Realizing product serialization by Grasshopper parametric design

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Abstract. The purpose of this paper is to explore how to realize serialization with parameterization by studying the application of Grasshopper parameterization modeling technology in the modelling design of serialization products. With the method of formulating the basic parameter series and setting the parameter algorithm, combined with the inheritance relationship of digital evolution of product characteristics, to reflects the series sense of product modelling, and demonstrates the feasibility of the method with practical cases. The conclusion is that in the background of high-speed development of information age and computer numerical control technology, parameterization provides a new way to realize product serialization design, promotes the combination of art design and digital manufacturing, maximizes design efficiency, flexibly updates products, and timely meets market demand.

1. Introduction

With the continuous advancement of economic globalization and the increasingly fierce market competition, the class diversity of consumers and the personalized and diversified demands of growing young consumers have caused irreconcilable contradictions between standardization and customization in large-scale industrial production. Product serialization is a systematic design method that adapts to the new economy and new business conditions, which can meet the needs of users to the greatest extent and improve production efficiency. Parametric technology is a very effective way to develop series products, which can quickly generate various design scheme by developing a series of basic parameters and dynamically editable logic programs. The following part 2 of the article introduces the concept of product serialization, design flow, and design principles. Part 3 introduces the connotation and characteristics of parametric design. Part 4 discusses the relationship between parameterization and serialization in product design and an application examples. Part 5 combines the parametric modeling design practice of the vacuum cup series, summarizes the design flow and method of implementing the product serialization with Grasshopper parameterization, and analyses the application difficulties. The last part is the conclusion.

2. Product serialization

Product serial design refers to scientific and unified planning of the size ratio, form, structure, parts, color, material, etc. of the same type of products, so that the series products are related in a certain dimension, and produce sense of series. In this paper, the range of product serialization is limited to
industrial product modeling design. Therefore, the following content mainly explores the possibility of serialization from the perspective of product modeling elements.

Modeling design is an important part of industrial design. In today's highly competitive market environment, a successful product model can increase the added value of products and enhance the market competitiveness of products. Modelling design of serialization products must plan the development idea of the product series at the beginning of the design, based on market research and user needs, selectively develop variant products from basic products, set application specifications of modeling elements such as form, structure, texture, color and materials in the serialized design, and try to embody the serialized features in each product. For example, the size and performance parameters of the base product are transformed according to a certain proportional relationship; or some design elements are designed and changed by adopting design methods such as additions or deletions, replacement, reconstruction, and deformation to ensure that serialized products, no matter how to innovate or improve the design, can always maintain a unified style, achieve uniformity in change, and form a relatively stable series of spectrum and style system in the development of upgrading.

In the design process of serialized products, we must pay attention to the following three design principles: First, there should have a clear point of design creativity, it can be a theme concept, or a structural form, modeling element, collocation mode, etc. so as to make the series sense of products coherent and prominent; Second, the series sense should be distinct. In the design of serialized products, the application of design points should have priorities and contrast, so that each product in series has its own characteristics; Third, the serialized products should be unified and changed, not only related, but also innovative. Under the premise of unification, the subtle changes of the serialization specifications will be extended to each product in series to form a rich and balanced effect.

With its flexible production mode, product serialization can save the design cost and production cost, improve research and development ability and production efficiency, develop new products flexibly, maintain the long-lasting vitality of the product line and meet the diversified needs of users. At the same time, product serialization is also a differentiated design strategy that shapes corporate image and expands brand influence, which is conducive to improving product identifiability and user brand loyalty.

3. Parametric design
As early as the 1970s, parameterization has been used to automate control the production process and results in large-scale industrial production. With the continuous development of computer and numerical control technology, parameterization has become a major trend in the information age and has been widely used in various design fields, changing the way of designing and manufacturing.

The designer's traditional top-down working model has been broken, nowadays the new generation of product designers are trying to use parametric tools to control the whole design process efficiently, and bringing infinite possibilities to "creation" through digital modeling technology.

Parametric design of industrial products, that is, taking certain elements that affect product modelling design as parameters, setting a logical relationship (i.e., algorithm) through computer software to construct a digital model, that is, the prototype of product modeling. This prototype is often multi-solution and non-quantifiable, because the adjustment of parameters can generate a series of modelling, so designers need to further screen, refine and evolve, then seek the best solutions in a large number of new forms, and finally determine the exact size to complete the design.

Compared with the traditional product design methods, the fundamental difference in logic between them is that whether a design first forms a modelling in the designer's mind or is realized by a parametric system. The advantages and significance of parametric design are mainly reflected in the following two aspects: First, parametric design allows designers to liberate from traditional hand-painted conception and model simulations, especially when designing and constructing some complex surfaces and organic forms, parametric design has natural advantage, the complex rules and algorithms become the basis of modelling design. Second, the dynamic change characteristics of
parametric model greatly improves the speed and quality of product digital model generation and modification, and realizes the close connection from product design modeling to NC manufacturing. The whole design process is fully intuitive, logical, and malleable.

4. Application examples of product serialization by Parametric design

In the field of industrial design, parametric design is often used to generate product modelling, especially complex surface modelling, and to quickly realize product serialization. When designing the same series and different types of products, product designers do not need to start from scratch, but design variants based on the existing base products in this series, which greatly improves the design efficiency, shortens the design cycle and reduces the repetitive work. Parametric design thinking and modeling technology have great application potential in the serialization design of home appliances, furniture and household items.

