INVESTIGATING THE COGNITIVE BEHAVIOR OF GENERATING IDEA SKETCHES

Neural network simulation

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Abstract. In idea sketches, there are a number of ambiguous shapes. Designers will associate and transform some shapes into others (Liu, 1993). Then, they evaluate these shapes in terms of functions and design requirements; furthermore, they would have generated other shapes that certified the design requirements (Huang, 1999). However, not only is the idea of design composed of one element, but also consisted of varied components. The purpose of this paper is to investigate how designers generate ideas of multi-component products, and to simulate this phenomenon by neural networks. At the same time, this paper attempts to study the design cognitive behavior of idea-generating stages, and explores the designers' cognitive phenomenon. Therefore, there are two stages in this paper: First, I conduct a cognitive experiment to realize how designers generate the multi-component product and acquire the sketches that designers generated. Second, I train the neural networks to simulate the behavior of idea generation and explore the cognitive phenomenon in design sketches. As a result, networks associate one shape that trained before, and then generate a complete idea. This phenomenon is similar to the cognitive behavior of designers who saw the ambiguous shape as one shape, which was retrieved from LTM. Moreover, the neural network is examined by a rectangle, which is totally different from the training patterns. The network will associate a confused shape. But the network will associate different shapes by adjusting some critical parameters. Designers can generate variable shapes from one shape, but the signal neural network can't simulate this kind of behavior. On the contrary, this paper proposes five sequential networks to generate variable shapes from the same shape and simulates how designers develop ideas.

1. Related Works

Design problem is one kind of "seeing-moving-seeing" processes, where seeing is a very important activity (Schön and Wiggins, 1992). Therefore, some researchers try to transfer the issues of seeing activities from physical visual cognition into the design thinking. Goldschmidt (1991, 1992, 1994) explored the designers' visual behavior from idea sketching by using protocol analysis. Recently, more researchers discover that idea sketching is the most important and creative behavior in the design activities. Then, some of them discuss the structure of sketching behavior (Verstijnen et al., 1998; Kavakli et al., 1998; McGown et al., 1998; Purcell and Gero, 1998).

In the recent studies concerning the processes of idea sketching, a study, conducted by Scrivener and Clark (1994) who recorded the sketching processes and inspected them by playing the video backward, showed that the processes of idea sketching were generated part by part. Moreover, Manolya et al. (1998) advanced the process of idea generation, in which designers, first of all, decomposed the design subject and drew the sketches by the steady order. Meanwhile, Verstijnen et al. (1998) proposed that a complex junction was combined by components, which transformed with each other. Each component fixes others by essentially transforming.

In addition, Goel (Liu, 1995) claimed that there are two major activities in the sketching: "Lateral transformation", a transformation from one idea to another, and "Vertical transformation" in which designers developed more detail sketch than previous one. The lateral transformation was occurred in the preliminary stage of idea generation, in which the idea was fragmented; the vertical transformation was generated in the detail-design stage.

On the other hand, in the area of visual cognitive behavior simulated by computer, symbolic systems can't simulate how people recognize the shapes and associate from one shape to another. However, neural networks can manipulate this kind of simulations (Coyne and Newton, 1989; Liu, 1993, 1995, 1996a, 1996b; Rueckl et al., 1989). Moreover, neural network also can recognize incomplete shapes and retrieve some attributions of shapes from long-term memory (LTM).

2. Problem Statement and Objective

In idea sketches, there are numbers of ambiguous shapes. Designers will transform and associate from some shapes into others (Liu, 1993). Then, they have evaluated these shapes in terms of functions and design requirements. Moreover, they will generate other shapes certifying the design requirements (Huang, 1999). However, not only is the idea of design composed of one element, but also consisted of varied components. What is the process that designers generate one sketch combined by multiple components? And how can the computer simulate this kind of behavior?

The objective of this paper is to investigate how designers generated ideas of multi-component product, and to simulate this phenomenon by neural networks.

At the same time, this paper tries to inspect the design cognitive behavior of the idea-generating stage, and to explore the designers' cognitive phenomenon.

