20th ISPE International Conference on Concurrent Engineering
C. Bil et al. (Eds.)

doi:10.3233/978-1-61499-302-5-235

Development of a Parametric Form Generation Procedure for Customer-oriented Product Design

Ming-Chyuan Lin[a,1], Yi-Hsien Lin[b], Ming-Shi Chen[c] and Jenn-Yang Lin[d]

[a] *Department of Creative Product Design College of Arts Nanhua University*
[b] *Department of Educational Administration College of Education and Human Services Texas A&M University-Commerce*
[c] *Department of Product Design TransWorld University*
[d] *Department of Creative Product Design and Management College of Commerce & Management Far East University*

Abstract. Currently, the involvement of consumer requirements in the early stage of product development has become an important issue in product design. The designer needs to correctly and immediately do customer requirement analysis and make decisions in the process of design alternative recommendation. However, the designer is usually difficult to grasp customer requirements. Fortunately, the enforcement of computer software and upgraded efficacy of computer hardware allow an embodiment representation of design alternatives to link customers with designers. Therefore, the objective of this research is to develop a parametric product design system that can provide designers with an interactive interface to consider customer requirements in the early stage of product development. The design of ear phones is used as a case to explore the applicability of the parametric product design system. The function of parametric design in the CATIA software is also used to help construct design appearance for the generated ear phones.

It is expected that the generation of parametric design incorporated with data mining system in the web site will enhance product design efficiency in grasping product design key factors and parameters at the initial stage. Designers can not only generate products fast in the process of product development, but also get the appropriate forms of product quickly and match the demand and preference of consumers.

Keywords. Customer-Oriented Product Design, Parametric Design, Data Mining, Decision Making

[1] Ming-Chyuan Lin, Ph.D., Professor
Department of Creative Product Design College of Arts Nanhua University
Chiayi, Taiwan 622
Tel: 886-5-2721001 Ext 56435, Fax: 886-6-2522609
e-mail: minglin@mail.nhu.edu.tw

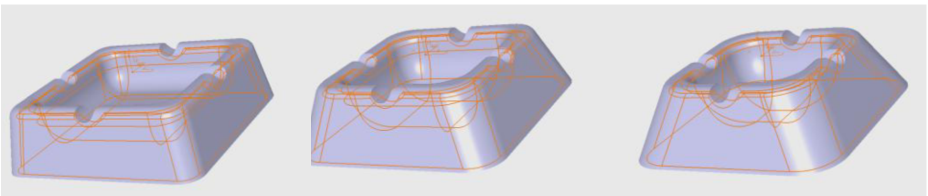
1. Introduction

The progress of technology and competition of global market has made the product life cycle shortened. Due to the significant improvement of digital technology and computer performance, product designers can use computers to generate solid modeling of design alternatives and make rapid revision and detailed design on the generated design alternatives. The digital data can even be directly transferred to the department of engineering design and manufacturing. As such, the introduction of computer-aided design and application of knowledge base have made product development more efficiently. This application of computer information technology in the design process of generation of product design alternatives is no longer a bottle-neck for designers [1]. However, involving customer requirements in the first stage of design process and making a quick analysis and decision become an important issue for designers. To face this trend, the designer needs to improve the product development process and enhance the efficient collaboration design. In the collaborative product design, customer requirements are involved to ensure the developed products can be closed to the expectation of the targeted market. Researches showed that the cognition between designers and customers is still significantly different [2]. It might be because customers can not explicitly depict the expected product form and requirements in a representational media that make designers difficult to catch the voice of customers. To help reduce the sale loss of the developed new products that is incurred from communication obstacles between designers and customers, an efficient design assistance system is needed in the design process. Currently, the enhancement of computer software functions and the improvement of computer hardware efficiency might provide designers with a friendly interface that can properly link customer requirements with designer ideas [3]. The objective of the proposed research is to construct a parametric product design system that can provide customers and designers with a communicative interface to help present different customer requirements and the corresponding product graphic representation. In order to explain how the proposed approach is developed, the design of ear phones will be used as an example to illustrate the steps of the approach.

2. The Development Procedure

As mentioned before, an interactive interface will be designed in the parametric product design system to allow designers to involve specific customer requirements in the design process. To help develop the system, the proposed approach also considers the data connections between customer requirements and customer attributes. A relational database is developed and then the technique of data mining is used to explore some useful customer preference. The identified customer requirements will proceed with product characteristics analysis, evaluation and design.

