A Design Model Using Mutation Shape Emergence

Focusing on Mutational Emergent Shapes

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Keywords: creativity, design process, mutational emergent shapes, design model

Abstract: The ability to recognize properties and characteristics unforeseen in the early stage of design, namely shape emergence, is considered one of vital aspects of human visual perception in creative thinking. This study aims at developing a design model by using an extended theory of shape emergence, mutation shape emergence which we call. The first part of this paper describes the definition of mutational emergent shapes clearly. In the second part, possibility of discovering mutational emergent shapes will be explored through protocol analysis. On the basis of the results of these efforts, we will examine closely the cognitive mechanism to discover mutational emergent shapes. In the last stage, based on our results we propose a design model for understanding the cognitive process implications for training architects.

1 INTRODUCTION

Much discussion has long been ongoing in academic and industrial circles on the creativity of human beings in design settings. In particular drawings and sketches produced in the design process appear to stimulate the transformations of mental processes to guide the creative thinking by providing various visual cues. These are important tools that make design more creative. These facts have been demonstrated by a number of researchers who have addressed different aspects of the problem (Suwa and Tversky 1997, Suwa, Purcell and Gero 1998, Kavakli 1998,Verstijnen and Hennessey 1998, Oxman 2002, Tovey and Porter 2003) .

The behaviour of ‘seeing something’, namely visual cognition, accompanies a basic analysis of form, shape, colour, outline, contrast, and movement (Solso 1996). According to Solso, the visual stimulus perceived at first glance is organized as a primary shape, and then we are able to see different objects through a blurry visual impression or even a very small detail.

As mentioned above, those features which are not explicitly represented but emerge through design process are called ‘emergent’. These emergent features help to create a novel and different design. Therefore the ability to recognize properties and characteristics of artefacts which were not anticipated in the early stage of design would be considered an important aspect of human visual perception in creative

thinking. Therefore, the emergence theory in the area of design has been proven as one of important aspects explaining creative human behaviour. This study aims at proposing a design model based on the cognitive mechanism of discovering mutational emergent shapes. A computational model of mutation shape emergence will be developed based on this design model in the future.

2 MUTATIONAL EMERGENT SHAPES

A primary shape is a shape that is drawn intentionally at the first of design process by designer and is initially represented explicitly. On the other hand, an emergent shape is a shape that exists only implicitly in a primary shape and is not represented at input time, but is represented explicitly through the re-interpretation process of designer. These emergent shapes have long been under study by many researchers (Mitchell 1990, Gero 1992, Gero and Yan 1994, Liu 1995, Soufi and Edmonds 1996, Knight 2002). Genereally, in the research reported up until now, emergent shapes are found from explicit properties of existing shapes such as by connecting or intersecting lines and vertexes. Therefore, properties of emergent shapes retain many parts of physical properties of primary shapes. Choi analyzed the similarities of these shapes and arranged the type of shapes (Choi and Jun 2004). By the classification, we suggested mutational emergent shapes as a new type of emergent shapes.

2.1 Definition

Mutation is the phenomenon of genes changing at random in the field of genetics. Figure 1 simply describes mutation: gene D, one of the genes making up a chromosome, turns into gene X by mutation. Mutation is a basic factor of hereditary diversity and evolution (Gardner, Simmons, and Snustad 1991).

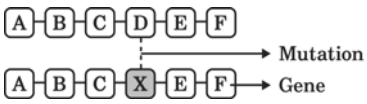


Figure 1 Mutation of gene

In the area of knowledge-based design, mutation seems an action of changing features or attributes of an object or concept in an unconventional manner. By ‘unconventional’ manner we mean that the change is not restricted by the usual rules and constraints. Therefore, a knowledge-based design system built on mutation looks promising as a process to produce creative designs (Coyne et al. 1989). Mutation could be regarded as one of the natures of random and unconventional thinking in the field of design. In this study, mutation is defined as a mechanism that makes possible the creative thinking in the diversity of shapes’ discovery.

