A FUNDAMENTAL STUDY ON ANALYSIS OF INTERACTION BY SKETCHES AND ACTS OF CREATIVE DESIGN IN ARCHITECTURAL DESIGN PROCESS

Focusing on emergent shapes

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Abstract. One of the characteristics of design process in the area of architectural design is the use of a number of different types of sketches. Designers place a great deal of emphasis on sketches often because it is thought to be associated with innovation and creativity. The emphasis has come to drive researchers to increasingly focus on sketch and its role in designing. Firstly, this paper is to review closely related researches that have looked at the role of sketches in design process. And then, this study is to review analogy and emergence that can be effective in facilitating creative design. Mutational emergent shapes are introduced in the last stage.

1. Introduction

Since the publication of Simon's Problem Solving Theory, research work on creative design behavior of human being and the design process has long been active in the architectural design area and other domains of science. Especially in nowadays, under reinforced by the theory that design thinking process is computerized more precisely in view of cognitive psychology, research activity on visual thinking is very brisk in the field of design. As a tool of visual communication and useful medium of conceptualizing creative design ideas in cognitive thinking process, sketches and drawings extended much help to designer's creative thinking by visualizing the designer's idea externally throughout the design process, and these facts have been demonstrated by means of various series of experiments.

Moreover, A growing number of researchers in architectural design and other areas such as mathematics, physics, and biology are found using the

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sketches, drawings and diagrams for embodying and developing their ideas in the research process. In other words, they play an important role in external representation, and as a result this means that they are helpful to creative thinking.

This research looks into the cognitive thinking process in which visual thinking exercise enormously influence on creative design behavior through the external representation such as sketches and drawing. Efforts are also devoted to developing a design process suitable to it.

This paper will make a four-stage approach to the subject matter as follows: The first part will review literatures related to the view of cognition and go over the cognitive mechanism between sketches and drawing behavior and design thinking. The second part is to discuss a cognitive thinking process in which designers find creative new shapes by means of sketches or drawing. The third part is to review analogy and emergence that play a significant role in generating creative design thinking. In the last stage, we look into the emergent shape that can be effective in facilitating the creative thinking of design by using re-interpretation and re-representation through sketches. In connection with this, mutational emergent shape, considered a new type of emergence that has not been found up until now, will be introduced.

2. Literature Review on sketches and acts of creative design

Goldschmidt divides the design process into 'moves' and 'arguments'. And Arguments within moves can be of two types – 'seeing as' and 'seeing that'(Purcell and   Gero, 1998). 'Seeing as' is directly linked to sketching because it involves the designer in 'seeing' figural properties in the sketch, that is in reinterpreting the figural interpretation of the sketch. Arguments are non-figural statements about design. Analysis of the design protocols revealed that 'seeing as' and 'seeing that' arguments alternated and further that all 'seeing as' arguments were made while sketching and 'seeing that' statements were made both while sketching and while examining a sketch.

That is to say, Goldschmidt argues that this dialectic between the two types of argument and their relationship to sketching allows the designer to interact with sketches.

Schön and Wiggins presented a similar view of the role of sketching in architectural design. They suggest that sketching presents as visual display which can potentially be perceived in different ways by designer and can be reinterpreted (Schön and Wiggins, 1992). For example, designer can look at the potential elements which are included in the sketches and drawings and then, seeing them again, they advance their design plans. This means that designer can detect new shapes after getting perceptual re-interpretation.

Schön and Wiggins defined that this kind of perceptual re-interpretation is 'moving' and the meaning of judgment about the results and of internal re-interpretation is 'seeing'. They assert that design thinking is the sequences of 'seeing -moving - seeing'. This process allows designer to embody their knowledge which can be solved the ill-defined problems with conscious thought.

Goel analyzed the drawings at the phase of problem solving in the design process in detail. First, he mentioned that the drawing moves from unstructured sketches to more precisely and explicitly drawn representations. Second two types of transformations can be identified in the drawings. They are lateral transformations where there is movement from one idea to a different idea and vertical transformations where one idea is transformed into a more detailed form. The lateral transformation occurs in the preliminary design phase and is associated with unstructured sketches while vertical transformation occurs during the refinement and detailed design phases and is associated with more detailed and precise drawings. He argued that sketching constitutes a particular form of symbol system, which is characterized be syntactic and semantic denseness and by ambiguity, and it is these aspects of sketching which allow lateral transformation to occur (Goel, 1995; Purcell and Gero, 1998).

