Using DECA to Design Automobiles with Affective Features

Hong Peng and Martin G. Helander

***Abstract*—Traditionally, product designers believe that the most effective strategy to enhance customer satisfaction is to improve the design performance. However, currently functionality is more and more taken for granted. Customers are looking for a new fulfillment at a different perspective of appreciation. Products are expected to generate pleasurable sensations and experiences. Affect and emotions play an important role in customers' evaluation, and it is essential, to investigate how affective products can be designed. In this study, the objective was to help designer understand and include affect and emotions into the automobile design process. Affective design can be decomposed into three distinct levels: visceral, behavioral and reflective. Design Equation for Citarasa Analysis method (DECA), which involves affective requirements, was developed to aid the design process.**

***Index Terms*—affective design, automobile, Citarasa, DECA.**

I. Introduction

Abraham Maslow's [1] hierarchy of human needs describes needs from the lowest level to the highest as: physiological, safety, belonging and love, self-esteem and self-actualization needs. Based on this hierarchy, Jordan [2] proposed the hierarchy of customer's needs, with functionality at the base, usability at the middle, and pleasure at the top. Research literature refers to pleasure as a product benefit that exceeds the basic functioning, more explicitly, pleasure is an emotional benefit of owning a product [3].

The concept of *affect* refers to a large variety of psychological states such as emotions, feelings, moods, sentiments and passions. These states vary in extent, impact and eliciting situation [4]. Aboulafia and Bannon [5] referred *affect* to an intense and relatively short emotional state brought by a sudden change in circumstances, a short-term and direct response to the situation; while *emotion* goes beyond the specific situation and lasts for a few days.

Conventionally, designers believe that the most effective way to enhance customer satisfaction is to improve the design performance and technical aspects [6]. Functionality is now more and more taken for granted while launching a new product. Customers are looking for fulfillment in various perspectives of appreciation. As Paul Hekkert [7], the chairman of Design and Emotion Society stated: "It is no longer sufficient to design good product or service; we all want to design experience and generate pleasurable or exciting sensations." This is true for the automotive industry as well. Automakers accelerate effort to design automobiles which really appreciate customer's needs.

Product quality has shifted from functionality and usability to satisfaction of affective and emotional needs. These refer to affective aspects associated to the automobiles in terms of individual preferences, life styles and values. Frog Design is a creative global leading design company, with the motto: "Form follows emotion". They claim that customers do not just buy a product; but actually a value in the form of entertainment, experience and self-identity. Affect and emotion play a crucial role in a customer's evaluation. However, customers face difficulties to express their feelings. They tend to evaluate the product holistically. It is necessary to break down holistic evaluations using abstraction levels; these issues need to be further investigated.

There are numerous products in the market, but only a handful can be applied for affective design. These are typically products that are expensive and expressive, such as automobiles, computers, perfume, etc. They enable users to experience uniqueness in style and personality. The prospect of possessing such product generates a variety of emotions that are not experienced when confronted with standard products. In essence, need for individuality, pleasure, and aesthetics cause emotion in product evaluation.

No single product is able to satisfy the needs and preferences of all customers, the only way is to provide a variety of products [8]. Most products are designed, manufactured, marketed and distributed differently in different regions, such as magazines, automobiles, electronics appliances, etc. They vary in forms of designs according to the targeted customers' needs.

As a result, understanding and designing for customer needs and enabling customization and personalization is essential to the success of product design. A wide range of consumer products allow customization, which is used to configure products in various ways; examples include: computers, shoes, clothing, automobiles and so forth. This is the concept of

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mass-customization. However, it must be realized that the range and level of customization is limited, since the choice of components and accessories are restricted.

Based on the challenges of adapting to fast changing customer's needs and markets, the objective of this work is to help the designer understand how to involve affect and emotion into the design process. We will explore design methods which can effectively transfer the customer's true needs, both affective and functional needs, into the detailed design solutions.

II. Background

Products are designed to appeal to customers' needs and preferences. According to Tractinsky et al [9] aesthetic design has a favorable effect on usability. Norman [8] investigated the interaction of affect, behavior, and cognition, an he noticed that emotional system changes the way the cognitive system functions; hence the aesthetics would change the emotional state, and subsequently the cognition. Affect, emotion, and cognition interact with each other, and each of them plays a different role in functioning. For example, affect and emotion are responsible of communication and value judgment, what is good or bad, beautiful of ugly, etc. while cognition is responsible of interpreting and understanding. The combination of affect and cognition is considered a powerful driver in product evaluation.