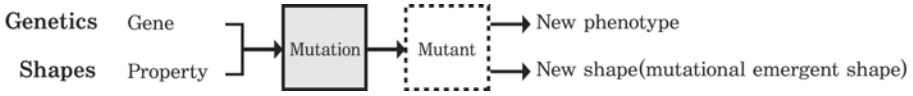


Figure 2 Mutation in Genetics and Shapes

Mutational emergent shapes are new shapes that generated by emergent representation and discovered by mutation of physical properties that are formed in primary shapes through de-structuring and re-structuring.

In this research, mutational emergent shapes are divided into two types on the basis of character of shapes: homogeneous mutational emergent shape and heterogeneous mutational emergent shape. The terms, 'homogeneous' and 'heterogeneous' are different to the ones in genetics to some degree. In genetics they mean respectively 'unmixed breed' and 'crossed breed' in genotypes. However, in this study, the definition of mutational emergent shapes is based on similarity of appearance of emergent shapes compared to primary shapes.

Homogeneous mutational emergent shape shows that mutations of physical properties occur but the representation of new shape is homogeneous to the representation of a primary shape (Figure 3a). As a result, appearance of new shape is similar to that of primary shape. An example of homogeneous emergent shape is displayed in Figure 3b. The primary shape is seen as composed of straight lines, and the mutational emergent shape emerging in the wake of the primary shape is also formed by lines.

Heterogeneous mutational emergent shape means that mutations of physical properties occur but the new shape has heterogeneous representation from primary shapes. As a result, appearance of new shape is different from that of primary shape. It shows new shape generated by mutation of the properties in primary shapes. Figure 3(C) shows that lines are changed into arc.

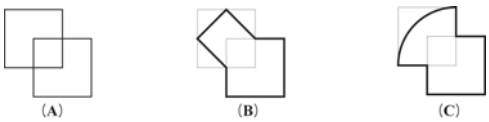


Figure 3 Example of mutational emergent shape: (a)Primary shape, (b)Homogeneous Mutational Emergent Shape and (c) Heterogeneous Mutational Emergent Shape

2.2 Discovering Mutational Emergent Shapes

Each discovering process of mutational emergent shapes is as follows. Figure 4 shows the generating process of homogeneous mutational emergent shape.

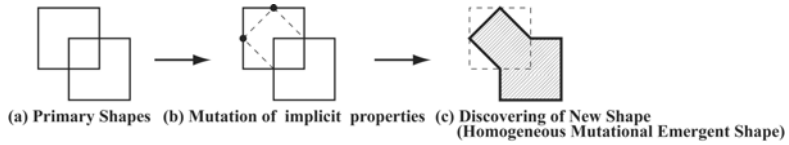


Figure 4 Discovering Process of Homogeneous Mutational Emergent Shape

The properties of (a) primary shapes, those are, the mid points of rectangle, gives way to the angle point of the rectangle (b). Using the mid points, we can draw a new rectangle by connecting the points. Re-interpreting and re-structuring the rectangle and primary shapes, will lead to the formation of novel shape such as (c), namely, homogeneous mutational emergent shape.

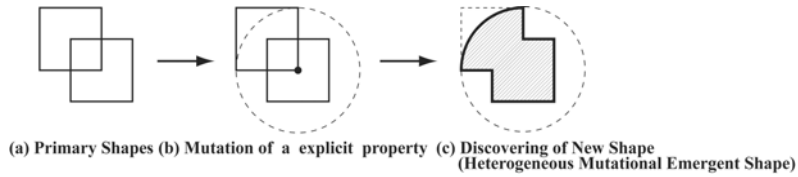


Figure 5 Discovering Process of Heterogeneous Mutational Emergent Shape

Figure 5 shows the discovering process of heterogeneous mutational emergent shape. 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 different shape such as (c), namely, heterogeneous mutational emergent shape. As presented above, Figure 4 and Figure 5 shows ones of the examples in which angle points and segments of primary shapes can be mutated in various ways.