3. Cognitive thinking process through re-interpretation

As mentioned above, not only does the external representation like sketches represent the designer's thinking externally, but also it makes possible visual thinking. In short, sketches induce the internal shapes and knowledge in addition to external shapes and play a vital role in assisting designers to turn to other new dimensions of thinking and they also function as a medium of interaction between sketches and designer. And as insisted by Schön and Wiggins, such interactions occur throughout design process recurrently.

The process starts from seeing sketches. Seeing the sketches is simply not 'seeing something'. It should be a broad observation of various and complex work(Herbert, 1993). Designers can use sketches to retrieve the images and shapes used in other designs and turn out entirely different fresh ideas.

The new information obtained through sketches is interpreted by designers and then interacts with cognitive thinking of designers. Subsequently, the information is re-interpreted through the same process to get new information as much as possible. The re-interpretation or restructuring is generated by an attempt to find out the new trends of ideas through sketches. The continuous compounding of these processes helps designers produce the creative thinking.

4. Design thinking process based on Analogy and Emergence

This study has looked into how sketches including visual cue would bring a positive impact on creative thinking by providing visual cues to designers. Generally the process of thinking that conceptualizes new types of shapes with the use of visual cues is divided into two categories: analogy and emergence.

4.1. ANALOGY

Analogical reasoning involves transfer or mapping of knowledge from one domain, called a source, to another domain, called a target (Finke, Ward, and Steven, 1992), and this process will help solve problems by providing new information to designer who are faced with problematic situations that have to be tackled(Finke, Ward and Smith, 1992).

In analogical reasoning, similarity of physical property is as much important as structural similarity in their mutual relations (Gentner, Holyoak, and Kokinov, 2001).

Figure 1. Structural parallels

Let us consider the Figure 1. It is readily apparent that pair A is the 'same' as the standard in a structure but pair B is not. Because the two rectangles in pair A have the same shape, just as do the two circles in the standard. It is an outcome of analogical thinking that deals with structural similarity, not similarity of shape, as seen in the relations between standard and pair A.

In analogy of visual shapes in design process, the peculiarities of shapes and the relations of properties depicted in sketches for visual cue make analogical thinking possible.

Moreover, when it comes to architectural design, analogical thinking based on visual data can be a good design strategy because problems in the architectural design area have to be solved through visual thinking with the use of physical components(such as vertex, segment, and face etc.) and images of special relations (Finke, Ward and Smith, 1992).
It is essential to find external characteristics of visual cues depicted in sketches for through understanding and analysis of their mutual relations.

4.2. EMERGENCE

A property that is not represented explicitly can be called emergent property if it can be explicit (Gero and Yan, 1994). The initial concept of emergence was introduced by Wassily Kandinsky, the Bauhous theorist and painter, as the nature of composition. In his discussion of chemical bonding, John Stuart Mill observed that it was not a simple sum of chemical components and that it would be impossible to predict how chemical combinations would turn out. The study, initiated by Mill, had continued until such chemical effects were termed 'emergence' by Lewes(Knignt, 2003). In nowadays, Holland, in his recent book, maintains that a whole entity is something more than simply combining numerous parts. He went on to point out that novelty and unpredictability are inherent in emergence and that emergence goes hand-in-hand with "perceptual novelty"(Holland, 1998; Knight, 2003). Wide-ranging theories have been presented to give precise definitions of emergence, but no clear-cut conclusion was drawn.

In the architectural design field, research work has been made in three areas: shape emergence, shape semantic emergence, and visual style emergence(Jun, 1997). Gero and Yan(Gero and Yan, 1994) developed a computation model which provides enormous help to find out emergent shapes by means of re-representation that made re-interpretation possible. Models of emergent shape have been also introduced by Soufi and Edmonds(Soufi and Edmonds, 1996). The shape semantic emergence is to find out the visual patterns from a simple shape or a group of shapes. A study has been undertaken by Jun(Jun, 1997) to make a theoretical presentation in this area.

Shapes of emergent property play a dominant role in the creative design process. As stated above, although the property remains unchanged physically due to the ambiguity of overlapping outlines, shape gives different looks depending on the side from which you see it. So designers get much more flexibility in finding out new shapes with the aid of property like novelty and unpredictability.

That is, re-interpreting the existing shapes gives designers a chance to interpret the existing ones in different perspective, creating a new foundation of emergence.