A. Emotions and Products

Some products are more likely then others to elicit emotional response from customers. Holman [10] identified five roles that product could play in consumers' lives on different emotional levels. The roles were: background, mediator to interactions, enhancement, expression of identity, object of emotions. In this classification, automobiles are identified as a symbol of identity and objective of emotions, and the product involvement is very high.

B. Norman's Model

Norman [8] indicated that emotion is a key component of user experience. Norman's model of emotion and affect reflected brain mechanism, the three levels of processing, and different design characteristics. There is visceral, behavioral and reflective design, which can be used in analyzing various consumer products. First, the visceral level of processing makes rapid judgments, and sends appropriate signals to muscles and brain. The Apple iPOD for example, this is a typical product which is examined mainly for its visceral design; the appearance - such as classy, unique and simple look. Product form is a component of aesthetics value and will appeal to users' senses [11]. In car design there are several visceral design features including: shape, color, material, ornamentation, and texture.

The second level of processing is behavioral, which often is subconscious and forms the basis of skill development. Here products should be designed for ease of use and manipulation. Some products are chosen solely because of functionality, ease of use and usability. Poor behavioral design can lead to negative emotions. On the other hand, a well designed product gives an opportunity to develop mastery in control, to the extent that task performance seems to flow. Czicksentmihalyi [12], the flow state may be achieved by a thoughtful design of controls. In the case of games the question the controls must be compatible with the movements, afford smooth actuation and be easy to handle.

The reflective level is conscious. Here user reflects about the design. Designers should therefore firsthand consider the conscious needs of consumers, such as to enhance an image, comply with a person's culture or the current fashion trends. Reflective processing can enhance or inhibit behavioral processing, but has no direct access to visceral reactions [8].

We conclude that designing for each of the three levels requires different strategies:

- Design at the visceral level may seem straight forward. For example, many users would prefer cars that are cute, sporty or prestigious.
- Design at the behavioral level often entails a usability and functionality evaluation.
- For design at the reflective level, it maybe required to develop an image that reflects upon the customer's sense of status or value.

C. DESA

Design Equations for System Analysis (DESA) [13] is a formal design method, which has been demonstrated to be effective in minimizing functional dependencies with in human-machine system. DESA builds on Axiomatic Design (AD), but is different.

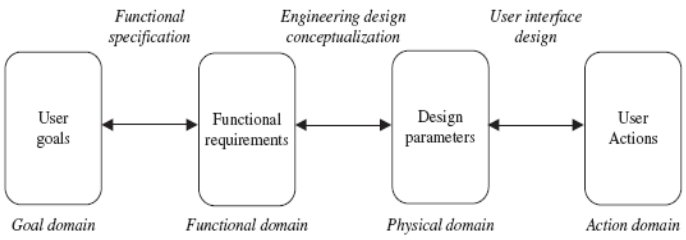

Fig. 1.Design Equations for System Analysis (DESA) Framework [13]

The functional domain contains a set of functional requirements (FRs), which characterize the function of a system, and used to achieve the user goals (UGs). The physical domain contains design parameters (DPs), which are physical variables that are selected by designers to satisfy FRs, and also controlled by the user actions (UAs). UGs are formulated in terms of the user's desired state of the system, such as "desired amount of light in the room". FRs are formulated in terms of engineering functions of the design artifacts, such as "provide a range of illumination". DPs are formulated in terms of engineering parameters of the machine or device, such as "electrical resistance". UAs are formulated in terms of user operations, such as "rotate light switch"[13].

Design equations are used to represent the mappings between four design domains:

$$\{UG\} = [A]\{FR\}$$
$$\{FR\} = [B]\{DP\}$$
$$\{DP\} = [C]\{UA\}$$

Hence, $$\{UG\} = [U]\{UA\}$$

And, $$[U] = [A][B][C]$$

DESA makes a system less complex by identifying the couplings in the system, and then proposing new design solutions that will de-couple the system. Subsequently, human performance will improve, while decision time and human errors will be reduced [14].

D. Citarasa Concept

Citarasa is a Malay term that refers to the customer's emotional intent and aspirations [15]. To investigate intent, there is an explicit identification of user's functional and affective requirements when buying a car or truck. *Citarasa* is generated from the visceral, behavioral and reflective needs of the customer or the search for pleasure of the mind. The customer's Citarasa is an expression of need and taste. In terms of a car, one Citarasa might be "elegant". The descriptor can be related to numerous characteristics such as color, shape, size and capacity that designers can manipulate to satisfy customer needs.

III. DECA

A. Overview and Procedures

Design Equation for Citarasa Analysis (DECA) method proposed here is adapted from DESA [13]. However, DECA considers affective needs and corresponding affective requirements as well as functional aspects, which can assist the designer to consider both affective and functional design.

