An Experimental Study for Applying Generative Design to Electronic Consumer Products

Ming-Huang Lin and Lin-Chien Lee

National Chiao Tung University
Institute of Applied Arts, Department of Industrial Design, Taiwan
ludwiglin@mail.nctu.edu.tw, lin_chien2001@yahoo.com.tw

Abstract. This study discusses the advantages of generative design tools, real-time calculation, and easy to modify and quick to review design details, to explore the feasibility of developing new modeling methods. The discussed method uses the MacBook Pro and MacBook Air as a typical type of minimal shape to test the possibility of product refinement, users' response and the need of bridging software interfaces to a stable structure and rational limitations.

Keywords: Usability methods and tools, Generative Design, Design Process, Grasshopper.

1 Introduction

As a tool to aid design, 3D software is not as intuitive when compared with paper and pencil drawing. Due to the proficiency of designers, in most circumstances it is used to refine ideas rather than extend design. Most designers have already created the shape they have in mind, before they start the modeling phase. Through the modeling process, the features of the shape are formed in a particular view, then confirmed in perspective view. Designers are required to practice using the tool persistently until they can have enough skill to utilize the software as freely as they want, otherwise, they will be forced to compromise their original idea in this learning stage. This research explores a new generative design application for both young and experienced designers that allows them to concentrate on their design without being obstructed by the tool.

Unlike non-routine design job which requires industrial designers to propose a unique shape, the design operations involved in well-developed electronic products usually belongs to an inside-out, routine design process. This means the specification or components were confirmed by sales or engineering departments in the early stage and the designer' s job is to create an elegant skin for the device or refine the interface. Although routine design job requires less creativity than non-routine design job, designers still have to control the details of shape and develop a universal or distinct shape language in different situations.

Presently, the mainstream application of generative design is using computer programs to support designers dealing with the computation of random disorder to

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generate a shape. Grasshopper's object-oriented, extendable programming environment offers the freedom to create a wide-range of possible design solutions based on a defined solution space instead of building a final, fixed digital model. This justifies its selection as a platform. In the way we think that industrial designers can use the intuitive interface to "choose' a perfect shape according to the extension of the product development of a routine design job. Firstly, industrial designers define the shape character (product language or shape grammar). Secondly, generative designers use the visualized program to build an easy to control parametric digital model. Thirdly, industrial designers choose a generative algorithmic form as the best solution to fit the object. This gives industrial and generative designers a chance to cooperate more closely. Industrial designers can concentrate on the construction and proportioning of shape, and generative designers apply the software to facilitate the understanding of shape structure and the modeling process in order to explore the flexibility of the model, and the convenience of interface.

2 Related Researches

Generative design theories emerged in the 1970s, (Bentley and Corne, 2002) and software companies continued offering various ways of applying these methods. Generative design was widely applied to explore complicated forms and the digital generative models were used for construction, cost and environment analysis. Shea et al. (2005) indicated that generative design systems created a new design process through exploring the calculation and production capabilities of current computers to produce a novel and buildable design.

Generative design techniques have increasingly been developed in the product design research field. Singh and Gu (2012) compared five generative design techniques: cellular automata, genetic algorithms, shape grammars, Lindenmayer systems and swarm intelligence, which form background techniques, design point of view and the factor of system structure. Their research proposed an integrated generative design structure to deal with different situations, bottom up or top down design exploration, applying different generative techniques for different levels of creativity. On the other hand, Shih-Wen H. (1997), Kuohsiang C.(1998), Ling Ling C.(2003)and Ming-Huang L(2003). continuous research on shape construct, transformation and sensitivity to build up a database with 2D or 3D pictures. By manipulating the contour of 2D or 3D morphing technique and replacing method for each component in one product, database offer predicable pictures of possible designs. However, the rough data of stimulation cannot be adjusted accurately with real design situation. Generative design breakthroughs the technical problem to offer the feasibility for practical design process.

Krish (2011) took an MP3 player as an example product to propose five generative design processes. The basic theory is that designers can explore solution space through a generative design method (GDM) according to genotype, to generate varied design outcomes, and then select the most suitable phenotype or arrive at a final answer using software. The main difference between generative design method and traditional CAD system is that GD techniques focus on exploring the change of shape through controlling the parameters. It means GDM offers an extended open-end solution. In traditional CAD or CAID processes, designers need to realize an appropriate shape, then modify and refine it before structuring a digital model using 3D software, until it is as close as possible to the desired shape. If GDM is directly applied into practical product design process without the aid of a generative designer, industrial designers need to add an extending process into their original refining modeling process. Thus our research proposes a co-operative work model: Solution space is defined by the CAD system, then shape grammar and the flexible parameters are defined by industrial designer. After that, a digital model is structured by generative designers. The final design solution could be chosen by industrial designer, customer or other decision-maker.