2.3 Classification of Emergent Shapes and Mutational Emergent Shapes

This study is based on groupings by Liu (1995) categorized in accordance with Mitchell's direction (1992). The shapes are classified into three categories. Liu included unclosed shapes in his categories, but emergent shapes in this study are limited to closed shapes. Emergent shapes and mutational emergent shapes can be classified by their characteristics as follows (Figure 6):

1) Explicit closed emergent shapes: shapes are both closed and located on explicit properties of primary shapes (Figure 6a)

2) Implicit closed emergent shapes: shapes are closed but not necessarily located on explicit properties of primary shapes. These shapes can also be defined by extending lines and connecting vertices (Figure 6b).

3) Mutational closed emergent shapes: shapes are both closed and generated by mutation of physical properties of primary shapes (Figure 6c).

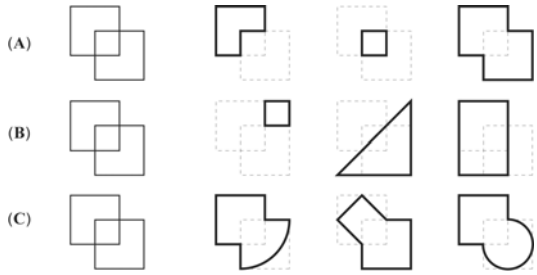


Figure 6 Emergent Shapes: (a) Explicit Closed Emergent Shapes; (b) Implicit Closed Emergent Shapes; (c) Mutational Emergent Shapes

3 EMPIRICAL STUDIES

The purpose of the first experiment was to explore the possibility of discovering mutational emergent shapes in design process. These new shapes are placed under the predefined category. By using verbal data and sketches collecting from the experiment, efforts were made to analyze how the whole process took place.

3.1 Empirical Study 1

Seven participants who were graduate students of department of architecture took part in the study. They were recognized as having knowledge and experience in the field of design. The experiment was conducted in a specially prepared room. Two cameras, set up the right side of the participants, were focused on the sketching area.

We collected protocols by recording the sketch process with analytical methods. Using a primary shape given for test, the sketch process was recorded by camera 1. The participants were asked to sketch various shapes as much as they could at their own discretion. In addition, they were told to make verbal reports concurrently on what was going on in their mind. The given time was 10 minutes and at the end of the session they discussed the results of the work to see if there were only missing parts. The review session was re-recorded by camera 2. Each participant spent approximately 40 minutes for the work including the review.

3.1.1 Scoring

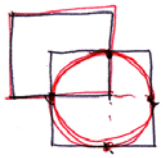
Two participants came up with two mutational emergent shapes. Verbal data from think aloud reports and retrospective reports were segmented to see how the work went on in every five seconds and arranged in the form of a table with sketches as shown in Table 1 and 2. As seen in the above verbal data and sketch of Table 1, participant 3 used quarter circles to generate the shape. Retrospective reports were not offered by this participant.

Table 1 Verbal Data and Sketches by Participant 3

Time	Think Aloud Reports	Sketch
09:30	Hmmm. This…	
09:35		
09:40		
09:45		
09:50	Ah, here comes quarter circle….	
09:55	I think this shape can be made using by quarter circle…	
10:00	…	

Table 2 shows participant 5 finding a new shape by means of contact points which are mid points of primary shape. The new shape was made by a mixture of circle and rectangle.

Table 2 Verbal Data and Sketches by Participant 5

Time	Think Aloud Reports	Retrospective Reports	Sketch
03:20	Now how about starting with the rectangle..		
03:25	Now I find four points for mid points of segments If I draw a circle..	If I connect mid points on the each four segments of rectangle…	
03:30	This new shape and this rectangle..	So I can draw the circle…	
03:35	We can make a shape with circle and rectangle.	This compounded shape of a rectangle and a circle is likely to emerge.	