In the procedure of parametric product design development, the designer conducts a systematic analysis on product structure to identify and set up the key product design parameters for the generation of graphic representation. The parametric data are transformed into the construction of component characteristics of a product form. Each generated component is then integrated into a complete product form. The developed design data base can be stored for further analysis. Data mining technique is also applied to product classification [4] and product design assessment to assist designers to extract the customer-oriented product design for the specific customer category [5, 6]. The approaches of this research include: (1) identification of product parameters for customer requirements, (2) decomposition of identified product parameters into several sections, (3) construction of product components and complete forms, (4) definition of the range of numeric data for each product component and (5) generation of design alternatives for a specific set of customer requirements. The research uses ear phone design as a case to help explain the development procedure. Note that a preliminary exploration of parametric product design is conducted as illustrated in Figure 1. It will help designers to learn how to use simple geometric form, position of control points, proportional adjustment, numeric change, and even transformation of form such as reduce-enlarge, revolution, transfer, gradual change, transition and twist in the generation of a variety of product forms [7-9].



(a) An ashtray design

(b) An iPod design

Figure 1. General concept of parametric product design.

3. Implementation of the Parametric Ear Phone Design

Since customer requirements and product characteristics are two major parts in product design development, the research will focus on a parametric adjustment of product form in response to a specific set of customer requirements [5, 10, 11]. A six pronged procedure for the development of parametric product design system is employed. In order to explain how the proposed approach is developed, the design of the ear phone will be used as an example to illustrate the steps of the approach.

3.1. Identification of Product Parameters for Customer Requirements

After a collection and classification of 65 ear phone samples, the research targeted the design of one piece mould ear phones as illustrated in Figure 2. In Figure 2, three design parameters are identified [10]. They are (1) head, (2) neck and (3) body.

Figure 2. Characteristics of a one piece mould ear phone.

3.2. Decomposition of Identified Product Parameters into Several Sections

In developing the parametric product design system, the research uses computer software CATIA to construct ear phone images for graphic representation. Based on the observation of the ear phone appearance shown in Figure 2, the research decomposed the ear phone design parameters into 5 composite sections [12]. The design parameter "Head" consists of the first, second and third sections, "Neck" consists of the fourth section and "Body" consists of the fifth section. All sectional graphics are constructed with circles. Note that the fourth section of the "Neck" defines two control points (above and under the neck) and the fifth section of the "Body" also defines two control points (above and under the body). In the construction of a 3D one mould piece ear phone, the research first connects end points of the first, second and third sections, then connects the corresponding control points of the fourth and fifth sections [12]. A conceptual construction for a one mould piece ear phone graphic representation is shown in Figure 3.

3.3. Construction of Product Components and Complete Forms

To apply the numeric data in the CATIA software for the construction of product components and adjustment of control points to fit for a complete product form, the research identifies 18 graphic parameters, as illustrated in Figure 4. The advantage of using parametric graphics includes: (1) product sample forms are constructed with numeric data to avoid subjective deviation of different designers in constructing graphics and (2) designers can do self control for some design factors based on the classification rules of samples.

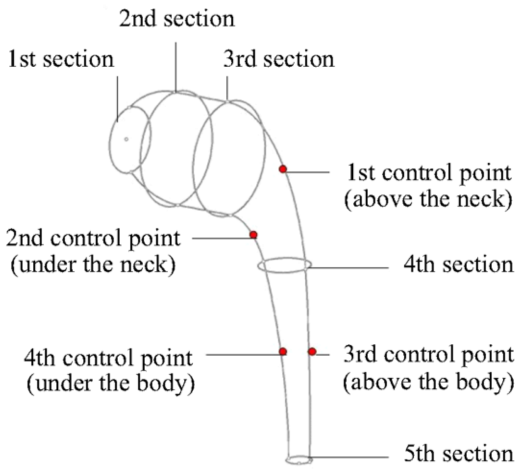
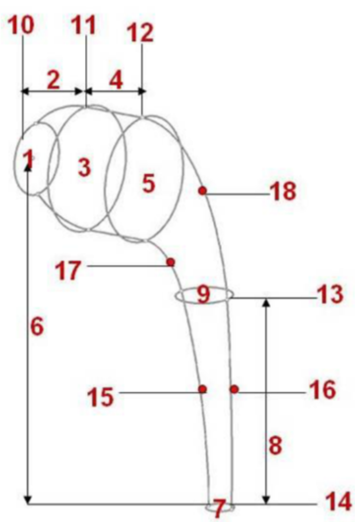


Figure 3. Decomposition of a one piece mould ear phone characteristics.