Fig. 2 illustrates the data flow process of DECA. The results from customer survey can be classified in terms of functional and affective user needs. The feedback loop is essential, as it provides important information about what has actually been achieved, and what parts need to be redesigned or refined.

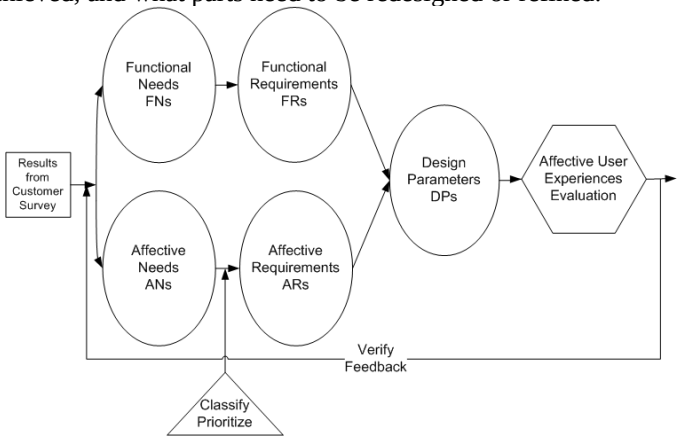

Fig. 2. Formulation of DECA

- *Affective Needs (ANs)* are defined as customer's needs related to affective product requirements. These are different from functional needs. ANs focus on how to derive pleasure in using the product. Normally ANs could be represented as descriptors or simple statement, in terms of customers' emotional needs.
- *Affective Requirements (ARs)* is the affective appraisals which are judgments concerning the product. Examples are: cute headlight, sporty shape, sexy color, etc.

The procedure to employ DECA in the design process can be summarized into the following steps:

1. State product's domain and list target customers, both existing and potential ones.
2. Classify and prioritize functional needs (FNs) and affective needs (ANs) from the Citarasa ontology and Citarasa database. The purpose of this step is that in case the designer cannot satisfy all the needs, he/she is able to satisfy the most important ones.
3. Define functional requirements (FRs) and affective requirements (ARs) related to functional needs (FNs) or affective needs (ANs), and suggest corresponding functional / affective design parameters (DPs).
4. Decompose ARs, FRs, and DPs into reasonable lower levels of responding hierarchy and put them in the design matrix.
5. Specify corresponding user scenarios and affective user experiences.
6. Analyze the mapping and coupling between ARs, FRs and DPs. Conventionally, the values in a design matrix will be either 'x' or '0', where 'x' represents a mapping between the corresponding vector components while '0' signifies no mapping.

It is not necessary that the mapping are uncoupled, which is often difficult to achieve. Thus it may be satisfactory to achieve a semi-coupled design, which will express each functional and affective requirement as a function of design parameters, and vice versa. In Fig. 3 FR_1 is fulfilled by DP_1 and FR2 is fulfilled by DP_2. However AR_1 also if fulfilled by DP_1 and DP_2. Therefore some design parameters can fulfill both the functional and affective requirements. This would be a successful design element since it combines "Form and Function".

The design matrix refers to:

$$\begin{bmatrix} FR_1 \\ FR_2 \\ \vdots \\ FR_i \\ AR_1 \\ AR_2 \\ \vdots \\ AR_j \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & x & 0 & 0 & 0 & 0 & 0 & 0 \\ & & \ddots & & & & & \\ & & & \ddots & & & & \\ x & x & 0 & 0 & \ddots & 0 & 0 & 0 \\ 0 & x & x & 0 & 0 & \ddots & 0 & 0 \\ & & & & & & x & \\ & & & & & & & x \end{bmatrix} \times \begin{bmatrix} DP_1 \\ DP_2 \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ DP_k \end{bmatrix}$$

Fig. 3 DECA matrix

A tool such as Axiomatic Design (AD) will help to structure the design process, and prompt the designer to consider both affective and functional design. It will also make the designer aware of the importance of affective design and instruct him/her to make trade-off decisions that can promote affective design. It is therefore considered as a helpful tool to designers. Future field validations of designers will test this hypothesis.

The mappings are based on the designers' considerations and thoughts, but they may not be consistent with the customers' thoughts, hence further validation by the customers is needed. During the user experience and evaluation, the differences between the designers and customers can be found and relevant modifications can be made, which forms the feedback loop. The customers are unaware of what exactly prompts their preferences, and the preferences of a product depends on a holistic assessment of product attributes [16], such as aesthetics design, functional design, ergonomics design, personal preference, experiences, etc. These could also be related to Norman's three levels of design.

IV. Case Study

To evaluate the feasibility of DECA, a case study was developed. Data related to car seat design was reviewed, analyzed and mapped into the design matrices. Safety and comfort are the two factors that automobile seat manufacturers use to distinguish and evaluate products [17]. Seat design characteristic are generally very important in designing an automobile seat.