3. Methodology and Steps

The process of generating multi-component product by designers is decomposing the subject of design, generating each part of the idea, and then constructing a more integrated sketch. Each part of the sketch was generated by designers who saw previous shapes that they drew. In addition, each part of the sketch can match with among of them. Finally, there is a complete, but rough idea.

There are two stages of this paper: First, I conduct a cognitive experiment to realize how designers generate the multi-component product and to acquire the sketches that generated by designers. Second, I train one set of neural networks to simulate the behavior of idea generation and explore the cognitive phenomenon in design sketches.

3.1. COGNITIVE EXPERIEMENT

In the cognitive experiment, the subject is "moka pot". In order to avoid the different definitions of each part of the subject, I detach the "moka pot" by each component and assign names for each component. Prior to the experiment, I illustrate the structures and functions of each component of the "moka pot" and make sure that each participant is familiar with the subject. By the way, I emphasize the integration of ideas, and not the detail design. Each participant generates 4 idea sketches on the A4 paper. During the design process, there is a camera which recorded the entire process for observing the idea generation. There is no limitation in the experiment until the participant has finished.

Participants - there are four undergraduate students who study industrial design in National Yunlin University of Science & Technology, and four graduate students who study in industrial design group, Institute of Applied Arts, National Chiao Tung University. Each of eight participants, who had educated for more than five-year professional drawing, at least, generates idea sketches of the experiment; eventually, I determine 12 sets of more complete sketches, which were the training patterns of neural networks.

Experimental process - 1.By illustrating the structure of the moka pot and the each function of components, I make sure that each participant realize that the subject of design and the objective of the experiment. 2.Each participant generates idea sketches on the papers which I prepared. During the experiment, I claim that each participant should draw the side view of the idea, which can train the neural networks. 3.While the experiment processed, the camera records the sequence of idea generations.

Results of the Cognitive Experiment

Thus, in the experiment, it is evident that designers defined a concept of the design in the original step of the sketching, and then produced the idea generation. Like the result that advanced by Scrivener and Clark (1994), designers generated the idea sketches part by part, but the sequence of idea generations produced by different designers is different than others. After arising one concept of the design, designers initiated the first part of the idea; then, by examining the first shape on the paper or thinking the original concept retrospectively, they drew the second part of the idea. But after drawing the second part, the sketch on the paper was including the first and second parts. By means of the combined sketch, designers will produce next parts of the idea by reviewing all parts on the paper, which they had drawn. Moreover, third part, fourth part, and so on. Finally, here comes a complete sketch of idea generation (Figure 1.). The process is similar to the phenomenon that proposed by Schön and Wiggins (1992), "Design is a seeing-moving-seeing process".

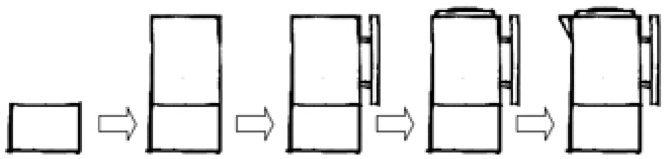

Figure 1. The process of idea generation.

Meanwhile, during the idea generation, participants intend to thinking by the concept which they defined; therefore, they produce each part of the sketch, each of which corresponded with the purposed concept and fit each other in shape. Like the outcome which was advanced by Verstijnen et al. (1998), in the idea generation designers were influenced by not only the original concept but also some parts of the sketches they had drawn on the paper.

Furthermore, not only is the side view used to presenting the profiles of the idea, but also other views--top view, perspective view, and so on—are used to projecting the conception, even using shadow, materials, and detail features. In order to train the neural networks, I intend to use only the side view. Therefore, other behavior in the sketching will not be concerning in this paper.

3.2. TRAINING THE NEURAL NETWORKS

According to previous experiment, the process of idea generation is a "seeing -moving-seeing" process. Therefore, I condense the process by illustrating Figure.2. Before sketching designers will arise one concept of design, and then produce all parts of the sketch. During the sketching process, whether all or some parts of the sketches drawn by designers will be saw recurrently. Finally, designers accomplish a complete idea.

