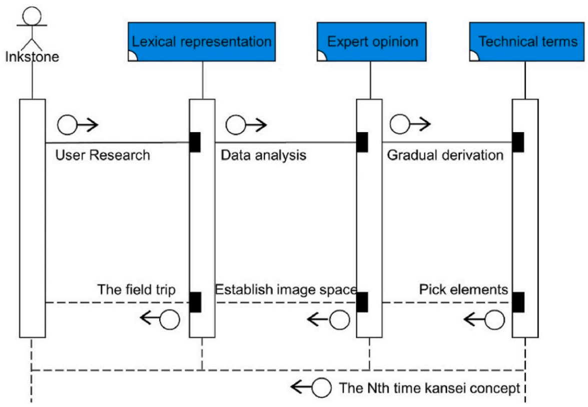


Fig. 9. IFD of the Nth time kansei inkstone.

kansei engineering system behavior interaction. Certain detailed description regarding specific steps of deduction processes for the inkstone kansei engineering system behavior interaction is illustrated in Figs. 6, figure 7, Figs. 8 and 9, respectively. An interaction flow diagram on the design of category behavior for the inkstone kansei engineering system is illustrated in Fig. 10.

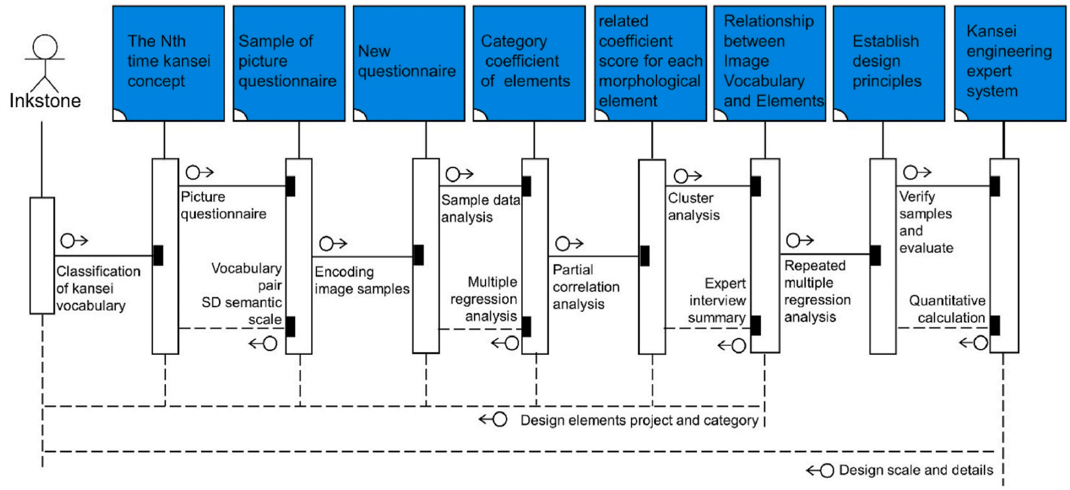


Fig. 10. IFD of inkstone kansei engineering system category.

In this research, 100 sets of words from the related inkstone morphological imagery were collected based on the selection criteria of inkstone kansei imagery. To help reduce the load on the subjects, the kansei vocabularies were screened. About 40 sets of representative kansei adjectives from the 100 sets of descriptive vocabularies that are suitable for describing long chi inkstone were derived from the interaction flow diagram of the kansei engineering system of inkstone. Table 1 listed the identified 40 sets of representative kansei adjectives for the long chi inkstone design. The selected 40 sets of kansei adjectives were forwarded to a questionnaire evaluation with the assistance of the expert weighting method.

To help identify requirements of potential product customers for further investigation, the research designed a questionnaire based on the collection of related inkstone information from calligraphers, inkstone collectors, teachers, designers and crafters. The content of the questionnaire includes seven parts: (1) Purpose and experience on using the inkstone, (2) Characteristics and advantages of inkstone, (3) Types and materials of current inkstone, (4) Symbolic meanings of the inkstone, (5) Effect of inkstone on calligraphy and drawing, (6) Representation of inkstone, (7) Future development and expectation of an inkstone. The designed questionnaire was distributed to approximately 50 potential voluntary tested subjects, including 33 males and 27 females. The measurement scale uses numerical values of 1–5. The five points 1, 2, 3, 4, and 5 denote the linguistic judgments very low, low, medium, high, and very high in importance, respectively. The collected data were stored and analyzed in Microsoft Excel.