![Figure 1. "Digital Object/Triangulation Series" chair design project.](image)

Independent digital artist and designer Zhang Zhoujie’s “Digital Object/Triangulation Series” chair design project (Figure 1) is based on Rhino+ Grasshopper parametric design platform and the latest open source program Processing. Its core idea is to explore the formative form of digital objects. By setting up programs and optimizing logic, taking the computers as the subject, the computer can “freely” create art forms and make it possible to combine art design with digital manufacturing. This series of chairs is designed with stainless steel as material, triangle as feature elements, and sharp form showing sculpture sense and futuristic look. The form is derived from the points around a plane, which naturally extends downward under the action of gravity in a digital environment, forming a flowing arch structure. The edges, surfaces, scales, etc. seem to be different, but with the same material and approximate structural logic, it realizes the serialization of modelling. All chairs are automatically generated by computer programs according to the algorithm, and various forms can be generated by changing certain parameters. Computers become an art of morphological algorithms, and “digital creation” creates a series of subversive visual modeling languages.

5. Product series design based on Grasshopper parametric platform

5.1 Introduction to Grasshopper

In recent years, Grasshopper has gradually become a widely used parametric design software in the field of industrial design. It has the characteristics of visualization and dynamic. The parametric modeling technology discussed in this paper is based on this software. Grasshopper is a modeling plug-in based on Rhino environment, it has powerful parametric design function, the arithmetic unit is the core of it. It completes traditional manual modeling operations such as drawing lines or complex forms, moving, offset and arrays by means of data programming and automatic calculation. It automatically generates and modifies the model according to the algorithm through the way of input parameters and output results and connecting lines to visualize nodes.
5.2 General procedure for parametric design of series products (Figure 2)

5.2.1 Plan parameters: According to the research results and design positioning, we should determine the design ideas, analyse the design requirements and constraints of the design project, digitize several key factors, set the quantitation and variable as the basis for formulating the algorithm in the parametric design.

Taking the vacuum cup design as an example, the author plans to design a personalized and modern "family" series of vacuum cup – designed for men, women and children. In the style of vacuum cup, we should not only distinguish them according to the user's characteristics and use needs, but also reflect the series sense and the integrity of "family". With "water" as the design inspiration, we can extract the water ripple as the element, analyze the constraints, set the functional parameters and morphological parameters, such as the length and width of the vacuum cup prototype model, the number of curves of the water ripple, the undulation direction and height, etc.

5.2.2 Formulate algorithm (Figure 3): The logical relationship and transfer relationship between parameters are analysed, and a set of logical algorithm for controlling parameter relationship and generating model is compiled.
5.2.3 Generate model: using Rhino+ Grasshopper modeling, establishing a basic parameterized model of the vacuum cup, setting the induction points or curve, affecting the fluctuation pattern of the water ripple in the way of image interference, adjusting the parameters in the logic input or adding new parameters, various surface modelling results are dynamically generated, showing a linear trend of change (Figure 4), then getting a series of related but characteristic modeling schemes; if the model results are not ideal, return to the previous steps to modify and adjust.

5.2.4 Optimizing and evaluating: According to the natural, experiential and economic attributes of the product, develop evaluation rules and select several schemes which are closest to the design objectives from a series of models.

For example, in the optimum design process of "family" series of vacuum cup (Figure 5), combined with the characteristics and functional requirements of the three targeted groups, and considering factors such as material, technology and structure, select three types of vacuum cup forms from the series modeling schemes. Then, adjusting the details, dimensions and texture accordingly. Finally, three modeling schemes are obtained. As a symbol, "water ripple" is not only a factor that
reflects the series sense, but also has the function of anti-skid and heat insulation. At the same time, it also uses metaphorical method to reflect the specific connotation semantics – “water” cup hold water.

Figure 5. "family" series of vacuum cup

5.2.5 Verification and improvement: According to market data, user feedback, etc., summarize problems and improve, expand the series, and continue iteration.

5.3 Difficulties in the application of parametric design for series products

5.3.1 The logic operator in Grasshopper involves the basic mathematics of computational design, such as vector algebra, trigonometric function, solid geometry, etc., so designers need to have clear logical thinking ability and basic mathematics knowledge.

5.3.2 The generation system of the three-dimensional product model is complex. The key point of parametric product design is to establish a constraint model for product modeling and solve the constraint. Therefore, in the design process, the designer should analyze constraints among the many factors such as function, structure and technique, and coordinate local constraints and global constraints, set the invariant parameters, variable parameters, and the relationship between parameters, achieve the parameterization of product model data.

5.3.3 The first consideration in the initial modeling is not direct modeling, but how this form is generated, and what is the law governing its morphological changes. Designers need to use “macro thinking” to think about a unified solution to such problems, create a set of computational methods and spatial organization logic for generating designs.

5.3.4 A parametric model contains a large number of design variants, which contain a product family. Therefore, in determining the final product series, it is necessary to establish an effective, comprehensive and objective evaluation system to solve the multi-solution problem and retain the best product modelling to form a series.

6. Conclusion
The article discusses the concepts, design methods, application cases and their relations of serialization design and parametric design in the field of industrial design, and puts forward the viewpoint of using Grasshopper parametric design to realize serial design of product modeling, and
draws the following conclusions: First, parameterization can be an efficient tool and innovation source for product serial design. The characteristics of rapid generation, dynamic adjustment and convenient modification of parametric model have obvious advantages for series product modeling, revision serialization design, multi-scheme comparison and evaluation, series product renewal iteration, etc. Second, combined with the parametric design practice of the vacuum cup series, the method and process of implementing product serialization by parameterization are preliminarily summarized, and the feasibility of the method is verified, and the product design theory is perfected, which has certain application and reference value in similar serialized product development.

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