3.1.2 Analyzing

The two shapes shown in the tables are classified into mutational emergent shapes. The process of discovering the properties of new shape from primary shape by participants is explained by analyzing the verbal data of each case.

In the case of participant 3, a new shape was generated after discovering quarter circles which have center points re-interpreted from emergent properties which are two angle points of primary shape and one explicit property which is an angle of primary shape. In the case of participant 5, a new shape was gained after discovering a circle which has a center point and contact points of the square re-interpreted from explicit properties which are one angle point and four midpoints of primary shape. According to a general theory of mutational emergent shape, these new shapes are discovered by mutation of the explicit and/or implicit properties including primary shape. In other words, these shapes are usually generated by mutation of physical properties of primary shapes based on unexpected representation. As defined previously in Section 2.1, these shapes are classified into heterogeneous mutational emergent shapes. Through this experiment, two important aspects were found. Firstly designers have a mechanism to discover new properties and become able to generate unexpected shapes. Secondly, the new shapes can be discovered through generating process of mutational emergent shape presented in Section 2.2.

3.2 Empirical Study 2

The purpose of the second experiment was to determine the degree of difficulty in recognizing the mutational emergent shapes and to analyze the cognitive process of mutational emergent shapes using the results which were collecting from participants' free sketches. A total of 104 participants took part in this experiment. They were undergraduate or graduate students of school of architecture. This experiment was divided into two parts – a test on degree of difficulty and a free sketch test. Before the test, the concept of emergent shape was taught to help the participants understand the task. They were asked to draw various shapes in two minutes. Then, we handed them a questionnaire and asked to check the degree of difficulty (degree of difficulty test). The questionnaire covered three type of shapes selected from the classification in Figure 6. The participants used the five-point Likert scale in marking the degree of difficulty. The given questions were mixed at random. In the free sketch test, they were given three blank primary shapes and asked to draw new shapes. Moreover, they were required to describe the generating process of new shapes and what has motivated them to draw the shapes. The test time was 15 minutes.

3.2.1 Scoring and Analyzing

A. The Degree of Difficulty Test

The results of the degree of difficulty test were plotted in Figure 7. When they went over Problem No.4, 6, and 8, a large number of participants felt it was easy or very easy to discover explicit closed emergent shapes. The number of students reacting to the problems stood at 91, 100 and 102, respectively. But they found Problem No. 2, 5 and 7 (mutational close emergent shapes) difficult or very difficult. The number of students broke down to 40, 43 and 55 for problems No. 2, 5 and 7, respectively. Therefore, we found that mutational closed emergent shapes are not easy to discover compared to other types of emergent shapes.

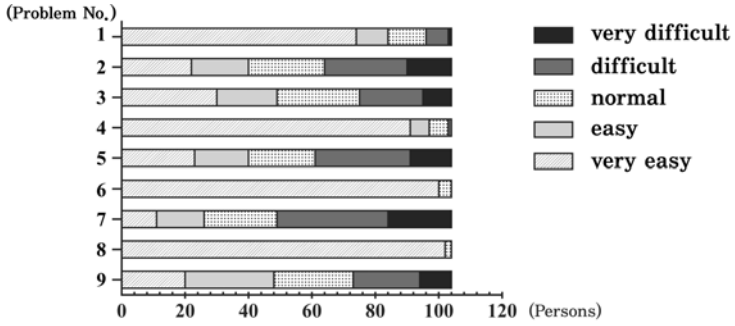


Figure 7 Responses of Students to each question measured by Five-Point Likert Scale Explicit closed: No. 4,6,8; Implicit closed: No. 1,3,9; Mutational closed: No. 2,5,7).