5. Emergent Shape

Researchers have long been studying emergent shape. Among them were Gero and Yan(Gero and Yan, 1994), and Liu(Liu, 1995; Liu, 1996) joined them later. Gero and Yan maintain that there are two kinds of emergent shape: one with boundary of primary shapes and the other without. Liu,

following Stiny's theory(Stiny, 1980), broke down the shape into two types: explicit and implicit. In the same manner, Soufi and Edmonds(Soufi and Edmonds, 1996) introduced two processes for finding emergent shapes: interpretative process and transformation process. The interpretative process shows that the possibility of primary shapes generating new types is limited and preditable. The transformation process, can lead to a large and unpredictable set of possibilities. The researcher classified emergent shapes by using simple shapes like Figure 2.
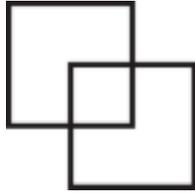

Figure 2. Primary shapes

In short, the types can be categorized as shown in Table 1. The explicit shapes and the implicit ones of Liu can be categorized respectively to same type such as the interpretative process and the transformation process of Soufi and Edmonds.

TABLE 1. Classification of emergent shapes

type	Soufi & Edmonds	Liu	Shapes			
A	The interpretive process	Explicit closed				
		Explicit unclosed				
B	The transformation process	Implicit closed				
		Implicit unclosed				

In case of Type A, emergent shapes can be found out in the existing shapes(primary shapes). This type carries with it explicit properties of

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primary shapes as they are. Therefore, the type is very constraint and predictable.

Type B will bring unpredictable result as boundary of primary shapes is extended or imaginary end-points of primary shapes are connected along the extended lines. In contrast with type A, these are new shapes contacting novel properties besides explicit properties. The shapes hold properties which have become explicit in the course of designers' work, namely, emergent properties.
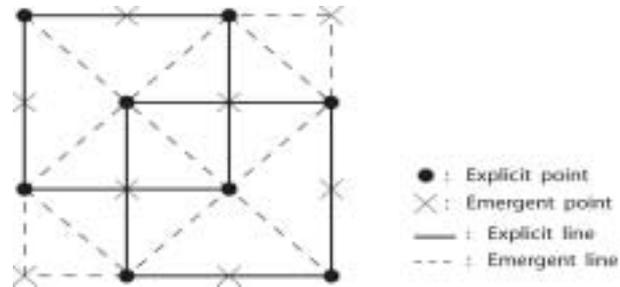

Figure 3. Example of explicit, emergent properties.

Let us take primary shapes presented before as an example(Figure 3). The properties of these shapes can be thought to provide two different views. One is explicit properties having eight distinctive points and eight clean-cut segments, the other is emergent properties which generated by connecting the mid-points of segments and the points on the extended lines. Emergent shapes can produce a great variety of properties in accordance with the designer's intention in the problem-solving process.

However finding this kind of shape is not impossible because new shapes overlap with properties of primary shapes such as vertex and segments. Experienced designer could easily find emergent shapes like type B as found in the experiment carried out by Liu(Liu, 1995). Moreover, Liu developed the computation model through connectionist approach in his research work(Liu, 1995).

6. Mutational emergent Shape

As explained in the Table 1, type A represented emergent shapes composed with explicit properties. Type B shows emergent shapes formed with emergent properties in addition to explicit properties of primary shapes. Type B does not include all the properties of primary shapes but shares some of them. For instance, the properties represented by the connected angle points in primary shapes is remain same in B. But emergent shapes can

occur through mutation of explicit and emergent properties in primary shapes.

In this study, the new shapes generated by changing properties are called as mutational emergent shapes. Generally emergent shapes are detected through the re-structuring of re-interpreted properties which come by way of de-structuring the properties of primary shapes. In case of mutational emergent shapes, properties de-structured in the wake of reinterpretation become properties of new shapes through mutation of properties and re-structuring. Figure 6 is an example of mutational emergent shapes is generated by mutation of an explicit property of primary shapes.
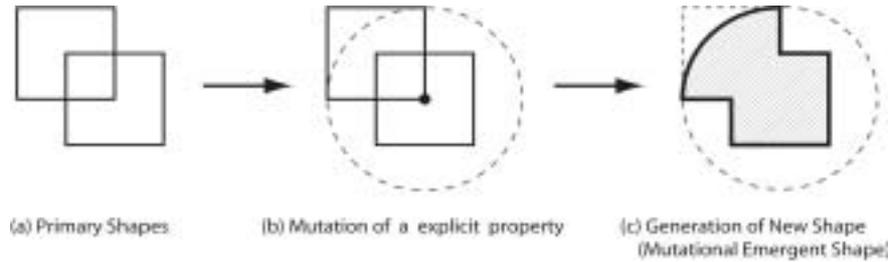

(a) Primary Shapes   (b) Mutation of a explicit property   (c) Generation of New Shape (Mutational Emergent Shape)

Figure 4. Example of generation process of mutational emergent shape.