(a) Identification of graphic parameters

No.	Definition of parameter
1	Location of 1st section's center (Origin)
2	Distance between 1st and 2nd sections' centers
3	Location of 2nd section's center
4	Distance between 2nd and 3rd sections's centers
5	Location of 3rd section's center
6	Distance between 5th section's center and origin
7	Location of 5th section's center
8	Distance between 4th and 5th sections's centers
9	Location of 4th section's center
10	Radius of 1st section
11	Radius of 2nd section
12	Radius of 3rd section
13	Radius of 4th section
14	Radius of 5th section
15	Location of 4th control point
16	Location of 3rd control point
17	Location of 2nd control point
18	Location of 1st control point

(b) Definition of graphic parameters

Figure 4. Decomposition of a one piece mould ear phone characteristics.

3.4. Definition of the Range of Numeric Data for Each Product Component

In constructing the one piece mould ear phone, the proposed approach uses the concept of line connection of circular contours. To allow the developed samples can cover different characteristics of ear phones for customer requirements and assist designers to expeditiously generate recommended design alternatives, the research defines variations for graphic parameters. It is noted that single variation such as radius, length, width and height is not enough to represent the characteristics of a product form. As such the research transforms the identified graphic parameters into characteristics of a product form. The characteristics of a product form are then transformed into numeric definition. Figure 5 illustrates the conceptual transformation of graphic parameters into characteristics of a product form and the corresponding numeric definition. Based on the conceptual transformation shown in Figure 5, the range of numeric definition can then be determined as illustrated in Table 1. Note that that numeric definition is based on the dimensional measurements of different types of marketed one piece mould ear phones.

No.	Definition of parameter
1	Location of 1st section's center (Origin)
2	Distance between 1st and 2nd sections' centers
3	Location of 2nd section's center
4	Distance between 2nd and 3rd sections's centers
5	Location of 3rd section's center
6	Distance between 5th section's center and origin
7	Location of 5th section's center
8	Distance between 4th and 5th sections's centers
9	Location of 4th section's center
10	Radius of 1st section
11	Radius of 2nd section
12	Radius of 3rd section
13	Radius of 4th section
14	Radius of 5th section
15	Location of 4th control point
16	Location of 3rd control point
17	Location of 2nd control point
18	Location of 1st control point

Affected exterior characteristics
Size of head
Length of head
Type of head
Front slope of head
Back slope of head
Length of entire headset
Slope of neck
Offset of body
Length of body
Thickness of top of body
Thickness of bottom of body
Curve of body
Body is straight or not
Bend of body
Width of neck

Numerical control
Radius of 2nd section
Distance between 1th and 3th sections's centers
Ratio of length to width of head
Ratio of 1st section's radius to 2nd section's radius
Ratio of 2nd section's radius to 3rd section's radius
Distance between 1st and 5th sections's centers
Ratio of 3rd section's radius to 4th section's radius
Ratio of 4th section's radius to 5th section's radius
Distance between 4th and 5th sections's centers
Radius of 4th section
Radius of 5th section
Difference between 4th section's radius with 5th section's radius
Centers of 4th and 5th section are collinear points or not
Types of 1st and 2nd control points
Types of 3rd and 4th control points

Figure 5. Conceptual transformations of graphic parameters into numeric definition.