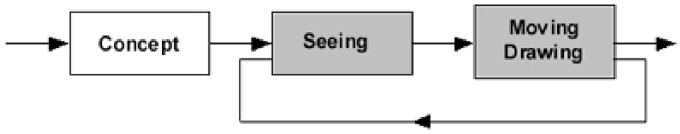

Figure 2. The process of "Seeing-Moving-Seeing".

While training the neural networks, the "seeing" step of designers is as importing the shapes into the networks, which seen by them; the "moving", or "drawing", step of designers is as propagating the shapes' information between the networks, and then generating new shapes, which included previous and new-generated ones (Figure.3). Following the circulation, there is a complete shape which was generated by networks eventually.

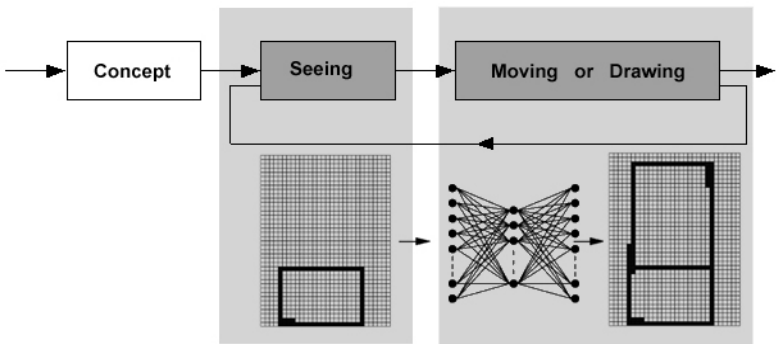

Figure 3. The relationship between "Seeing-Moving-Seeing" and neural networks.

3.2.1. Training Patterns

After the cognitive experiment, I determined 12 sets of completely idea sketches, which were used for training the neural networks. Each complete sketch includes 4 steps of "Seeing-Moving-Seeing" processes; therefore, there are 48 pairs of training patterns in the network. In terms of efficiency, the network was separated into 4 sub-networks—Bottom to Body (Figure 4.a.), Body to Handle (Figure 4.b.), Handle to Hood (Figure 4.c.), and Hood to Beak (Figure

4.d.) —each of which trained by 12 pairs of sketches and generated 4 steps of idea generations separately.

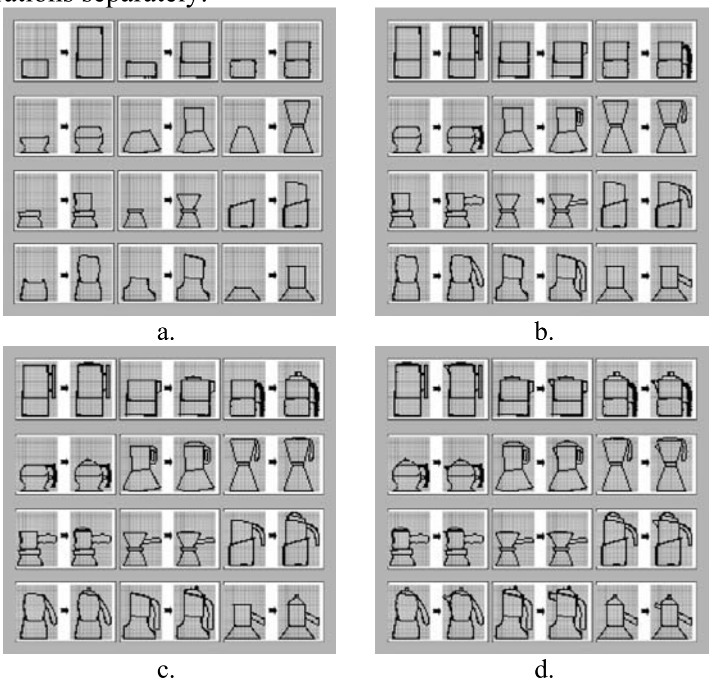

Figure 4. The training patterns of 4 sub-networks.

