# COMPUTATIONAL SKETCH SYNTHESIS: ENHANCING DESIGN CREATIVITY THROUGH INTERACTIVE SKETCH MORPHING IN DIGITAL ENVIRONMENT

KYUNG HOON HYUN
[1]*Hanyang University*
[1]*hoonhello@hanyang.ac.kr*

**Abstract.** This paper identifies how Computational Sketch Synthesis (CSS) methodology can help designers improve their design outcomes. The interactive CSS introduced in this research aids designers in exploring unvisited design options through the instant visualization of gradual alternatives of design sketches. This CSS allows designers to conduct both the hand-drawn sketch (drawing production) and computational synthesis (transformation) simultaneously. CSS interactively synthesizes hand-drawn sketches from the designer and creates novel design alternatives through morphing the sketches. Also, CSS invites designers to flexibly reflect new design directions requested in the middle of the design process. The research also has both academic and professional contributions. In the interests of academia, this paper identifies a possible area in sketching where computational design synthesis can automate a traditional sketching process. In the professional realm, design professionals can progress their design processes more efficiently while exploring every iteration of different design variations.

**Keywords.** Computational Design; Design Creativity; Design Synthesis; Sketching; Digital Environment.

## 1. Introduction

Designers strategically compare their design outcome with competing products to reflect the design trends in order to create novel designs (Hyun et al., 2014, 2015). Sometimes forms and shapes of artifacts that are thought to be unrelated to the product inspire novel designs. For example, a designer can gradually combine primitive shapes, like a teardrop, with a car silhouette to explore aerodynamic forms (Chen and Parent, 1989). In car design practice, designers conduct similar process with hand-drawn sketches to derive more sophisticated design outcomes. One of the significant tasks of car designers is to generate design alternatives of their new products. To do so, car designers regularly and consistently sketch design alternatives to explore possible design combinations. Sketching is a process which helps designers visualize their thoughts and develop their design ideas. During the conceptual design process, in which the designer concentrates on generating the design idea, sketching assists the progression of

T. Fukuda, W. Huang, P. Janssen, K. Crolla, S. Alhadidi (eds.), *Learning, Adapting and Prototyping, Proceedings of the 23rd International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2018*, Volume 2, 463-470. 

design solutions, as well as knowledge acquisition and representation (Bilda et al., 2006). However, the level of intensity in the expression of design ideas and number of design alternatives generated significantly varies depending on one's expertise (Kavakli and Gero, 2001). According to Kavakli and Gero (2001), the different levels of a designer's experience in information processing influence cognitive activities based on image generation (drawing production), inspection (attention) and reinterpretation (transformation). In this respect, computational synthesis in sketching can be an ideal method to reduce cognitive processes in drawing production and transformation which ultimately bridge the gap between expert and novice designer in design alternative generations.

Thus, the first objective of this research is to analyze the design alternative generation process in both hand-drawn sketching and computationally synthesized sketching. The second objective of this research is to investigate the implication of the proposed methodology in design process. Two major tasks have been conducted to test this - developing interactive Computational Sketch Synthesis (CSS) software and conducting expert interviews. The Computational Sketch Synthesis methodology proposed in the research is a mixture of hand-drawing sketch (drawing production) and computational synthesis (transformation). Computational Sketch Synthesis methodology interactively synthesizes hand-drawn sketches from the designer and creates novel design alternatives. The methodology consists of two components: a sketch capturing function and a design synthesis function. The sketch capturing function stores hand-drawn sketches from interactive pen display to capture hand-drawing characteristics of sketching. The design synthesis function allows designers to morph and synthesize captured sketches for design exploration. two designer groups were recruited - three expert designers and three novice designers - and they were instructed to test the method. An in-depth interview was conducted to evaluate the implication of the proposed method based on the judging criteria taken from Kavakli and Gero (2001): How innovative is the design? How creative is the design? How well does the sketch fulfill design requirements? How practical is the design? How flexible is the design?