Table 1. Determination of ranges of numeric definition for a one piece mould ear phone

Affected exterior characteristics	Numerical control	1	2	3
Size of head	Radius of 2nd section	Small: 2.2~3(mm)	Medium: 3.1~4.9(mm)	Large: 5~6.5(mm)
Length of head	Distance between 1th and 3th sections's centers	General: <5(mm)	Longer: 5~7(mm)	
Type of head	Ratio of length to width of head	High and narrow: 0.6~0.9	Spherical: 1~1.5	Flat and long: 1.6~2
Front slope of head	Ratio of 1st section's radius to 2nd section's radius	Flat: 0~1	General: >1	
Back slope of head	Ratio of 2nd section's radius to 3rd section's radius	Flat: 0~0.2	General: >0.2	
Length of entire headset	Distance between 1st and 5th sections's centers	Short: 7~15(mm)	Long: 16~24(mm)	
Slope of neck	Ratio of 3rd section's radius to 4th section's radius	General: 0.5~2.25	Steeper: >2.25	
Offset of body	Ratio of 4th section's radius to 5th section's radius	Offset: 0	Offset: >0	
Length of body	Distance between 4th and 5th sections's centers	Short: 2~8(mm)	Moderate: 9~12(mm)	Long: >12(mm)
Thickness of top of body	Radius of 4th section	Fine: 0.6~1.1(mm)	Coarse: >1.1(mm)	
Thickness of bottom of body	Radius of 5th section	Fine: 0.4~0.6(mm)	Coarse: >0.6(mm)	
Curve of body	Difference between 4th section's radius with 5th section's radius	Columnar: 0(mm)	Large arc: 0.1~0.4(mm)	Small arc: >0.4(mm)
Body is straight or not	Centers of 4th and 5th section are collinear points or not	Offset: 0	Offset: >0	
Bend of body	Types of 1st and 2nd control points	Straight line	Oblique line	Bending
Width of neck	Types of 3rd and 4th control points	Uniform	Taper	Sharp

3.5. Generation of Design Alternatives for a Specific Set of Customer Requirements

According to the determination of the range of numeric definition, the research planned the generation of some experimental design alternatives. Figure 6 shows an operational interface of the parametric product design system. In Figure 6, an experimental design alternative is generated for a specific set of numeric data [13]. The research generated 40 experimental design alternatives that will be forwarded to explore the close linkage between customer requirements and the recommended design alternative. Figure 7 illustrates the generation of 40 experimental design alternatives.

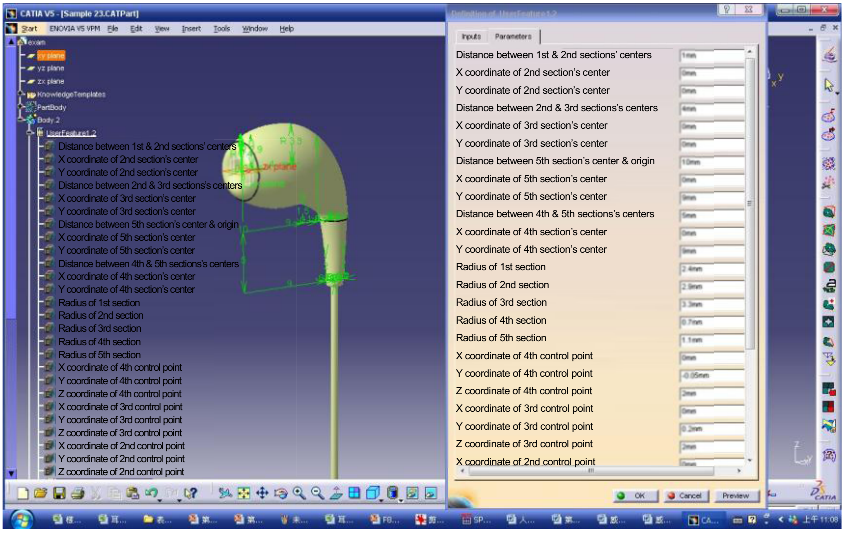


Figure 6. Operation Interface of the parametric product design system.