Let's go over the Figure 4. The property of (a) primary shapes, that is, the angle points of rectangle, gives way to the center point of the circle (b). Using the center point, we can draw a circle. Re-interpreting and re-structuring the circle and primary shapes, will lead to the formation of novel shape such as (c), namely, mutational emergent shape. Figure 6 is one of examples showing that angle points or segments in primary shapes can be variously mutated. Figure 5 shows examples of mutational emergent shapes.
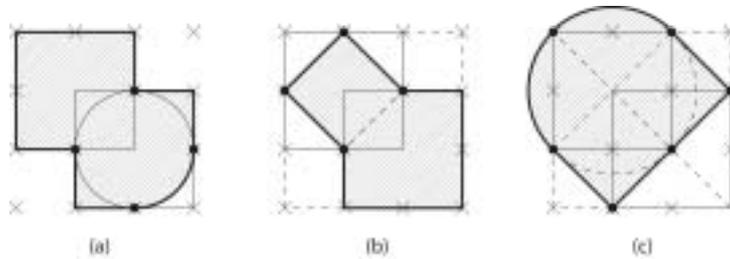

[a]   [b]   [c]

Figure 5. Examples of mutational emergent shapes

In the case of (a), mid-points of segment, emergent properties of the primary shapes and one of explicit properties of primary shapes are mutated as contact points and a center point of a circle respectively to create a circle,

and (b) is an illustration of mid-points of segment, emergent properties of the primary shapes, mutated as angle points of diamond shape. In (c), angle points of rectangle, explicit properties of primary shapes, mutated as contact points for a circumcircle.

The mutation of explicit and emergent properties take various forms that can be seen as manipulated by designers. Therefore, it offers very useful tools to help find out creative shapes.

A process model of mutational emergent shapes is introduced as follows. First, each property of primary shapes is de-structured. The next stage of the process is divided into two parts: mutation of explicit property itself and mutation of emergent property discovered through re-structuring.

New shapes are recognized through mutated properties, and then, they are re-interpreted with primary shapes. Novel shapes, namely, mutational emergent shapes, appear at last after going through the whole process.
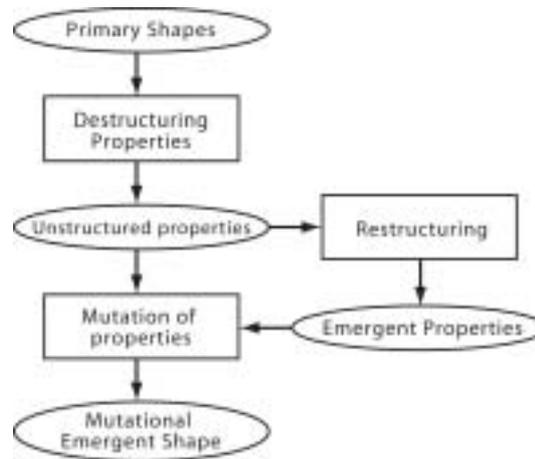

Figure 6. Process model of mutational emergent shapes.

7. Conclusion

1. External representation such as sketches will not only enable designers to express their thoughts externally but also help them make visual thinking possible. It was found that sketches and drawings offer enormous assistance to the designers in their efforts to come up with new ways of thinking by exploring immanent shapes and inducing knowledge resulting from review of related researches. This process of thinking occurs recurrently through all the stage of the entire course, and repeating the process will make it possible for the designers to bring out creative thinking.

2. This study dealt with about analogy and emergence, which play an important role by using external representation such as sketches that will lead to creative designs. Through the discussion, we found new emergent shapes namely, mutational emergent shape. Mutational emergent shape is new type that is represented externally through mutation of physical properties and re-interpretation in primary shapes. Therefore, the formation process is considered another important process of cognitive thinking.

8. Future work

Further research work is necessary for the development of design models for thinking process on formation of mutational emergent shapes. In the first place, we need to thoroughly review expert theories and experiments in the field of cognitive psychology and other related areas before conducting appropriate test to verify the formation process of mutational emergent shapes. Second, concrete design models of formation process of mutational emergent shapes have to be studied and developed.

Finally, based on newly developed design models, computerization will be needed to build a system to support creative design thinking of designers in the early stage of design process.

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