## 2. Related Works

Despite the advancement of computer-aided design (CAD), designers still use the classical method of sketching to generate creative design alternatives. According to Haller et al. (2006), the creative process is composed of two phases: 1) creating order from chaos; 2) bringing ideation to implementation. Digital programs that designers use are primarily implemented in the second phase of the creative process due to the limited support of free-form explorations (Haller et al., 2006). A quick and easy method of externalizing ideas through sketching helps designers to produce, evaluate, refine and replace ideas rapidly (Plimmer et al., 2002). According to the survey from Muller et al. (2003), sketching is used both for preparing the CAD work and during the CAD work. Their study indicated that 35% of designers are always sketching, and 90% replied that they sketch mainly for developing new design solutions in the conceptual design phase. The literature on CAD investigated the possibility of finding a method to bridge the gap between CAD and sketching by combining only the advantageous components from both areas. For example, Bae and Kijima (2003) digitally captured and projected free-hand drawn sketches on the wall, allowing designers to modify real-size large spline curves on the wall interactively. Muller et al. (2003) introduced a 3D-sketching tool that allows users to draw design alternatives in three-dimensional space with augmented reality. Haller et al. (2006), implemented free-hand sketching with a shared interactive tabletop where designers can collaborate face to face. The literature integrated hand motion quality with digital software for modification, presentation, and collaboration. However, concept design development is considered as the most crucial phase in design development (Tang et al., 2011). And yet, research on digital sketching concentrates on improving effectiveness and efficiencies of early design process by adding and digitizing on top of hand motion features rather than investigating a method to create novel design alternatives in the concept generation phase. For example, whether the designers can create modifiable or three-dimensional sketches, human designers can only create x number of design alternatives per day. However, the literature not yet investigated involves generating numerous design alternatives through synthesizing sketches. In summary, digital sketching requires an essential component, computational synthesis and free-hand motions. Hand motion is an especially critical component of freehand sketching. The use of mouse and keyboard for sketching loses the hand motion component (Muller et al., 2003). The advantage of CAD is its arrangements of essential shape components in space. Freehand drawn sketches on paper cannot be modified or transformed. On the other hand, CAD models can be translated, rotated and scaled (Muller et al., 2003). Also, a computer implemented sketch can be incorporated into CAD, Augmented reality and Virtual Reality for detailed design modification in late design stages. Thus, integrating hand motion and transformation is critical in developing a new digital sketching tools.

## 3. Methodology

### 3.1. APPARATUS

The methodology proposed in the research includes a stylus and a tablet. In this research, we used Wacom 27HD Cintiq with a resolution of 2560 by 1440, along with adjustable stand (Figure 1) for displaying the output, as well as the Wacom Pro Pen as an input device. The orientation of the stand was calibrated depending on the user. The tablet is connected to a computer (OS = Windows 10; CPU = i7-7700; GPU = 1070; Memory = 32GB).

Figure 1. Apparatus Setting (Cintiq on the left; adjustable stand on the right).

### 3.2. COMPUTATIONAL SKETCH SYNTHESIS METHODOLOGY

The Computational Sketch Synthesis (CSS) methodology incorporates free-hand sketching and computational design synthesis. A system overview is shown in Figure 2, which represents an essential component of CSS. The system is written in Python. The system allows users to sketch design ideas freely on a display and computationally synthesize new designs based on the sketches. Therefore, the CSS consists of two features: sketching and synthesizing. First, it captures free hand-drawn sketches from users and captures stylus's x and y coordinates and draws a curve. Users can also choose between two different drawing modes; pencil or pen mode. Just like the designers' finalize sketches, CSS users can practice drawing with pencil mode. The pencil mode is depicted in blue. After practice, the users can complete the drawing through pen mode in black color. Thus, CSS consists of all the qualities that the digital sketching needs to capture the quality sketches by the users. Another feature of the computational sketch synthesis methodology is the synthesis of new designs by morphing two-dimensional representations. Once the users finalize the sketch, users can synthesize the sketch with existing designs or previously created sketches.

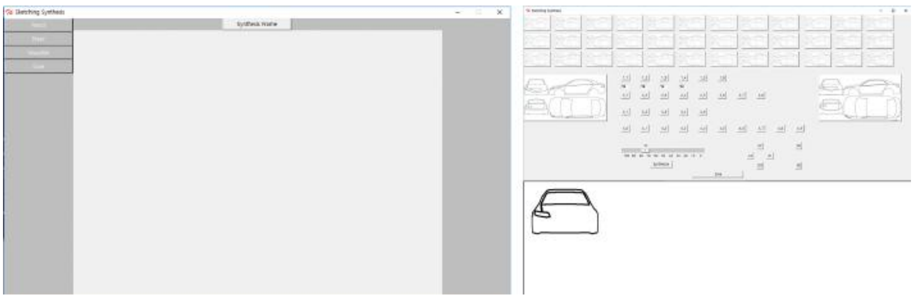

Figure 2. Computational Sketch Synthesis Software Components (sketching frame on the left; synthesis frame on the right) .