The processes of acquiring training patterns are several steps: 1.Scaning the sketches, which drawn by designers in the cognitive experiment, into the computer and dividing each complete sketch into 5 steps, like figure 1. ; 2.Saving the sketches as 30x40 bitmap format by using Photoshop v5.0; 3.Programming a encoding program by Visual Basic v6.0, which transfers all sketches into binary data for training networks, and a decoding program which transfers the binary data, which were generated by networks, into bitmap format pictures, which were presented by 10-level grayscale.

3.2.2. The Structure of Neural Networks

The purpose of the neural networks is simulating how designers saw shapes from the sketches and generated new shapes. In order to achieve the aim, these networks are multi-layered networks which adopted the "back-propagation" method. There are 4 networks, mentioned above. First one was input by one shape which was acquired from the sketches and encoded by the encoding program. After generating one set of numeral data by first network, the next one received the numeral data, and generated next data (Figure 5.). Therefore, the set of networks will produce the process of idea sketching. Each set of numeral data can transfer to bitmap picture, which indicates each step of sketching behavior.

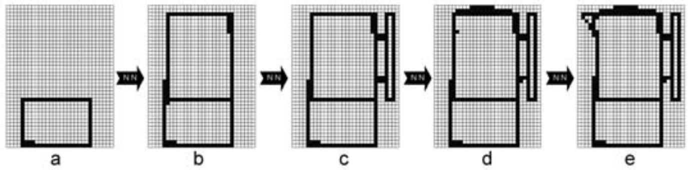

Figure 5. The structure of simulating idea generation.

The structure of networks - the networks, which adopted bitmap representation (Hinton, 1989), transfer one shape to another. The input and output nodes use 30x40 matrices, 1200 nodes; on the other hand, the hidden layer use 600 node.

Simulating conditions - Each network is a 1200-600-1200 neural network. The learning rate is 0.1; the total error is 0.05.

4. Remarks

After training the four networks and testing the reliability by training pattern, the set of networks can generate a complete sketch (Figure 5.) such as designers did. Furthermore, the networks will be tested by one similar shape and one distinctive shape.

4.1. THE EXAMINATION OF SIMILAR SHAPE

In this examination, one similar shape (figure 6.a), which was not included in the training patterns, tested the set of networks. Although the similar shape did not train the networks, the set of 4 networks will produce a complete sketch (figure 6.) by following the training structure. In the process of sketches, the first network generated an ambiguous shape (figure 6.b); however, the second, third, and latter network generated more distinct shape than did the first one. By the way, the sketching process is similar to one other process, which tested by a training pattern (figure 7.).

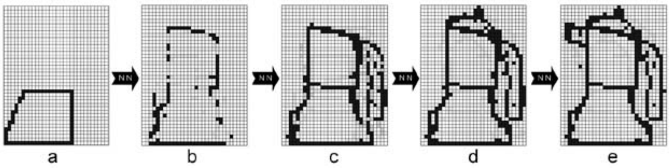

Figure 6. The result of the similar-shaped examination.

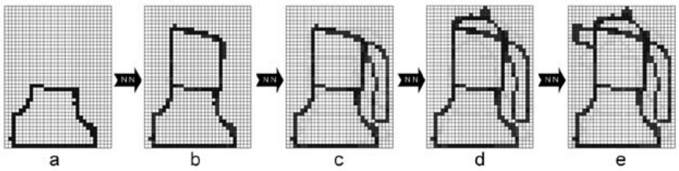

Figure 7. The process of one training pattern.

According to the similar-shaped examination, this simulation is similar to the behavior of idea sketches. Designers will draw some obvious and unobvious shapes in the preliminary sketches. Prior to generating next part of the idea, they will see either one obvious shape, which designers could recognize, or one unobvious one, which was "seen as" a more complete shape from long-term -memory (LTM). Furthermore, they produce a complete sketch.

Between the similar shape (figure 6.a) and the training pattern (figure 7.a), we can perceive some identical feathers, like the slant of left-up corner and orthogonal shape of right-up corner. Therefore, it is predictable that both idea generations are alike.

