# Product Design Decision Oriented by Hierarchical Relevance of User's First Perceptual Demand

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# Product Design Decision Oriented by Hierarchical Relevance of User's First Perceptual Demand

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**Abstract:** The characteristics of "multi-dimensions, multi-hierarchy and correlation" of users towards the same product are shown in their perceptual demands. However, one or two perceptual expressions cannot precisely describe users' comprehensive perceptual demands for products. A semantic-associated multiple perceptual demand model is proposed in this paper, focusing on the multiple perceptual demand model oriented by users characteristics. Through feature analysis of users and perception evaluation test to product, different perceptual demands for products corresponding to the typical characteristics of different users are established. Then the *n*-dimensional perceptual demand information of users to product plan and the corresponding position in the semantic space with typical features of user groups can be comprehensively described. By taking the design of electric scooters as the example, the "Product Design Decision Oriented by Hierarchical Relevance of User's First Perceptual Demand" is verified and a hierarchical classification method for first perceptual demand is proposed.

## 1. Introduction

User's preference oriented personalized product design has become the key to attract purchase. Scholars established user emotional demand model to integrate user's requests into the early stage of design. Kansei engineering combines perceptional information of users with product modeling attributes through mathematical quantification. However, users often describe their emotional demands for products through language, while language has different meanings for different people and often shows obvious ambiguity and uncertainty. So it is difficult to predict users' perceptual demand for products and combine these demands with modeling features of products. Studies based on product conceptual design framework have proposed a user demand mathematical model to integrate user's perception into product design. Literature proposed that different fuzzy models can be used to determine product schemes and special demands of users will be transformed into different actual product schemes.Literature proposed that product design based on emotional space can comprehensively deal with emotional response of users to product scheme.

From the above studies, it can be seen that effective acquisition and processing of users' perceptual demand information is the basis of in-depth research. However, users' perceptual evaluation to products is described by language. In addition to ambiguity and uncertainty, their perceptual demands for the same product also show "multi-dimensional, multi-level and dynamic" features.Therefore, one or two perceptual expressions to product cannot cover the essential demand of users for product. Therefore, this paper proposes a multi-dimensional perceptual demand model construction method based on semantic associated hierarchy process. Through feature analysis of users and perception evaluation test to product, different perceptual demands for products corresponding to the typical

characteristics of different users are established. Based on the example, which has laid the foundation for personalized design of product based on semantic retrieval in future studies.

## 2. Analysis of users' perceptual demands and modeling

### *2.1. Analysis of perceptual demands*

From the perspective of product design, users' demands are divided into demands for function, performance, structure, aesthetic perception, economy, reliability, maintenance, safety etc. According to the expression form, user demand information can be divided into numerical data (including discrete data and continuous data), semantic data (fuzzy data, redundant data, missing data) . In literature , according to the mapping relationship between user demand information and product design parameters, user demands are roughly divided into structured numerical demands and perceptual demands.

The structured numerical demand refers to user's ability to clearly express the characteristics of the product by numerical values. It is a numerical data and is directly mapped to the characteristic parameters corresponding to the product.

Perceptual demand is mainly the response generated by user's perceptual evaluation to product features. It is mostly qualitative semantic description data in the genre of language description, such as the aesthetic appearance of the product, style perception, product image and other evaluation. This information cannot be directly transformed and exhibited on product features, it must be analyzed, quantified and mapped with parameterized product features.User's perceptual demand for product is not unique. Even a single feature of the product will bring various demand characteristics from users, such as the demand for color, fashion, dynamic, feminine, nobility and so on.

### *2.2. Multidimensional perceptual demand model with semantic association*

Demand modeling defines and analyzes the characteristics of user demands through mining, cluster analysis, etc., and models with abstract demand descriptions are established to aid product design decisions.The demand hierarchy model based on the association among the demand information and the topological relationship enables the product design to fully meet the needs of different levels of users. However, when establishing a multi-dimensional demand classification system, layer-by-layer mapping of different view models is required, and the process is too complicated to turn into the actual design. Therefore, it remains as a hot issue of current research.