The opinions of 10 experienced experts from the industries were solicited, and the form of independent score was used to quantify and make reasonable estimates of weights based on a large number of difficult-to-use technical methods with the help of EXCEL. Invite 10 experts to give weights to the importance of variables and establish a matrix β. Establish a matrix X by allowing experts to give appropriate ratings to product variables at their discretion. Convert the matrix β multiply the variables by matrix X to obtain matrix T. After a careful analysis and examination on the survey results, the research amalgamated to three inkstone design orientations: (1) users tend to prefer the feeling of inkstone material property, (2) users emphasize usage efficacy of the inkstone, and (3) users consider symbolic attribute representation of the inkstone as its collection value. In Table 1, 20 groups with higher ranking of scores were selected and marked as "●" to denote the most suitable discourse for assessing the description of the inkstones. To establish the

Table 1
Representation of 40 sets of kansei imagery vocabulary.

Kansei Vocabulary							
Traditional	modern	Individual	popular	Gorgeous	plain	Decorative	Crude●
Simple	tedious●	Delicate	rough	Texture	vulgar	Practical	enjoyable●
Rhythmic	No rhythm	Textured	No texture●	Valid	invalid	Clumsy	anxious●
Firm	soft●	Regular	customized●	Gorgeous	elegant	Linear	Curvilinear●
Smooth	stagnant●	Heavy	light	Coordinated	messy	Regular	casual●
Delicate	rough●	Portable	inconvenient	Sparse	dense●	Fine	rough●
Smart	dull●	Flat	undulating	Strong	weak●	Elegant	restrained●
Elegant	popular●	Plain	quiet●	Void	solid●	Majestic	slim
Glossy	dull●	Symmetrical	organic	monotony	creativity	Concrete	abstract
Interesting	boring	clean	dirt	Wear proof	abrasion	Deep	crisp

relationship between the morphological elements and the kansei vocabulary of long chi inkstone, the research designed a comparison questionnaire based on the attributes of preference and cognition on the 20 adjective vocabularies, and distributed to the 10 experienced experts. A scale of 1–10 was used for the experts to evaluate each adjective vocabulary. The adjective vocabularies were then clustered [28,52] using Equation (1) to express consumers' perceptual demand, as shown in Fig. 11. Note that the statistical software SPSS v17.0 was used in this analysis. According to the data analysis result, the research grouped the adjective vocabularies into four clusters and defined them with specific adjective terms. They are (1) ancient and quaint, (2) simple and Zen, (3) ethereal and vivid and (4) exquisite and intricacy.

4.4.2. Inkstone reliability test

Reliability refers to the consistency or reliability of test results [52]. According to the focus of attention, reliability can be divided into internal reliability and external reliability. Intrinsic reliability refers to investigating the internal consistency between these questions. The most commonly used internal reliability index is Cronbach coefficient. As an indicator of reliability, it measures the reliability of a group of synonymous or parallel test sums. The formula is:

$$a = [K/(K-1)][1 - \left(\sum S2i\right) / (S2x)] \tag{2}$$

A coefficient evaluates the consistency of scores of various items in the scale, which belongs to internal consistency coefficient. This method is more suitable for the reliability analysis of attitude and opinion questionnaire (scale). The reliability test results of kansei imagery evaluation dimension of inkstone is shown in Table 2.

4.4.3. Morphological analysis of the long chi inkstone samples

The research collected 45 existing images of long chi inkstone shapes to help identify the characteristic elements of inkstones as shown in Fig. 12. According to the outlines of the inkstone samples, the research classified components of inkstone morphology into inkstone hall, inkstone edge, inkstone side, inkstone pool, inkstone post, inkstone forehead, inkstone back, and inkstone surface.