The design process contains three parts, imagination, presentation and inspection (Zeisel, 1981). The conceptual ideas are extended and refined as a cycle repeatedly in the spiral. Krish's five GDM steps can be mapped to the spiral by extended and refined trends tendency (Figure 1). The first and third steps, 'creating the genetic model' and 'generating designs', belong to shape extend. The second and fourth steps, 'setting the initial envelope' and 'filtering phenotypes' belong to concept refine.

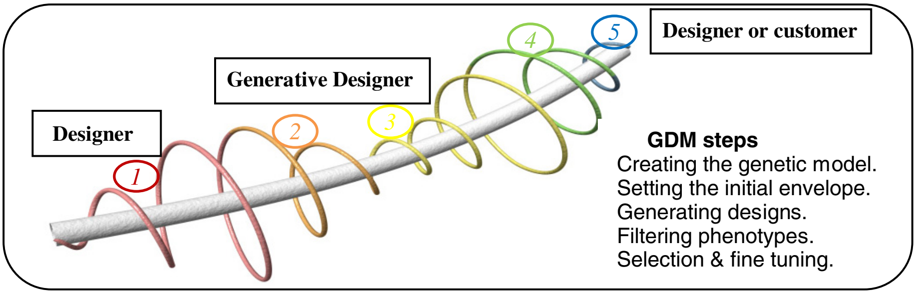

Fig. 1. GDM steps in design process spiral

Krish proposed Genoform™ as a shape refining tool in order to retain the creativity extension for designers. However, if the system requires designers to learn or construct an open-end model, then control the model to choose a solution while they are dealing with design issue, it creates a task overload. Therefore, this research proposed generative designers participate by setting the envelope and constructing generative model (the two middle steps of GDM related to refinement and extension) (see Figure 1), while industrial designers can concentrate on all possibilities of shape development.

3 Exploring and Testing

In order to see the feasibility of applying CGDM in real design situation this research carried out two interviews with managers and designers in brand and ODM companies to ensure the possibility of new process. After that, discussions with expert group were held to offer suggestions for improving and building up prototype for testing.

3.1 Interview

In order to better understand their design process, interviews with two design department managers and four designers with five years of experience from each company.

Company A is an independent company/brand. Their design process fits in with traditional CAID process. In terms of Figure 1's design spiral, the use of hand illustration retains a tendency to extend ideas, as once designers enter the 2D drawing phase the shape starts to be refined. Once in the 3D modeling phase, despite there being small corrections in terms of image (extension), the direction has already been determined in the 2D drawing phase. Both the designers believed that in a virtual space, 3D can help to confirm whether the image is like the sketches, as well as confirm problems in the configuration of components and size ratios. Even though the image is a simple straight line geometric shape, in terms of the R angle dependence and ratio evaluation or even in the consideration of space sizes, post production, and packaging, a routine design job still has a large number of creative elements. Regarding generative design and the use of generative modeling as a guide, designers would welcome any additional methods that were more efficient, allowed for greater accuracy, and helped clarify ideas, as long as they were easy to learn and did not need extensive study.

Company B has business only on internet communications ODM products. Their design proposals are created only with 3D tools because they desire their designers to have already considered details and limitations beforehand. Both experienced designers agree with the extended and refined tendency of the design spiral. However, they utilize hand illustrations or mental imaging methods then quickly enter the 3D phase for confirmation (refinement). Their first step of idea extension is therefore very short. During the proposal process, Company B's designers often make on-the-spot adjustments to the 3D model and offer more design iterations due to their customer's demands, Regarding generative modeling, the Both designers believe that if it is meant to simply define generative design as a parametric way of making adjustments to digital models in order to match the requirements of mass production, or the aesthetic demands of concept visualization, they were already doing this with Pro-E. However, they expressed a high level of interest in the dragging interface of Grasshopper if it can provide greater ease-of-use, especially if the customer or non-design related co-workers can use the program to make adjustments in the proposal or early confirmation phases, replace text suggestions with visual suggestions, and take part in discussions while offering clear information, and even more so if it allows them to directly pass their ideas to the marketing department to use as marketing tools.

3.2 Experiment

In order to testing out the feasibility of CGDM in a practical design scenario, we used the basic form of a MacBook notebook for the original generative model prototype because of its minimal, but well-defined shape. The designers required scope for appropriate creative freedom, but without the excessive burden of an overly complex shape.