Although users' perceptual demand for products is diverse, it also shows hierarchies to a certain degree, that is, the most important (primary) perceptual requests, secondary perceptual requests, weaker requests, etc. $R_i, \overline{R_i}, (i = 1,2 \cdots n)$ is set as an anti-sense semantic phrase for describing users' perceptual requests, such as "quiet-dynamic" etc. In addition, there is certain relevance among the semantic expressions used by users to describe their perceptual demand for a product. For example, in a user's perceptual demand for certain product, "elegance" has a stronger association with "simplicity and softness" than with "solidity and sports". "Elegance" and "nobility" are closely related in a higher level, while "sports" and "noble" are related in the middle level. On the contrary, "elegant" and "vulgar" are antonyms, the latter is in low level relation with "noble", and the antonym of "sports" is "quietness", which is also strongly associated with "noble" in the middle level. Therefore, "emotional semantic ball" model can be used to express a user's multidimensional perceptual demand, as shown in Figure 1. However, how to classify, refine, simplify and effectively map these sensible needs to product design features is the key to the decision-making of the personalized design of product oriented by users' visual perception.

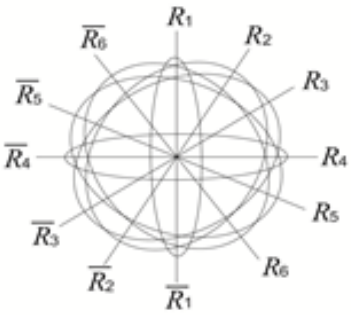


Figure 1. "Emotional semantic ball" model for expressing a user's multi-dimensional perceptual demands.

According to the "Emotional Semantic Ball" model of product perceptual demand, the multi-attributes of products and the diverse multi-user demands,the study proposes the relationship between the perceptual demand set and the semantic axis level to simplify the "emotional semantic ball" model, so as to better summarize the mainstream demand, improve the practical value of the model, and use the cluster analysis of the multi-dimensional perceptual demand of products. Here is the method:

Step 1: Use a statistical method to preliminarily extract the emotional words or phrases that a user frequently selects from a wide semantic vocabulary about perceptual demands to establish the user's perceptual information set about the product, $Y = \{Y_1, Y_2, \cdots, Y_n\}$ ;

Step 2: Establish the hierarchy of "demand $R_i$, $i = 1,2,\cdots,n$ ".

Step 3: Select the perceptual demands of higher hierarchy as the semantic axis MR*j* in the "perceptual demand semantic space". When $j$ = 1, $MR_1$ is a linear semantic axis which can be used to define or quantify one-dimensional perceptual demands. When $j$ = 2, the semantic axis $MR_2$ and $MR_1$ constitute a two-dimensional perceptual demand map, as shown in Figure 2, which is a perceptual design tool commonly used in current product designs. This two-dimensional perceptual demand cannot cover the user's multi-perceptual demand for a product, so the superposition of multiple two-dimensional demand maps often becomes necessary for the realization of the user's comprehensive perceptual demand for the product. However, this superposition process is too blunt and tends to cause the final solution to become an "empty set." Therefore, the two-dimensional perceptual demand map only provides reference and analysis in the design process. When $j$=3, the semantic axis $MR_3$ forms a three-dimensional inductive requirement semantic space with $MR_2$ and $MR_1$. As shown in Figure 3, the semantic axis $MR_3$ (popularity-elegance) are perpendicularly intersected with the $MR_2$ (dynamics-quietness) axis, with the focus being vertical with the main axis $MR_1$ (nobility-cheapness), constituting a "three-dimensional semantic correlation model of perceptual demands".

According to the complexity of the user's perceptual demand for products, when $j \geq 4$, it is relatively complicated to construct a multi-dimensional perceptual semantic association expression model. Literature proposed to use the rose diagram to express the multi-dimensional style, but how to express the inter-related characteristics of user's multi-dimensional perceptual demand require in-depth study. This paper proposes that there are different preference tendencies for users' perceptual needs of products that can be represented by multiple three-dimensional semantic spaces. By referring to different requirement semantics, products can be multi-stylized and serialized to meet differentiated needs of diverse consumer groups.