## 4. Implementation

CSS consist of two essential frames: a sketching frame and a synthesis frame. A user needs to start from the sketching frame. As shown in Figure 2, the sketching frame has a rectangular white canvas in the center, a pen/pencil button (input mode), a save button, erase button, visualize button, and a synthesis frame button. The default input mode is pencil. The pencil mode outputs drawings in cyan for simulation sketches, and the x and y coordinates are not stored. The pen mode, on the other hand, is used to finalize the sketches and the drawing data is kept as the series of black points. Once the user is confident with the practiced sketches, the user needs to switch the pencil mode to pen mode to complete the sketch. When the stylus first touches the display, an empty red ellipse is drawn to guide the user to complete the curve at the starting point. If the current location of the stylus is near the starting point, the curve automatically closes, and the input mode changes to pencil mode (Figure 3). The closed curve is then interpolated with N number of equidistant points and, in this case, it was 1500 points to increase accuracies when transforming the curve into harmonics. If the user is satisfied with the sketch, the save button stores the interpolated points. Otherwise, the erase button deletes the sketch and clears the canvas.

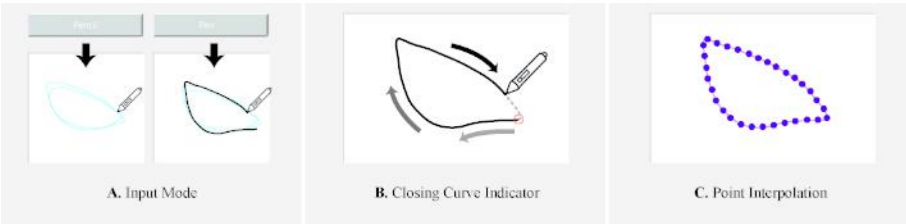


Figure 3. Detailed Descriptions of Sketching Frame.

The synthesis frame button on the sketching frame leads to synthesis frame. The synthesis frame consists of three sections (Figure 4). The top part includes the image list of previous sketches and existing designs. Users can choose the designs for synthesis by selecting the images. The first selected image is then loaded on the left side of the middle section of the synthesis frame and the second image to the right side. In the center of the synthesis frame, there are 29 numerical buttons, a slider, four directional buttons and two scaling buttons. The 29 numerical buttons represent 29 design elements. By clicking each button, a user can select specific design elements to transform and synthesize sketches and visualize the outcome on the bottom of the synthesis frame. The directional buttons can translate the position of the design elements. The scaling buttons change the size of the design elements. The slider defines the percentage of similarity of the morphing of the sketches on the left and right sides. The morphing is based on Fourier Decomposition of the closed curve which is expressed as a series of points. User's sketch can be interpolated with sketches of existing designs through morphing. Figure 5, for example, visualizes the interpolation of front headlight design from Infiniti M 2013 to a sketch from a user. In this respect, novel designs can be explored and synthesized.

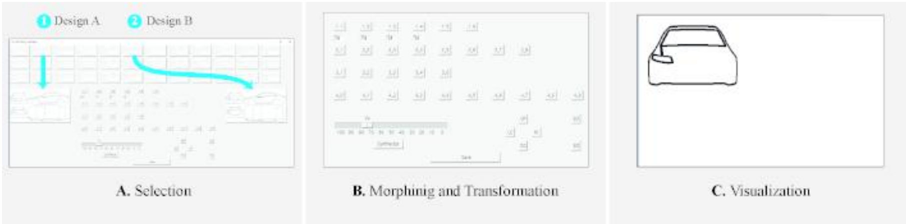


Figure 4. Detailed Descriptions of Synthesis Frame.