Shape Grammar. The Macbook is a typical product in the current minimalist mainstream style. It is easier to control the parameter settings when compared to organic shapes with complicated curves, and as demanded by this research, reduces the complexity to the user. The basic shape is a rounded square and the characteristics of the structure characters are described as below:

1. According to the definition of the solution space, the structure is built around eight points. Each two lines controlling movement in horizontal and vertical directions.
2. The end points of two adjacent curves control the tangent continuity of the resulting corner.
3. To move up and expand the bottom curves creates the second level. It is related to the first level and is also able to adjust the height and expansion area.
4. The size of level 2 and level 3 is the same, but level 3 is higher than level 2. It can also adjust the height.
5. Top cover and main body are the mirror structures. The height of three levels can be adjusted.
6. The width of top and bottom surface from front view can be adjust independently.

CGDM Example Modeling. The Grasshopper plug-in for Rhino was used to build a Macbook-shaped generative digital model prototype as shown in Figure 2. Industrial designers will only have to adjust five parameters: Length, width, front, back view and radius, as shown in Figure 3. After finishing the whole generative digital model, as in Figure 4, the interface can be arranged according to the sequence of shape process, and users can refer to corresponding top, front, and side views, as in Figure 5, increasing users' opportunity for comparison during operation. Using these 27 parameters in total, rounded-corner quadrilateral shapes with different features for electronic products with cover can be controlled.

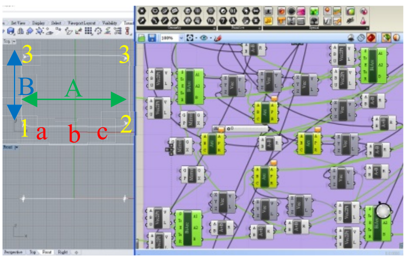

Fig. 2. Rounded square structure

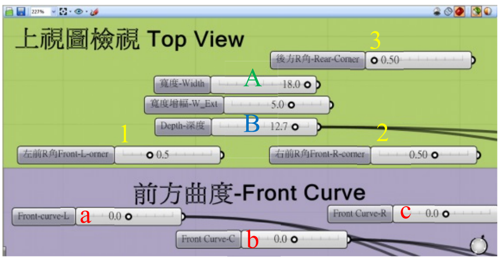

Fig. 3. Interface of rounded square

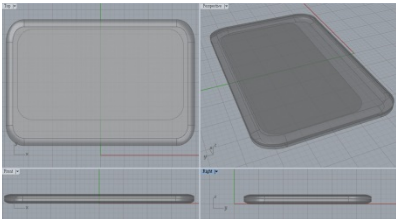

Fig. 4. main body in GD

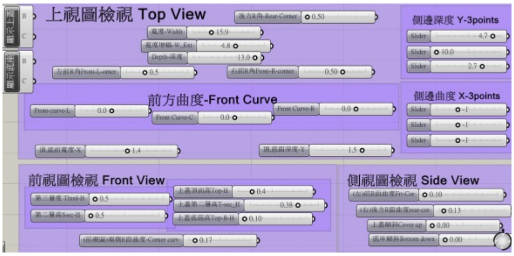

Fig. 5. Interface of main body

Similarly to the shape grammar for rounded square, keypads only need a size of Z direction. Although the advantage of generative design can be applied to the position and numbers of keypad, the human factor and user habit need to be considered. Here, the prototype only tests the usage for position, numbers and curvature arrangement (Figure 6). There are fifteen parameters in total for the keyboard, for testing. Due to Grasshopper's use of linkage as history, the detail part can be built in another file, and it can be used in any other shape once the related parameters have been linked.

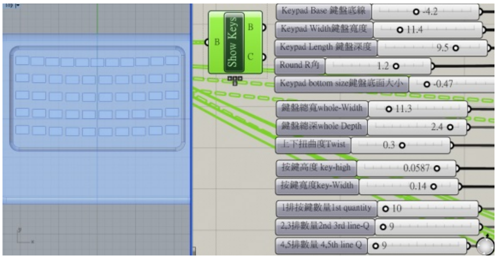

Fig. 6. Keyboard model and interface

Fig. 7. Experiment execution

Equipments. Software: Rhino as platform, Grasshopper as interface. The process was divided and arranged to fit in with three views. Only a few parameters such as length, width, height and radius, were available for each item in one view window. Subjects can use extra parameters to add details, such as making straight line became a curve. The software Camtasia Studio was used as the screen capture tool. Hardware: A MacBook was used as a hardware platform, in part to allow the subjects to use it as a reference. Also, a fifteen inch upper screen was used to extend the user window. A DV was used to record the subjects' movements, Figure 7.

Subjects. Subjects do not have to familiar with Rhino due to the interface only requiring subjects to pan and zoom camera or tilt the view to check details. However, basic graphic drawing training is required to enable subjects to easily recognize the relationship between 3 sectional views and the perspective view of 3D space. This experiment focuses on designers with some previous experience of using 3D software. 5 junior designers with less than 1 year experience, and 5 senior designers with more than 3 years experience, participated in the experiments.