By comparing the importance of the components of the inkstone and their corresponding functions, the research determined three important components that will affect three basic functions of the inkstone. They are inkstone hall, inkstone forehead, and inkstone edge. It is noted that the core of the inkstone is located in the center which determines the quality of the stone and the value of its use. The front of the inkstone is an important part to improve the aesthetic ornamental value that is generally treated with ornaments, patterns, inscriptions, carvings and other crafts. The edge of the inkstone forms the contour to store water or ink. However, some famous ink stones do not have an edge because of their ornamental and collection value. The designer analyzes the shape and form of the inkstones by using the interaction flow diagram of design category behavior of the inkstone kansei engineering system to identify the elements that have important impacts on the shape, texture, pattern, carving and decoration of the inkstone. Each element is subdivided according to consumer imagery and expert importance assessment [53]. Due to the large number of product element variables involved and the large rating matrix, we will not list them one by one here. Then evaluate the importance of different components from aspects such as shape, texture, pattern and carving, etc., marked with "×". The corresponding results are illustrated in Tables 3-5.

4.5. Characteristics of four styles of imagery of the long chi inkstone

The design of long chi inkstone with ancient and quaint style in Tables 3-5 should have specific modeling elements such as the

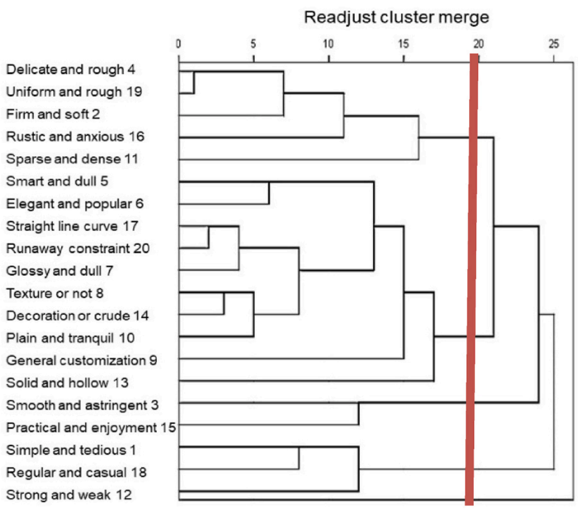


Fig. 11. Four clusters of representative inkstone samples.

Table 2
A coefficient test of inkstone shape category.

Dimension	Number of morphological categories	Cronbach a Reliability coefficient
Shape element	5	0.762
Texture element	8	0.853
Pattern element	4	0.747
Carve element	5	0.812
Decorative element	4	0.718

Fig. 12. Images of inkstone samples.

Table 3
Relations between style images and design elements of inkstone hall.

Style Image / Inkstone Hall		Ancient and quaint	Simple and Zen	Ethereal and vivid	Exquisite and intricacy
shape	Geometric shape		×		
	Utensil shape	×			
	Bionic shape				
	Following shape			×	
	Allusion shape				×
texture	hard	×	×		
	robust	×	×	×	
	soft			×	
	gentle	×			×
	slender			×	
	greasy				×
	purify	×	×	×	
	pretty				×
pattern	metal pattern				
	velvet pattern	×			
	geometric pattern		×		
	bionic pattern			×	
carving	bas-relief				
	stencil				×
	Surface carving			×	
	round-sculpture				
	seal cutting	×			

inkstone hall, inkstone forehead, and inkstone edge. The imagery characteristics should be mainly in the shape of biomimetic, and the lines are firm and neat that the decoration can reflect the natural velvet pattern. As to the carving, it should not be complicated and will mainly be shallow carving by seal engraving. In overall decoration, it is best to use the wooden inkstone box packaging support for better reflecting the ancient and quaint style imagery.

The long chi inkstone with simple and Zen style of imagery characteristics should have specific modeling elements such as the

Table 4
Relations between style images and design elements of inkstone forehead.