A. DECA Procedures

1. Product: Car seat
2. User Needs: a good car seat. Classify and prioritize functional user needs (FNs) and affective user needs (ANs), to simplify the case only one need is used here.
3. Define and decompose ARs and FRs into reasonable lower levels of hierarchy, which are related to specific user needs:
   a) *FRs:* FR1: ergonomics
      FR2: comfortable
      FR3: spacious
   b) *ARs:* AR1: sporty
      AR2: elegant
4. Decompose DPs into reasonable lower levels of responding hierarchy and put them in the design matrix.
5. Specify corresponding user scenarios and affective user experiences. Designers must have a clear understanding of product constraints, context of use and what sort of design is needed. Scenarios embody concrete and accurate design requirements, which is helpful in discussing and understanding product features [18]. A specific scenario to perform the task is presented below:

   Task: Test drive car
   Persona: Patrick
   User Group: Sales Manager

   Background: Patrick would like to buy a new car. His old car seat is too small, fixed and cannot be adjusted. Patrick is a tall guy with big body size, and he would like a sports car. He has worked for more than 10 years and around 30 to 35 years old. He also needs to visit his client very often.

   Scenario: In the car showrooms, several cars were selected for test drive. Some of the cars which were test driven provided adjustable seats. Some seats tested were too narrow and small for his body. Patrick may need to drive for long time, and sometime would like to take a short rest in the car.

6. Specific DP decomposition for Patrick's scenario, see Fig.4.

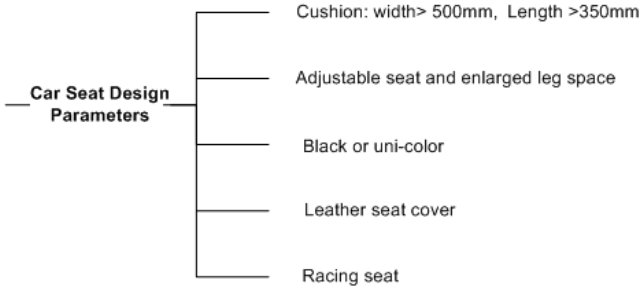

Fig. 4. DP decomposition according to "Patrick scenario"

7. Analyze the mapping and coupling between ARs, FRs and DPs. Conventionally, the values in a design matrix will be either 'x' or '0', where 'x' represents a mapping between the corresponding vector components while '0' signifies no mapping.

B. Discussion

The mappings do not necessarily have to be uncoupled. In this case there is a semi-coupled matrix, which can reduce the complexity of design. Map each AR and FR to several matching design parameters, and vice versa.

In Fig. 5, the inputs are affective and functional requirements, which can be obtained from a customer survey. It is observed that a semi-coupled mapping is achieved, and as mentioned, some affective or functional requirements can be associated with more than one design parameters.

The DECA method helps to structure the design process, and prompts the designer to consider both affective and functional design. It also makes the designer aware of the importance of affective design and instructs him to make trade-off decisions that can promote affective design. It is therefore considered a helpful tool to support designers.

$$\begin{bmatrix} AR_1: \text{Sporty} \\ FR_1: \text{Ergonomics} \\ FR_2: \text{Spacious} \\ FR_3: \text{Comfortable} \\ AR_2: \text{Elegant} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 & 0 \\ 0 & x & 0 & 0 & 0 \\ 0 & x & x & 0 & 0 \\ 0 & x & x & x & 0 \\ 0 & 0 & 0 & x & x \end{bmatrix} \times \begin{bmatrix} \text{Racing seat} \\ \text{adjustable seat and enlarged leg space} \\ \text{cushion : width} > 500\text{mm, length} > 350\text{mm} \\ \text{Leather seat cover} \\ \text{Black or unicolor} \end{bmatrix}$$

Fig. 5. DECA mapping of car seats design

The car seat design demonstrated here is a fairly simple design. For a more complex system, it might be more difficult to achieve a semi-coupled design matrix. More research and case studies are needed to investigate this method.

V. Conclusions and Future work

Most automobiles today are of excellent quality. To improve product competitiveness and subsequently customer satisfaction, affective and emotional design factors need to be considered. The selection of such factors is influenced by individual preferences, including status, life styles and values. It is important to explore the design methods that can be used effectively to model customer needs. A specific design model (DECA) was introduced. DECA included affective as well as functional design requirements. The model is helpful in guiding the design process.

In the future we will further refine and validate the proposed method. We need to understand how the model can help the designers in designing a product with affective features accurately and effectively, and subsequently if this method can increase the competitiveness and effectiveness of product design.

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