Step 4:The user's emotional information set is integrated into the association level between the product plan $P_i$ and the demand semantic axis to determine the position of the product plan in the user demand semantic space.as shown in Figure 2 and Figure 3. The position of the product in the two-dimensional and three-dimensional perceptual semantic space can be found. Through the above

four steps, the semantic hierarchical association clustering of the perceptual requirements of the user's multiple attributes is solved.

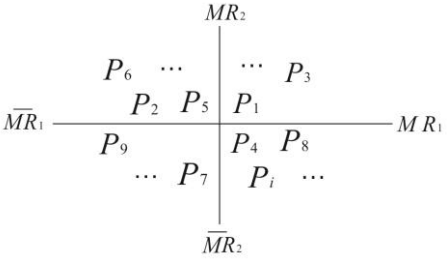


Figure 2. Location of products in the Two-dimensional semantic space.

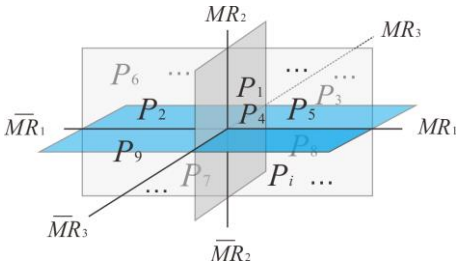


Figure 3. Location of products in the Three-dimensional semantic space.

*2.3. Multi-dimensional perceptual demand model oriented by user characteristics*

In Norman's "user-centered" product design, users' interests in products are more about the using experience than the product itself. Product development has shifted from functional, cost-based design to user-specific design.The multi-dimensional perceptual demand model oriented by users' characteristics extracts the typical features of users $U_i$, ($i$=1,2,…n) through survey and statistics at first, and uses two pairs of complementary adjective phrases $F_i, \overline{F_i}$ in its expression, forming a typical feature semantic space of the user group, as shown in Figure 4.

Through the product perception evaluation experiment, the user's "comprehensive perception" of the n-dimensional perceptual demand of the product plan Pi is related to the typical characteristics of the user group and to mark its position in the semantic space, such as the "multi-dimensional perceptual demand model of product oriented by typical semantic space of users" shown in Figure 5, it corresponds user's multi-dimensional perceptual information to the product plan.

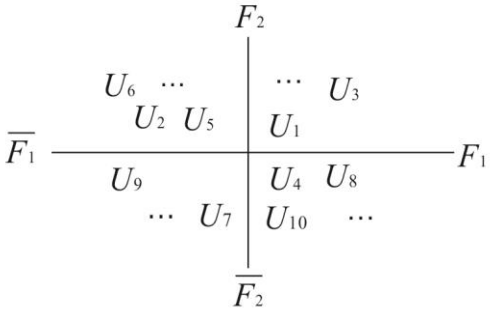


Figure 4.Typical semantic space of user group.

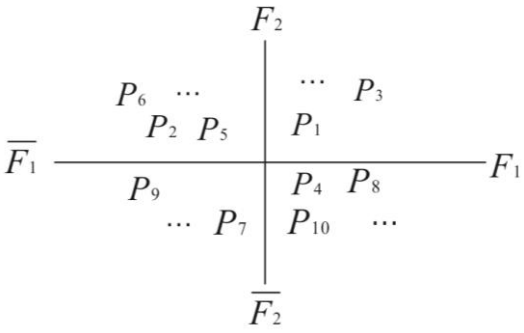


Figure 5. Multi-perceptual demands model of product oriented by typical semantic space of users.

## 3. Decision model of product design based on hierarchy correlation of first request

*3.1. Feature analysis on target users*

Product development directing at core users often serves as one of the key marketing plans of an enterprise. In order to find out the proper product plan satisfying the core user group, such target user group would be analyzed and subdivided into different sub-groups before making the final design decision. User group $U_i$ is thereby divided into a core user group, a secondary core user group and a non-core user group.

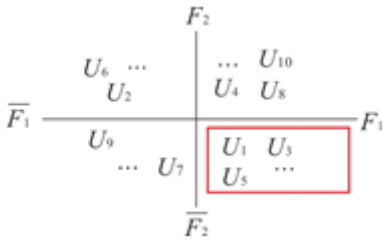


Figure 6. Typical semantic space of core users group.