Style Image / Inkstone Forehead	Ancient and quaint	Simple and Zen	Ethereal and vivid	Exquisite and intricacy	Ancient and quaint
shape	Geometric shape		×		
	Utensil shape	×		×	×
	Bionic shape		×		
	Following shape	×		×	
	Allusion shape				×
texture	hard	×	×		
	robust	×	×	×	
	soft			×	
	gentle	×			×
	slender			×	
	greasy				×
	purify	×	×		
	pretty			×	×
pattern	metal pattern				
	velvet pattern	×			×
	geometric pattern		×		
	bionic pattern			×	
carving	bas-relief	×		×	
	stencil				×
	Surface carving			×	×
	round-sculpture				×
	seal cutting	×			

Table 5
Relations between style images and design elements of inkstone edge.

Style Image / Inkstone Edge	Ancient and quaint	Simple and Zen	Ethereal and vivid	Exquisite and intricacy	Ancient and quaint
shape	Geometric shape	×	×		
	Utensil shape				
	Bionic shape		×		
	Following shape			×	
	Allusion shape				×
texture	hard	×			
	robust	×	×		
	soft			×	
	gentle				×
	slender		×	×	
	greasy				×
	purify		×		
	pretty				×
pattern	metal pattern	×			×
	velvet pattern			×	
	geometric pattern	×	×		
	bionic pattern			×	×
carving	bas-relief				×
	stencil				×
	Surface carving			×	
	round-sculpture			×	×
	seal cutting	×	×		

inkstone hall, inkstone forehead, and inkstone edge. In general, it should be geometric types such as square, round, and triangular that the shape of the corner can reflect the line surface and the corresponding contrast, and the ornamentation is generally based on artificial geometric pattern. Note that the carving techniques to seal cutting or thin carving can be used in the overall packaging design to show the simple and Zen style.

The elements present in the design of long chi inkstone with an ethereal and vivid style: such as the shape of the inkstone, the front of the inkstone and the edge of the inkstone can be applied in the shape of an object (bell-shaped, tile-shaped, etc.) or follow the shape to show the sense of floating. In this situation, the texture should highlight the softness and delicacy of the inkstone as well as its neatness and elegance. The lines of the shape are slender and delicate having rounded corners at the combination. The color can also be shaped by artificial imitation pattern. Since the carving technique is used in stencil carving or surface carving, the overall packaging can be enhanced with the help of bright and smooth silk brocade to reinforce the dynamic imagery.

With the exquisite and intricacy style of long chi inkstone, the modeling element include numerous and orderly lines and rhythms. The general shape can be allusion-shaped, showing folkloric themes or auspicious meanings of patterns. As to the color, it is bright, with natural gold and silver patterns. The technique of round-sculpture can show the exquisiteness of the inkstone to the fullest extent, while the packaging is considered to avoid overly cumbersome.

5. Results

The design method of long chi inkstone with architecture-oriented kansei engineering system is discussed, and the application of kansei engineering concept in the inherit and innovative design of long chi inkstone is proposed in this research. In the local innovative design of long chi inkstone in Jiang le, the abstraction of traditional elements is used to match the usage and functional context [54] of long chi inkstone in the form of semantics. A multi-level analysis of the practical, aesthetic, and cognitive functions of the long chi inkstone enriches its expression by creating a certain logical relationship between traditional decoration elements. Using the traditional modeling mechanism, the research grasps factors such as shape, color, and material at the external level of the shape of the long chi inkstone in Jiang le. The research also emphasizes some important factors at the internal level of the shape such as position, direction, and number. It is noted that the meaning and spirit of the oriental culture is expressed in modern forms to enhance and expand the understanding of the cultural identity of the long chi inkstone.

