PARAMETRIC DESIGN OF A PRODUCT FAMILY

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Abstract: *Parametric design (PD) is an approach in which the parameters are set, and they are responsible for the outcome. The approach is known and familiar, but the new technologies and advancements in production are making it more applicable now.*

Parametric design is an emerging research issue in the design domain. The development of a product family requires product architectures in three domains, defining the required function, technological realization, and the physical realization. A product architecture separates the stable and the variable aspects of the design. By the proposed modeling approach, the focus of product configuration can be shifted to identification and definition of attributes instead of modules and components. It is also shown that classification is a means for identification of multiple abstraction levels.

With this paper we want to explore the possibilities to use parametric design as a tool for the design of a product family. Parametric design is an approach that can be used for design of a family of products. At the same time this approach enables fast changes and modifications in the initial design. This is a fast and efficient way for serial production products but also for creation of unique and personalized products fast.

Key words: *parametric design, product design, product family*

1. INTRODUCTION

Industrial design has a long history that started in the early 1900s, as an effect of the industrial revolution. Industries have expanded quickly because of innovation in the field of industrial design. Over the time the meaning of the term industrial design has broaden its meaning. According to the IDSA, industrial design is the professional practice of designing products, devices, objects, and services used by millions of people around the world every day…. During this process, myriad decisions are made by an industrial designer (and their team) that are aimed at improving your life through well-executed design (IDSA, 2020). Form this definition it is consequent that design of a contemporary product or service is a complex task. In the last years designers work in interdisciplinary teams in order to respond better and faster to the market demands. The advantages of the interdisciplinary teams are countless, such as: increased level of innovation (Rosenberg & Kumar, 2011), team creativity (Repko, 2012; Sanders & Strappers, 201), customer satisfaction and company profit (Norman, 2002; Akinnawonu, 2017). But main problem in this type of teams is the lack of communication. This is why methodologies and approaches that facilitate that are always welcomed.

With this paper we go with the premise that a parametric design can be used as an approach to the design of a product family. This approach can be used as an effective tool for communication in the team especially in the early design phases of form-findings.

Product family design and development essentially entails a conceptual structure and overall logical organization of generating a family of products by providing a generic umbrella to capture and utilize commonality, within which each new product is instantiated and extended so as to anchor future designs to a common product line structure (Jiao et al., 2007).

The interpretation of product families depends on different perspectives. The engineering view of product families embodies different product technologies and the associated manufacturability and thereby is characterized by various design parameters, components, and assembly structures (De Lit & Delchambre, 2003; Simpson, 2004).

1.1. 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 (Sun, 2019).
The goal of parametric design, therefore, is to add the dimensions and any other specific information needed for functionality and manufacturability. If the exact material has not already been designated, it is also chosen. To put it another way, parametric design provides all the dimensions, tolerances, and specific material information required for a design that complies with both the marketing concept and the engineering design specification.
Parametric design can be used as approach for product personalization, since one algorithm can provide multiple variations (Djokikj et al. 2022). Abdullah and Kamara (2013) propose the procedures for parametric design in order to increase the idea generation in the conceptual phase. Dean (2009) uses parametric and generative modelling to fully exploit the AM's possibilities and to offer personalized products to users.
Parametric design has few advantages that are important to the designers: design of complex geometries – organic designs inspired by the nature in various dimensions can be easily created from jewelry to bridges and automobiles (Fu, 2018); accuracy – advanced software's for parametric modeling can accurately and effectively modify any design in addition to complex shapes; time efficiency – use of algorithms improves the workflow efficiency by automating repetitive operations; hand-in-hand with manufacturing – new technologies like the additive manufacturing provide easy fabrication of the parametric designs (Djokikj, 2020).

1.2. Grasshopper

Grasshopper has increasingly gained popularity in recent years as a parametric design tool. Grasshopper is a visual editor within Rhinoceros that is a modeler for complex freeform shapes, while Grasshopper is utilized for additional mathematical modelling, or even programming (Khabazi, 2009). However, Grasshopper on its own can be used for the modelling of the whole part. Rhino uses non-uniform rational B-splines (NURBS) to precisely model geometry (Zhang & Yin 2015). With visual programming, you can algorithmically generate geometry by composing diagrams that link data to functions. Through its intuitive visual programming, architects and designers can swiftly create complex forms and make changes to multiple elements by adjusting a single value—a testament to the power of parametric design (Dai, 2016).