Adhering to the same logic, two pairs of complementary adjective phrases $F_i$ and $\overline{F}_i$ are selected to form a typical semantic space of users based on analysis on target users. Supposing that core user group is located at the lower right quadrant of typical semantic space of core users as shown in Figure 7, the rectangle clearly indicates the location and its characteristics of core users.

*3.2. Establishment of user's first request*

Mathematical statistics is adopted to rank the multi-dimensional perceptual demand of users for product. Top demands are selected as *FR* (First Request) and is divided into n hierarchies. When *n*=3, *FR* can be divided into "High, Medium and Low" sub-hierarchies; when *n*=5, it is divided into "High, Relatively High, Medium, Relatively Low, Low" sub-hierarchies. To improve the practicality of the decision model of product design based on hierarchy correlation of the first request, this paper proposed to express the multi-dimensional request of users to product with a visualized two-dimensional form rather than a three-dimensional model. Set *n*=3, *FR* is thus divided into high, medium and low sub-hierarchies and the "decision model of product design based on hierarchy correlation of the first request" will transform from that shown in Figure 7 to that in Figure 10, turning to be more intuitive and practical.

*3.3. Design decision oriented by the hierarchy of users' first request*

On the basis of the hierarchy of core users' first request, the n sub-hierarchy is selected for making final product design decision. If such semantic association of these perceptual demands is established based on big data of users' need, this model will be able to describe multi-attribute individual request of users more precisely. When users determine their characteristics with semantic retrieval, their perceptual demands for product and personalized product features can be obtained. Supposing that the final product planning is made focusing on the medium and the high sub-hierarchies, superimposing Figure 6 and Figure 7, the product planning in wire frame shown in Figure 8 will be the final decision.

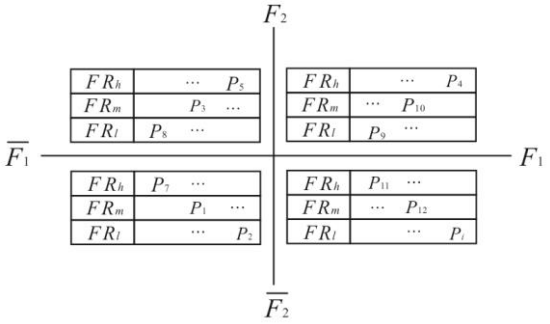


Figure 7. Decision model of product design based on hierarchy correlation of the first request

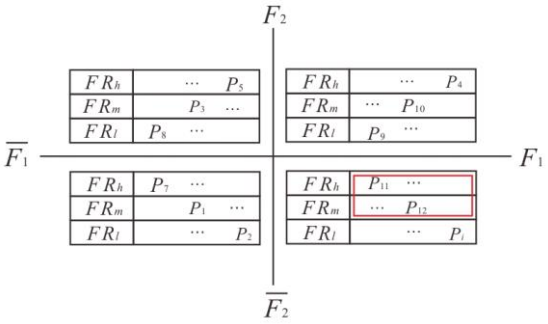


Figure 8. Decision model oriented by the hierarchy of users' first request.

## 4. Electric scooter design based on value hierarchy analysis

The design of 10 scooters of 3 kinds, i.e. "stand-riding scooter", "self-balancing scooter (the scooter using people's self-balancing to reduce the inertia force)", and "sit and stand-riding scooter", were selected in this research, as shown in Figure 9. Based on the analysis of the comprehensive perceptual

demands of users on the product, such as the function and the style, (10 scooters were numbered as $P_i, i = 1,2,\cdots 10$ from left to right, top to bottom), this research aims at determining the product characteristics favored by target users and providing necessary data support and decision basis of personalized designing for product optimization in later period. First of all, the target consumers were determined as people between 12-45 years old, among which 25-35 years old ones were the core group while 12-24 years old ones were the secondary group, their characteristics were acquired through investigation. The target consumers are expressed as "elder -- younger, high-profile – low-profile", as shown in Figure 10.