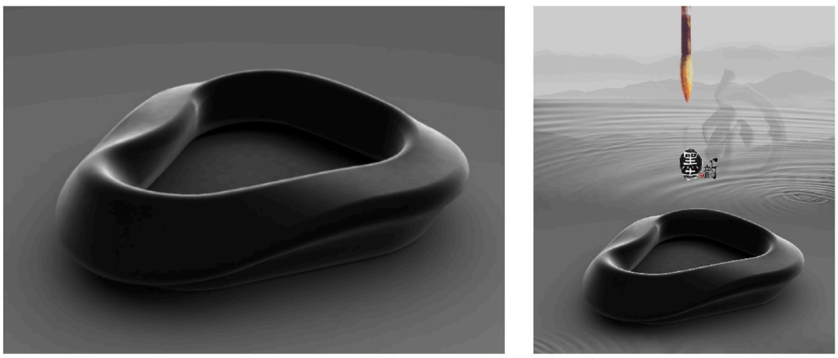
Specific details about the design solutions of the four styles of imagery of the long chi inkstone can be obtained from Table 3\4\5. The effect of the design solution is explained in terms of the simple and Zen style that the elements can be presented in the modeling performance: such as the inkstone hall, forehead, and edge for mainly geometric (e.g., round, triangular) representation. In addition, the details of the modeling for the simple and Zen style can reflect the psychological and emotional intention of the consumers. Note that the clean and sharp lines associated with the corners of the shape can reflect the product lines and the corresponding contrast to reality. The design concept on the ornamentation is generally based on the artificial geometric pattern that using the carving technique on seal cutting or surface carving to make the overall packaging show its simple style with the help of simple cloth or cotton and linen texture. The final design effect is shown in Fig. 13(a and b). Fig. 13(a) illustrated a conceptual idea based on the analysis recommendation; Fig. 13(b) showed a scenario representation for the long chi inkstone design idea.

With simple and Zen style.

This research introduces a systematic approach to kansei engineering in conjunction with the local ecological and humanistic environment on collecting and analyzing the design object of long chi inkstone as well as its morphological elements such as shape, texture, and craft and tapping into the innovative design of long chi inkstone in Jiang le. The design elements of the long chi inkstone are systematically summarized in terms of its function, shape, texture, theme and technical processing, respectively. The artistic beauty of long chi inkstone is not only functional, but also the form of appearance such as the shape of the inkstone associated with its carving and decoration characteristics. The relationship between the design elements and consumer groups of the long chi inkstone showed that a traditional artifact having its folk tradition, craftsmanship, rarity of materials, and cultural artistry will contribute to its collection value. In this regard, the role of consumer orientation is very important and need to be carefully analyzed on the characteristics of consumer groups, so as to maximize the market value of inkstone products.

6. Discussion

Kansei engineering is a user demand-oriented product design engineering technology [55]. The focus is to fully integrate the physical elements of design with the user's emotional information by utilizing the interrelationship between sensibility and rationality in design, in order to obtain more optimized design solutions. In the application process of kansei engineering, there are many



(a) Prototype design representation (b) Design scenario representation

Fig. 13. (a, b). Representation of long chi inkstone design.

overlapping methods, so the design needs to be improved with more precision. The implementation of one method must have another method as a prerequisite to achieve maximum effectiveness [56]. The integration of vocabulary meaning quantification is the fundamental method of kansei design. Only by quantifying and integrating the vocabulary used to express emotions can we accurately understand consumers' feelings. By removing excessive interfering information, we can accurately grasp important kansei information [57]. Factor analysis is a necessary method for processing data in survey statistics. It can process key techniques such as weight setting and factor integration, accurately grasping the main factors and controlling the effectiveness of design [58]. In short, the application process of these methods must be cross disciplinary, and only through integration and integration can the expected effect of product precision design be achieved [59].

However, no precise design method can completely replace human sensory system. Therefore, when conducting design practice, it is not necessary to rely solely on data, and the design process should not be turned into a rigid formula process. Attention should be paid to the variability of kansei information [60]. In the application of the design method in this study, maintain a certain degree of kansei operational freedom. For example, in order to have a more accurate evaluation of the importance of variables, representative and authoritative experts are familiar with and master the scoring standards during the scoring process to obtain the internal variation status of each variable in the product element. Effectively determine the level of importance between each variable [61]. Subjects can also adopt more flexible and appropriate ratings for the importance of each variable. Their expression of the importance of each variable relative to the design elements will also be more accurate.