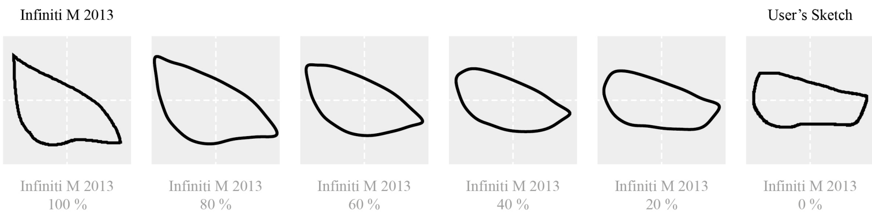


Figure 5. Interpolation of the Headlight Design from Infiniti M 2013 and User's Sketch.

Designers were recruited to participate in an experiment to evaluate the implication of CSS in practice (three expert designers with over three years of industry experience, and three novice designers with less than one year of industry experience). Approximately 30 minutes of the tutorial session was given to the designer to become familiar with the prototype. Then the designers tested the potential implementation of the proposed methodology by creating design alternatives (Figure 6). The most useful feature that designers mentioned was the ability to synthesize sketches of existing designs and previously saved sketches. Therefore, they were able to check the interpolations between the newly sketched design with competitor's designs in the market. With the synthesis feature, designers were able to flexibly converge the two designs. Through this feature, they were able to explore design variations rapidly and evaluate the potential of the new design that they had just sketched. Therefore, the experiment participants were able to make effective managerial design decisions during the early design stage.

Figure 6. Computational Sketch Synthesis in Use and a Sample Sketch.

## 5. Conclusion & Future Work

This paper identifies how Computational Sketch Synthesis can help designers to improve their design outcomes. The interactive CSS proposed in this research aids designers in exploring unvisited design areas through the instant visualization of gradual alternatives of design sketches. Also, CSS invites designers to flexibly reflect new design directions requested in the middle of the design process. The research also has both academic and professional contributions. Academically, this paper identified a possible area in sketching where computational design synthesis can automate the traditional sketching process. In the professional arena, design professionals can progress their design processes more efficiently by exploring every iteration of design variations. Thus, Computational Sketch Synthesis software opens up new possibilities for generating creative design alternatives during the concept design process. Currently, we are starting a formal evaluation of CSS. The objective of the evaluation is to identify how CSS used in the early design stage can impact the quality of final design outcome in design practice.

## Acknowledgement

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government (MSIP; Ministry of Science, ICT & Future Planning) (NRF-2017R1C1B5018240).

## References

Bae, S.H. and Kijima, R.: 2003, Digital Styling for Designer: In Prospective Automotive Design, *Proceedings of Virtual Systems and Multi Media 2003*, 546-553.

Bilda, Z., Gero, J.S. and Purcell, T.: 2006, To sketch or not to sketch? That is the question, *Design studies*, **27**(5), 587-613.

Chen, S.E. and Parent, R.E.: 1989, Shape averaging and its applications to industrial design, *IEEE Computer Graphics and Applications*, **9**(1), 47-54.

Haller, M., Brandl, P., Leithinger, D., Leitner, J., Seifried, T. and Billinghurst, M.: 2006, "Shared design space: Sketching ideas using digital pens and a large augmented tabletop setup." Advances in artificial reality and tele-existence (2006): 185-196., *Proceedings of ICAT 2006*, Hangzhou, China, 185-196.

Hyun, K.H., Lee, J.-H., Kim, M. and Cho, S.: 2014, Style analysis methodology: identifying the car brand design trends through hierarchical clustering, *Proceedings of CAADRIA 2014*, Kyoto, 327–336.

Hyun, K.H., Lee, J.-H., Kim, M. and Cho, S.: 2015, Style synthesis and analysis of car designs for style quantification based on product appearance similarities, *Advanced Engineering Informatics*, **29**(3), 483-494.

Kavakli, M. and Gero, J.S.: 2001, Sketching as mental imagery processing, *Design studies*, **22**(4), 347-364.

Müller, F., Pache, M. and Lindemann, U.: 2003., Digital free-hand sketching in 3D-a tool for early design phases, *Proceedings of ICED 2003*, Stockholm.

Plimmer, B. and Apperley, M.: 2002, Computer-aided sketching to capture preliminary design, *Proceedings of AUIC 2002*, 9-12.

Tang, H.H., Lee, Y.Y. and Gero, J.S.: 2011, Comparing collaborative co-located and distributed design processes in digital and traditional sketching environments: A protocol study using the function–behaviour–structure coding scheme, *Design Studies*, **32**(1), 1-29.