2. METHODOLOGY

The design process in utilizing parametric design requires different approach. In the initial design phases with the functional aspects of the product and all the design criteria, the parameters need to be determined. This means that very fast in the conceptual phase the work is converted from paper to computer. We propose the use of Grasshopper as it is relatively easy to use and still has all the advantages of the parametric design. Also it is a visual editor, so it is user friendly the designer. Once the algorithm has definite shape, the variations in the outcome can be conducted by all team members. This can increase the time for final design decision, but it is valuable step in the co-designing process.

3. DESIGN OF A PRODUCT FAMILY WITH GRASSHOPPER

As mentioned before, when designing a product family it is necessary to define the similarities and differences between the products. The similarities are the design elements that will visually connect the products and the differences has to give unique take on each product. This is why we proposed the use of parametric design and Grasshopper as a tool in the design process. Because with Grasshopper with the creation of an algorithm, the basis of the product family is determined, and the differences can be explored with the use of sliders. The result is immediately visible in the Rhinoceros, so the manipulation is easy and straightforward.

3.1. Planning parameters

Based on the research findings and design positioning, we should choose our design concepts, examine the project's requirements and constraints, digitize several critical elements, and choose the quantitation and variables that will serve as the foundation for our parametric design algorithm.

3.2. Creating an algorithm

After analyzing the logical relationships and transfer relationships among the parameters, a collection of logical algorithms for managing parameter relationships and generating models is put together, as presented in Figure 1.

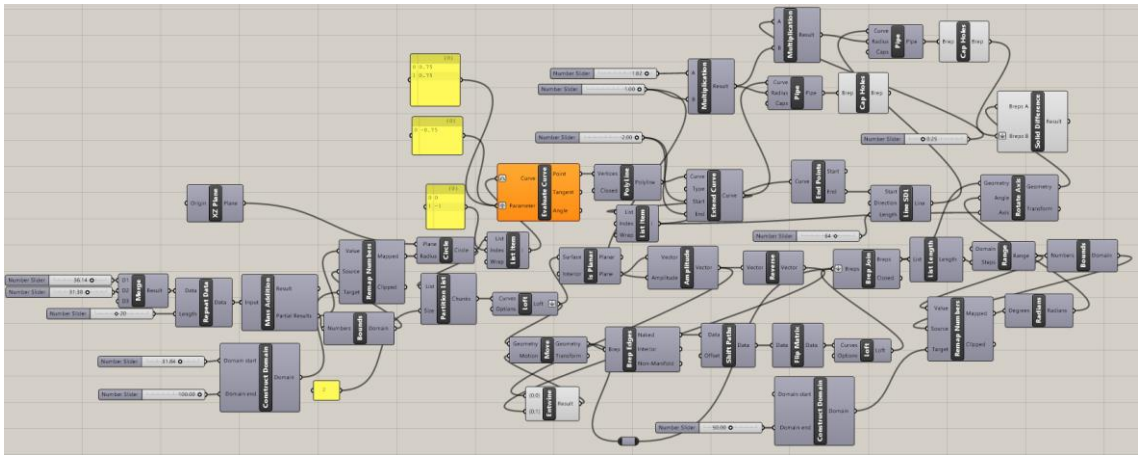

Figure 1: Grashopper alorithm for the lamp family

3.3. Design of the model

Design of the product is consisted of series of concentrically circular elements. Each element is a separate one, which means that move independently. In order to constrict the movement the circular elements are fixated in two places along the Z axis. In Figure 2, some of the variation for a celling lamp are presented. Furthermore these designs can be scaled, colored, elements can be added or omitted in order to create the whole product family.