The innovation described in the research is the development of an integrated architecture oriented kansei engineering system for product design in ceramic art. The system procedure associated with the concept of kansei engineering provides a designer with a useful way to generate design alternatives to be able to assess the quality of the design recommendation while still in the process of solving the design problem. The design of long chi inkstone is used as an example to help explain the development of the proposed procedures. During the development process of architecture-oriented kansei engineering system, the research categorized various sub-systems as external environment, components, operations, output and input parameters and interaction order between the operations. Each sub-system in any particular situation will reflect the relationships among the customer requirements and the interaction linkage of input/output information. The kansei vocabulary is identified based on the opinions of related experts for the long chi inkstone design. The kansei vocabulary is involved in the design of a questionnaire to help link inputs of customer requirements with design features. The questionnaire is distributed to the voluntary test subjects who have the experience of using inkstone as well as the understanding of long chi culture. Finally, the research recommended a new prototype of long chi inkstone design alternative having characteristics of simple and zen style. This prototype model just represents one of the emotional feeling and perception of customer expectations among numerous design styles [62]. The proposed architecture-oriented kansei engineering system should also be applicable in product design for application areas as varied as office equipment, daily necessities, electronic appliances, and clothing. In other words, the research demonstrated the applicability of the system framework more close association the product design process with kansei engineering for ceramic arts and traditional cultural development. It is expected that the proposed application of kansei engineering in the developed system architecture in inkstone design problems will help designers to systematically consider relevant design information and make the most effective use in related cultural arts of product design process.

This study attempts to establish a precise design method that can fill the gap between randomness and illusion in emotional design, but it does not necessarily negate the diversity and richness of design creativity. Only by combining both can we truly achieve the goal of excellent design.

7. Conclusion

The main purpose of this research is to propose a kansei engineering design system for the design of long chi inkstone that uses a structure-behavior coalescence in the architecture of an innovative specification of the system to explore the feasibility of innovative design for the long chi inkstone. The critical path of the structure-behavior coalescence includes the combination of the hierarchical decomposition of kansei engineering and expert systems. By using the system architecture description language, the implementation method and operation steps of the kansei engineering system are presented step by step, and the components and behaviors of the kansei engineering system are integrated into the design specifications of the kansei engineering system for different design objects. The integrated system specification model based on the system architecture is presented without separate system structure and behavior models that can guide the system reengineering development and enhance the success rate of system creation.

The combination of the system architecture and kansei engineering approaches has its obvious advantages. In this research, the system architecture can make the complex system simple and easy to understand that helps the simplification of kansei engineering system. Besides, the system architecture with a hierarchical diagram whether it is interpreted from the top down or from the bottom up can be quickly identified. In brief, the proposed architecture-oriented kansei engineering system can clearly categorize the same properties and characteristics of the system with the help of the framework diagram of the architecture, and put aside the hierarchical relationship to focus on the combination of components. It is noted that combination of six specifications of the system architecture in various design systems, including external environment, components, operations, output and input parameters, and interaction order between the operations can be more clearly reflected.

Therefore, the use of SBC-ADL to describe the kansei engineering system specification mold can integrate the structural and behavioral viewpoints, and improve the original system or method of each independent viewpoint whether their own separate system structural model and behavioral model may occur. It is expected that the SBC-ADL proposed in this research can be used to guide the designer in the implementation of innovative designs for various products not only to help build a series of solutions for office equipment, but also for other design systems especially involving behavioral components and multiple viewpoints. However, this research has only developed the structure of an integrated system framework as illustrated its use in a long chi inkstone design example. To fully assess the contribution this system can make in cultural product designs, further study should be focused on the design of an interface between the proposed system and stand-alone procedure to enhance the ability of product design.

Declarations

The research of the collected data analysis in this manuscript follows the moral correctness of ethics. No personal private information is needed throughout the survey process. All the opinion surveys in this research primarily dealt with specific products and are not related to human behaviors. Besides, the tested subjects are voluntarily invited and agreed to do the survey.

Data availability statement

The data associated with this study has been deposited into a publicly available repository.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Jing Chen: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Software, Visualization, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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