4.2. THE EXAMINATION OF DISTINCTIVE SHAPE

The networks are examined by a rectangle which totally different from the training patterns (figure 8.a). The first network will associate a very ambiguous shape, which can't be used for next network (figure 8.b). However, I set a critical parameter, tolerance of stronger level (TSL), which is simulating the "see as "action of visual cognitive behavior (Goldschmidt, 1991, 1992, 1994). While the network was input by a distinct shape, the network generated a hardly usable data for next network. The meaning of STL is adjusting each nodes of output layer by a range from 0.9 to 0.1 - for example, if the shape generated by the first network cannot be detectable, we can set the TSL to lower value. Suppose each node of output layer is the same as the TSL value which we set.

All of them will be adjusted to 0.9 value. - The lower the value of TSL, the more obvious the shape.

Designers can see an ambiguous shape as a more complete one, which was retrieved form LTM. On the other hand, the networks also can associate different shapes by adjusting TSL, and then they produce two distinct processes (figure 8. and 9.).

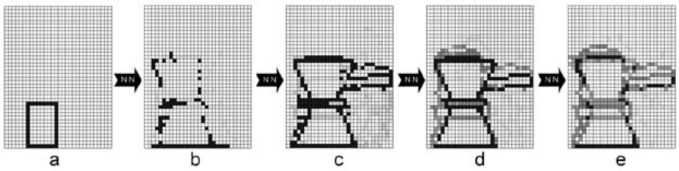

Figure 8. The process of distinct shape (TSL=0.3).

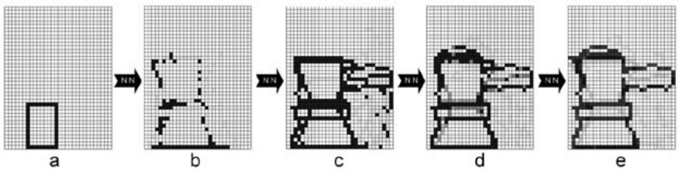

Figure 9. The process of distinct shape (TSL=0.2).

In the result of the examination, it is too hard to explain how the rectangle can produce these different sorts of idea generations. Designers can "see as" distinct shapes from the same shape and produce different sketches. The mean factor is that designers can see one shape as diverse ones and associate with variant ideas. Practically, signal neural network can't simulate this kind of behavior. On the contrary, by means of TSL, the set of networks can produce different idea sketches from the same shape as designers did.

5. Conclusions

The target of this paper is to investigate how designers generated ideas of multi-component product, and to simulate this phenomenon by neural networks. At the same time, this paper tries to inspect the design cognitive behavior of the idea-generating stage, and to explore the designers' cognitive phenomenon.

According to the first examination, this simulation is similar to the behavior of idea sketches. Designers will draw some obvious and unobvious shapes in the preliminary sketches. Prior to generating next part of the idea, they will see either one obvious shape, which designers could recognize, or one unobvious one, which was “seen as” a more complete shape from LTM. Furthermore, while producing next part of sketch, they also consider the integral sketch in terms of each shape. The ability of shaped associations is the crucial factor of idea generations. Thus, different designers, who saw the same shape, will produce distinct sketches.

In the result of the examination, the set of networks can produce different idea sketches from the same shape by adjusting TSL value. This phenomenon is similar to the cognitive behavior of designers, who see the ambiguous shape as one shape retrieved from LTM. The mean factor is that designers can “see” one shape “as” diverse ones and associate with variant ideas.

This paper is investigating the sketching behavior in the idea generative phase. Therefore, the paper did not discuss other behavior in different phases of design process. In the design process, the primitive ideas in sketch have most important effect then in other phases of design process. The expert designers will generate more speedy and quality ideas than novices do. Consequently, trying to realize the behavior of shape association and to simulate by neural networks will make computers generate more variable shapes. Meanwhile, combining the relative knowledge of design with computers, they will create more reliable idea that could be used by designers, ultimately.

Acknowledgments

Thanks to the crucial advises from my conductor, Professor Y.T. Liu, who usher me into the computer-aided design’s field, and to these 8 participants who finished the cognitive experiment, the paper had done eventually.

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