Process. First of all, a ten minute introduction was given to the subjects to enable them to understand the task and interface. Subjects who had never used Rhino, had ten minutes more to practice the camera pan, zoom and tilt functions. Secondly, subjects were told that a client wanted to produce an electric dictionary that referenced the MacBook shape. Subjects need to design an electric dictionary with minimalist style, or other shape, by controlling generative digital model from Grasshopper. Thirdly, subjects got twenty five to thirty minutes to adjust the model. They could ask any questions about the interface or setting while adjusting the model and the timer would be paused. Once the question or problem was solved, the timer was restarted. No matter whether time is shorter or longer than twenty five minutes, subjects would not be disturbed until they think they had finished their design. A camera record and screen captures were taken while subjects were using the software. Finally, a post-test interview for ten to fifteen minutes was conducted.

4 Preliminary Results

1. The results from junior and senior designers was shown in Figure 8 and 9. There is no significant difference in terms of average operation time and number of adjustments. The average values collected from two groups of users are as follows:

- Junior designers: average operation time for: 25.5 minutes; average number of adjustments: 53
- Senior designers: average operation time for: 23 minutes; average number of adjustments: 42

2. Three of the participants requested to change constraint parameters in both individual group, and two junior designers created unusable shapes due to twisting or reverse radii caused by them inputting overly high or low values.
3. It can be seen from the experiment that all senior designers observe top, front and right side views to confirm the shape. Among the 5 senior designers, only 2 requested aid in finding corresponding parameters. Only 2 of the junior designers double-checked the 3 side views; the other 3 designers refer to perspective view directly, and they all encounter missing corresponding parameters when they try to adjust certain curves. This demonstrates that the original experimental model which uses a 3-side view layout to build the parametric model is generally accepted and understood by designers; however it also appears that not every designer follows the same pattern of thinking.
4. A junior designer mentioned in later interviews that the structure and corresponding parameters can be clearly found through the interface in the experiment. As a consequence, excelling in manipulating the physical model and having a strong mental model for extensity does not relate to personal experience, but personal experience does help increase the designers' control of, or mapping parameters to, shape in virtual space.
5. Although the generative prototype provides curve and asymmetric settings, two of the senior designers compared the difference of side curves and still decided to use

a straight line structure because of the beauty but not the request for minimalism, expressed during interview. The result corresponds with what experienced designers from company A expressed (see section 3.1). Even with simple geometric shapes, 3D can assist designers in dealing with aesthetic problems. In other words, the same square box with radii can lead to different opinions between designers.

6. For junior designers, one participant (Figure 9-B1) took more time, 10 of the 23 minutes total completion time, concentrating on front and side view adjustment. Only one participant used a curved shape for three sides, besides the fixed rotation axis (Figure 9- B2). In Figure 9-B3, the participant spent more time on adjusting radii.
7. One senior designer presented an expectation for three-dimensional complex surface parameters which can help in shape-form. One junior designer (Figure 9-B1) hoped to add parameters for rotating top or bottom sides.

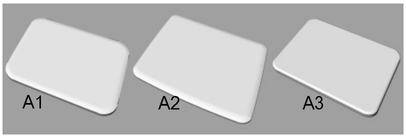

Fig. 8. Results from 3 senior designers

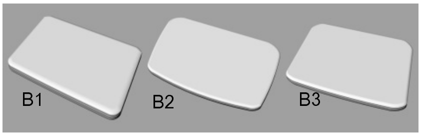

Fig. 9. Results from 3 JUNIOR designers

5 Suggestions

The advantage of the CGDM application is that the designer does not have to learn new tool, as the generative designer will be responsible for model building and calculation. For designers, the advantage is that they can focus on creativity and perception thinking. The disadvantage is that the structure is built by generative designers, so if designers want to make huge modifications, they need to rely on generative designers.

Unlike traditional generative application method, this research is focus on the availability of practical application and user interface, hoping to explore another derivative design application mode beside current calculation in outstanding shape. We proposed the generative digital model based on CGDM for experienced and young designers to take advantage of parameters to adjust the shape and test if it meets designers' wants. However, it is initial research to test practical feasibility, so further research to include different shape grammars is urged. Further testing in quality and quantity can ensure research results closer to actual design scenarios.

6 Conclusions

This research separated shape development and generative modeling as two professions. It is essential that two kinds of designers co-operate. Industrial designers need to clarify the shape characteristics and adjustable parameters, then translate it and express the shape grammar clearly in order that generative designers can offer a suitable generative model. If the generative designer can work in the stages of early design, he can understand the designer or customer's thinking or design philosophy, and increase work efficiency. In future, industrial designers must be able to understand the visualized programming of Grasshopper and develop their own generative models when they want. Generative designers can also apply the program to different products or industries when they are familiar with the software, and have sufficient modeling skills and aesthetic awareness. Moreover, developing individual software for specific product features will be a further goal of this research.

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