B. Free Sketch Test

Mutational emergent shapes generated in the free sketch test are as follows (Figure 8):

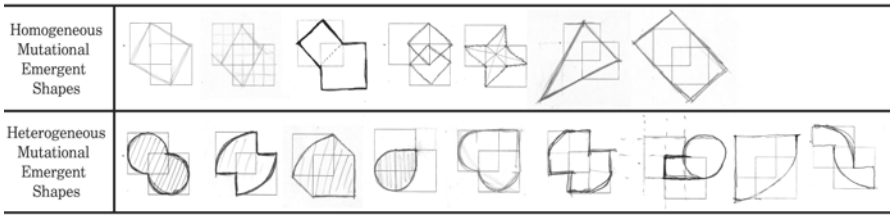


Figure 8 Classifications of Sketches

Twenty eight shapes out of three hundred twelve shapes were classifies into mutational emergent shapes. They represent 8.9% of the total. Though the discovery rate of mutational emergent shapes is lower than others, students demonstrated an ability to handle such a task. In addition to that, two types of mutational emergent shapes are confirmed to exist by this experiment as shown in Figure 9.

3.3 Results and Discussion

An analysis of the verbal data and sketches collected from the first experiment led us to conclude that the mutational emergent shapes are generated in design development process. The second empirical study showed that, although mutational emergent shapes are not easy to discover as seen in the test on the degree of difficulty, participants could analogize such shapes by means of sketching. Shapes could be drawn in various ways. Close examinations enable us to see that mutational emergent shapes are discovered resulting from mutation of the new properties stemming from the primary shape. The shapes are divided into two types: homogeneous mutational emergent and heterogeneous mutational emergent shapes. Especially in the process of discovering the new properties, participants came up with new shapes by using implicit and/or explicit properties of primary shapes such as mid points, contact points, angle points and n-section points.

3.4 Process Model

The results of the two experiments enable us to present a process model of mutation shape emergence. De-structuring is the process of breaking down primary shape to individual properties based on intended representation. Figure 9(A) shows this process. These properties are fundamental elements of primary shape, which are explicitly represented by designers.

Re-structuring, in contrast, is the process where new properties are discovered through multiple representations. Figure 9b shows the process of re-structuring by newly discovered points and lines in addition to explicit properties such as eight points and eight lines. The explicit and emergent properties shown in Figure 9 become fundamental elements of mutational emergent shapes generating through mutation of properties by designer's intention.

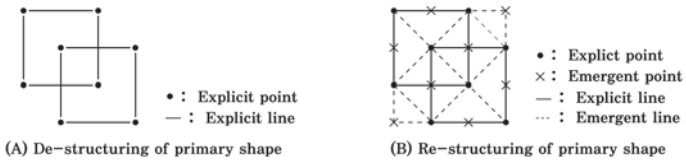


Figure 9 De-structuring (a) and re-structuring of primary shape (b)

Figure 10 introduces a process model of mutational emergent shape. The primary shape drawn by designer's intention comes into being. Through de-structuring, properties of primary shapes break down to individual properties. The next stage of the process is divided into two parts: mutation of unstructured properties, and mutation of emergent property through re-structuring of unstructured properties. The mutational emergent shape is discovered through re-interpretation by the designer. That is, new shapes are recognized through mutated properties, and then they are re-interpreted with primary shapes. As a result, mutational emergent shapes as novel shapes are discovered. Novel shapes, namely, mutational emergent shapes, appear after going through the whole process.

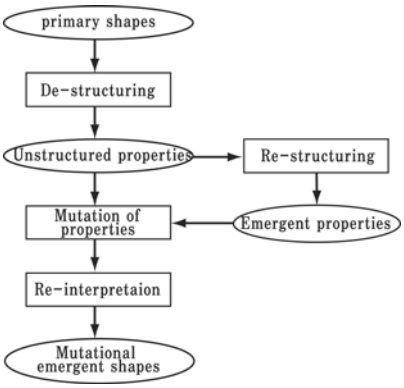


Figure 10 Process Model of Mutation Shape Emergence

4 CONCLUSION

Two experiments were conducted with simple shapes. Further research work is necessary to explore the design process at the practical level with the use of mutational emergent shapes. Moreover, concrete steps of representation of mutational emergent shapes should be suggested for computation of mutation shape emergence.

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