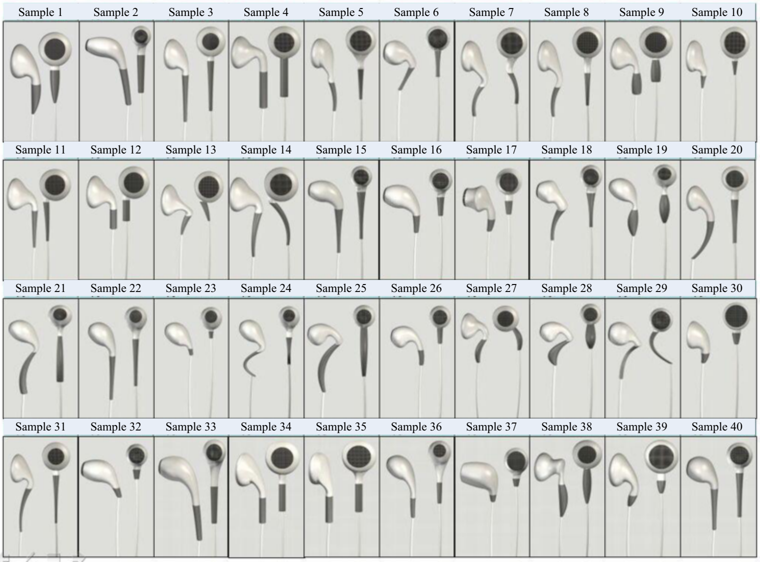


Figure 7. Generation of 40 experimental one piece mould ear phones.

4. Conclusions

Product design is an activity that relies on experience, thought and knowledge of the designer. Each designer might have his or her own subjective opinion, but the integration of knowledge, experience and customer requirements from designers of similar products will significantly improve the quality and reliability of product design. When the product designer or design team develops a product design using classical methods, the range of design alternatives that are developed is limited by the creativity of the designer or team members and the processes used in evaluating alternative designs may require a considerable amount of time. The research that this document describes is to explore possible connection of the parametric product design system with customer requirements. An evaluation of customer's preference and analysis of market trend via internet network will be conducted for future development. The evaluation will be conducted with an Internet survey type of questionnaire. The technique of semantic differential method in Kansai engineering will be applied in the design of questionnaire. In the questionnaire, a set of adjective vocabulary incorporated with the 40 experimental ear phone design alternatives is arranged to investigate the customers' preference. The stored data will be analyzed by the statistical software SPSS. The result of the questionnaire will assist designers to identify a specific group of customers with a particular type of one piece mould ear phones. When knowing different group of customer requirements, the parametric product design system can make a quick search for a most suitable interface and product type as shown in Figure 6. The customer can then generate a preferable product form. The development of the parametric product design system has shown the potential benefits that can be achieved with the involvement of customer requirements.

5. Acknowledgement

The authors are grateful to the National Science Council, Taiwan for supporting this research under the grant number NSC97-2221-E-343-009-MY3.

References

[1] Huang GQ, Huang J and Mark KL (2000) Early supplier involvement in new product development on the internet: implementation perspectives. Concurrent Engineering: Research and Applications, 8(1): 40-49
[2] Du XH, Jiao JX and Tseng MM (2006) Understanding customer satisfaction in product customization. Advanced Manufacturing Technology, 31(3-4): 396-406
[3] Yan W, Chen CH and Khoo LP (2007) Identification of different demographical customer preferences for product conceptualization. Engineering Design, 18(1): 39-54
[4] Witten IH and Frank E (2000) Data Mining, Academic Press, San Diego
[5] Chen CH, Khoo L P and Y W (2005) PDCS—a product definition and customization system for product concept development. Expert Systems with Applications, 28(3): 591–602
[6] Gologlu C and Mizrak C (2011) An integrated fuzzy logic approach to customer-oriented product design. Journal of Engineering Design, 22(2): 113-127

[7] Chen SE and Parent RE (1989) Shape averaging and its applications to industrial design. Computer Graphics and Applications, IEEE, 9(1): 47 – 54
[8] Gologlu C and Mizrak C (2010) Customer driven product determination with fuzzy logic and taguchi approaches. Journal of The Faculty of Engineering and Architecture of Gazi University, 25(1): 9-19
[9] Liao SH, Chen YJ and Deng MY (2010) Mining customer knowledge for tourism new product development and customer relationship management. Expert Systems with Applications, 37: 4212-4223
[10] Zwicky F (1967) The morphological approach to discovery, invention, research and construction, new method of thought and procedure. Symposium on Methodologies, Psadens, 316-317
[11] Liu QS and Xi JT (2011) Case-based parametric design system for test turntable. Expert Systems with Applications, 38(6): 6508-6516
[12] Lin MC and Chen LA (2005) An integrated prototyping and knowledge representation procedure for customer-oriented product design, Product Development, 2(4): 353-370
[13] Zhou S, Chin KS and Prasad KDV (2003) Internet based intensive product design platform for product design. Knowledge-Based System, 16: 7-15