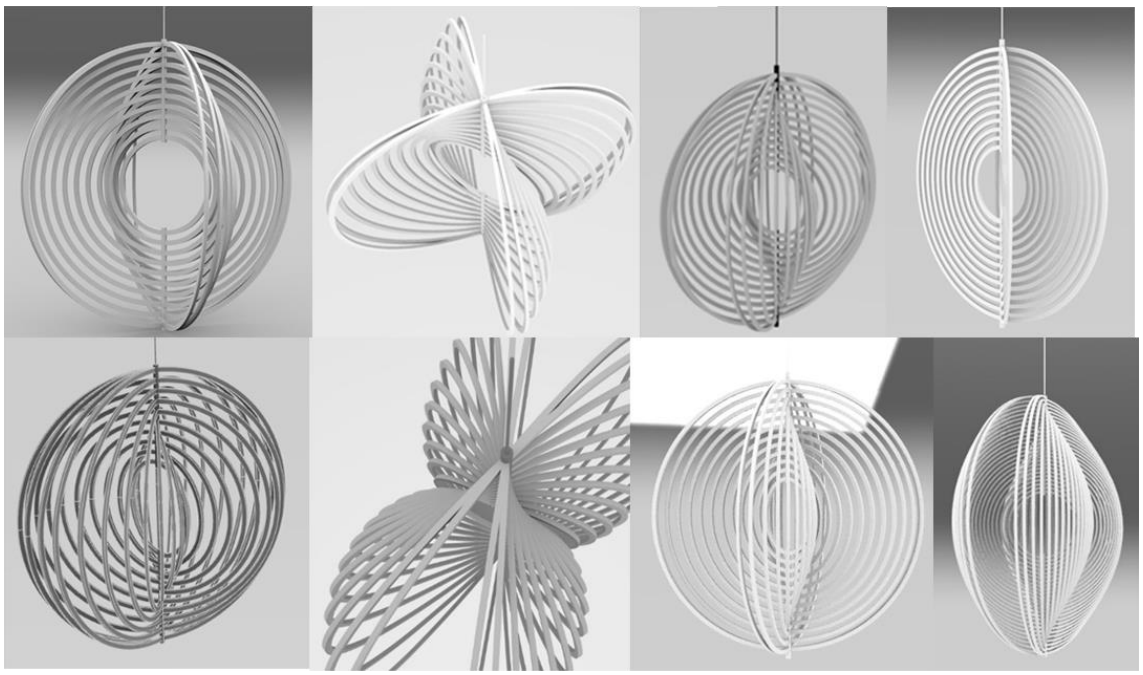

Figure 2: Different variations of one design

In Figure 3 design of one product family is presented. These designs can be explored and result in many different solutions. In the example only celling lamps are presented, but again this method can be applied for bigger product family.