Figure 9.Personal stand-riding electric scooter design samples


Figure 10.User characteristics analysis of personal stand-riding electric scooter

Through experiments and statistical analysis, user's sentimental demands of products were acquired primarily among many perceptual words, which were: (1)$Y_1$-value; (2) $Y_2$-prevalence;(3) $Y_3$-novelty; (4) $Y_4$-comfort;(5)$Y_5$-elegence;(6)$Y_6$-gender (refers to the style inclining to "masculine" or "feminine");(7)$Y_7$-sportiness. In order to simulate actual and accurate situation of design determination, the product development process underwent one year, including 3 parts: user's sentimental demands were acquired through market survey before designing, front-line salesman's sentimental demands were concluded through demand investigation after designing; and after the determination of the final plan, designer's sentimental demands were obtained through survey statistics analysis.

Hereby,through the experimental evaluation, the order of the perceptual demand information biased by the user's comprehensive perceptual evaluation can be ranked as: $Y_1$-value, $Y_7$-sportiness, $Y_3$-novelty, $Y_2$-prevalence, $Y_6$-gender, $Y_4$-comfort and $Y_5$-elegence.Specific experimental data and calculations can be found in the literature 12.

Since the primary demand of users is "value", it was select as the primary demand in this study. Three-dimension semantic level of product's perception image was constructed based on "the score of value". According to consumer's typical semantic space of "elder – younger, high-profile – low-profile", the corresponding plan in semantic space was divided into "high, medium, and low" level based on its "value" in the early stage, forming an "analysis chart at value level". With this chart, plans in the semantic space can be re-designed. The "analysis at value level" of "multi-dimension" sentimental plan decision of stand-riding scooters was completed accordingly (Figure 11). Several kinds of scooters favored by core user group can be selected. According to the value level, plan at medium and high value level were picked as chosen plans (plans framed by rectangle in Figure 3) for design optimization later.

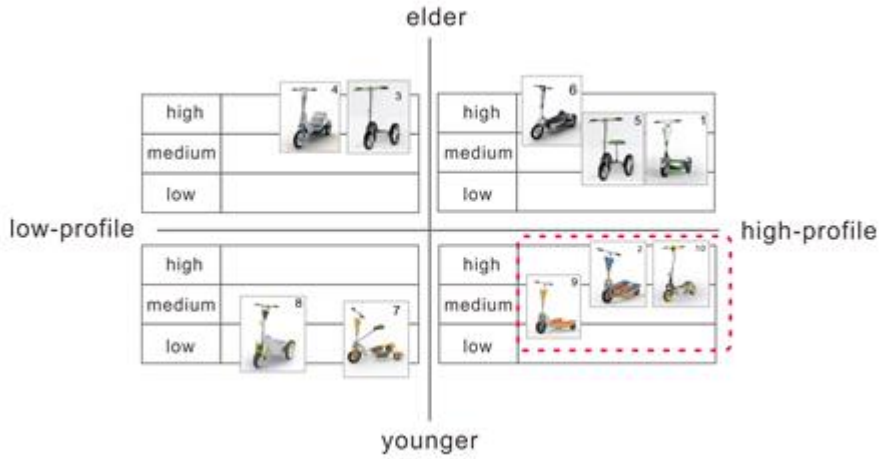


Figure 11.Value hierarchy analysis for the design of stand-riding electric scooters oriented by user characteristics.

## 5. Conclusion

"Emotional semantic ball" is adopted in this paper to describe perceptual demand features including "multiple dimensions, multi-hierarchy and correlation" of users towards the same product.Finding the user demand emotional semantic axis "MRj" from these tangible emotional needs.When j≥4, different preferences and tendencies of perceptual demands of users towards product are manifested by multiple three-dimensional semantic spaces. Stylized and serialized products can be achieved by referring to different primary request semantics to satisfy differentiated demands of various consumer groups. The approach provides a great solution to the dynamic trend of multi-attribute perceptual demand from users towards product.

Multiple perceptual demand model oriented by user characteristics proposed based on the above-mentioned approach comprehensively describes the position of n-dimension perceptual demand from multi-attribute perception evaluation of users towards product in typical semantic space of core users. The experiment results show that hierarchy of first request proposed in this paper is able to provide a simplified model, express multi-attribute comprehensive perception of users towards product intuitively and avoid one-sidedness, subjectivity and uncertainty in design decision. Such method can also improve the scientificity and availability of product style design decision and lay foundation for personalized innovative design theory based on users' demands.

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