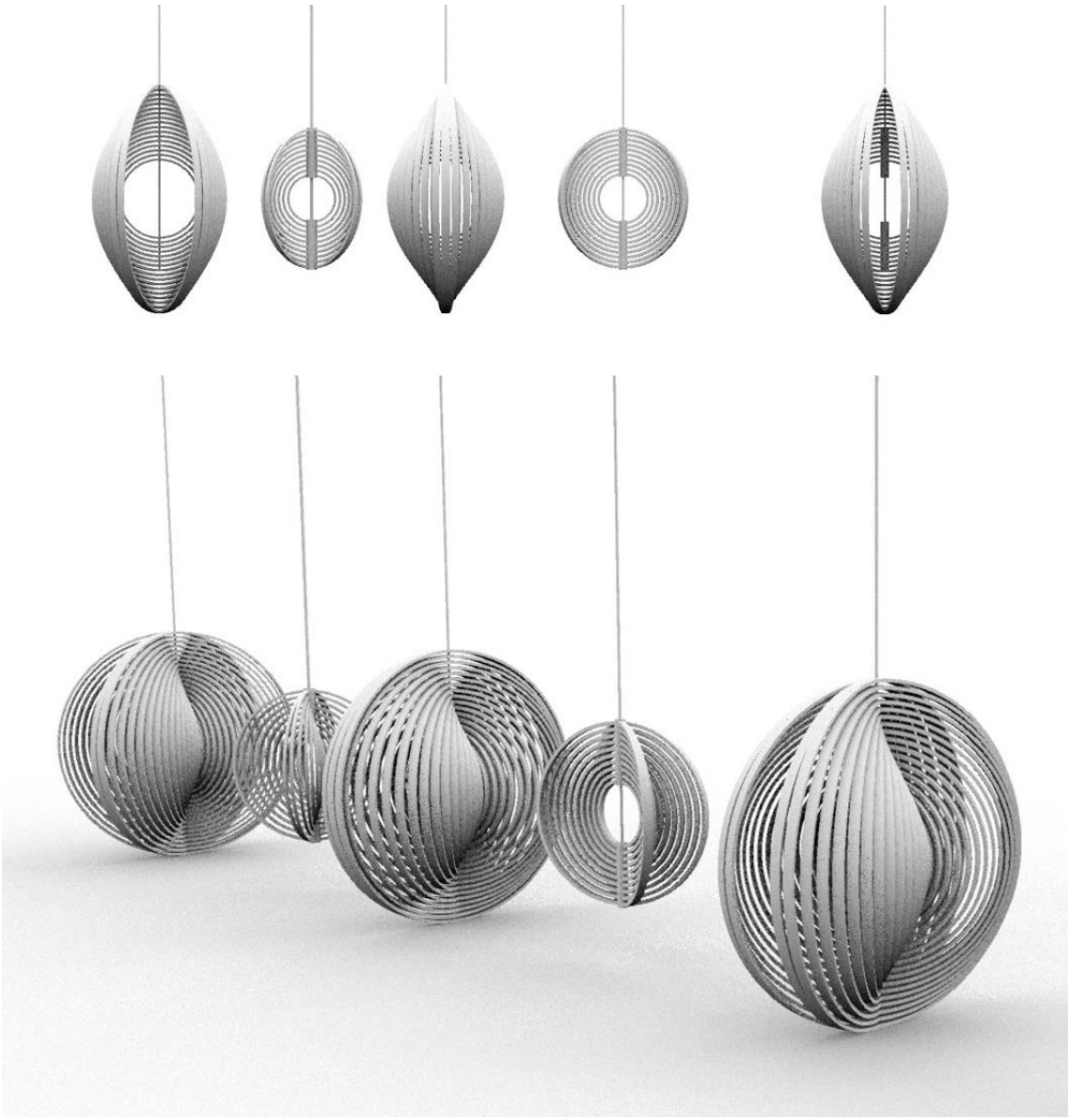

Figure 3. Design of one product family

4. DISCUSSION

The process of designing a product using parameters is challenging, it is completely opposite of the classical design process. The parametric design requires precision and detail planning of the parameters. Positioning and setting of the parameters needs to be precise, especially in the case of product family.
The use of Grasshopper can be also challenging for some designers, since it requires basic knowledge of mathematics, three-dimensional visualization, basic CAD modeling logic.
Then again, once the parameters are set and the algorithm is working properly it is pretty easy to change the design and create variations. The application of this design approach is extremely helpful for designers in the initial phases of the form-finding process or research through design. Also, it can be useful for bigger co-designing project, when many people, most of the non-designers need to intervene on the design and give their input.

5. CONCLUSION

The paper explores the use of parametric design for a product family. As a software for the design exploration Grasshopper, part of Rhinoceros, was used. The proposed methodology was applied on a one example product family of lamps.

From previously stated, it can be concluded that this approach is valuable as a tool for the new ways of designing, like co-design. Having large group of participants working on a design, without previous knowledge in 3D modeling or CAD software, can be difficult to communicate. This is where tools like the one proposed in this paper can be useful. Also, designers can exploit it in the initial design phases as a form-finding tool.
Therefore, it can be concluded that parameterization can be a useful tool and a source of creativity for a serial production of a product design. Offering the possibility for a renewal iteration, revision serialization design, multi-scheme comparison and evaluation, rapid parametric model creation, dynamic adjustment, and convenient modification all have clear benefits.
For further research, the methodology needs to be tested by applying it to a various design tasks.

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