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A Study on the Convergence of Meaning and Creativity of the Generated Concepts in Design

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Abstract. This paper discusses an approach to convergence in conceptual design. The main issue is the ambiguity with regard to the manner in which ideas are structured and formed from diverse concepts in this stage of design. In this study, we integrate the user's perspective on the convergence of meanings into design methodology by applying a meaning-based framework in conceptual design. This methodology introduces a user-derived evaluation of 'structure of meaning elements' (SoME), based on their convergence. We test the proposed design methodology in a case study with three designers. This study reveals details of how concepts are converged in design and how concept formation can be achieved using design methodology. The significance of this study for design creativity lies in the comprehension of convergence and its connection with of creative processes in the conceptual design.

Keywords: conceptual design, concept generation, convergence, design methodology, design creativity

1 Introduction

The conceptual design process (i.e. the design phase from the beginning to the formation of the concept of design) can be enhanced by various means, many of which are focused on providing a wider or divergent range of ideas (Mougenot et al., 2008; Segers et al., 2005; and many others). However, there is ambiguity with regard to the manner in which ideas are structured and formed from such diverse concepts. Few studies focus on the relations within conceptual stimuli (Chiu and Shu, 2007; 2008) or the manner in which concepts are synthesized by the designer (Nagai and Taura, 2006), particularly with regard to the creativity behind the idea (Finke et al., 1996). This issue is even more important from designers' perspective, where the stages of divergence and convergence have special importance with respect to creating a successful conceptual design (Liu et al., 2003). From the designer's perspective, the most important stage of the conceptual design process is the stage of convergence, wherein concepts are evaluated and selected to be synthesized for the design. Therefore, it is very important that the designer be directed and assisted at the stage of convergence.

1.1 Convergence

In order to address the dimension of convergence in the conceptual design process, we conduct an integration of the user's perspective on the convergence of meaning from our previous study (Georgiev et al., 2010a), into the design methodology we discuss and test in a case study in the present research. This study showed that the higher convergence of concepts derived from design was connected with higher users' evaluation. Thus, we consider that it may be necessary to have a good convergence of the design concepts. We looked for a method to allow us to improve the convergence, especially in cases with low convergence in the initial state. To build such method, we apply a meaning-based framework to the process of concept formation during the conceptual design process.

2 Background

2.1 Approaches to meanings of design

Number of methodologies investigate the user's viewpoint on meanings of design. These methodologies quantitatively express the user's viewpoint in the form of evaluations. An example of such a methodology is the semantic differential (SD) method, based on the work of Osgood, Suci and Tannenbaum (1957). The SD method focuses on the evaluation of the connotative meanings of designs. Research based on this method has been carried out in different studies.

The approaches, which study user's viewpoint as the meaning that an artefact has for the user, are product semantics (Krippendorff, 2006) and product affordances (Van Rompay, 2008). Product experience bridges product semantics and affordances from the perspective of the user's apprehension towards the product. Studies on product expression discuss relationships between the concrete (product's actual features) and the symbolic (product's perceived expression) (Van Rompay, 2008). This demonstrates an interactional, embodied approach to product expression. The insights allow designers to relate the abstract and difficult notions to their own experiences while translating the idea into form.

On the other hand, the approaches based on users' impression emphasize on the user's subjective interpretations of the product based on his/her personal impressions, that is, the user's cognitive interpretation of the designed product. The emotional design approach manifested from this impression-based perspective. Norman (2004) highlights the interaction between affect, emotion, and cognition. An emotional response to a product design that agrees with its efficiency is a major attribute for a product's success. Norman also relates this view with the perceived functional use of the products from the perspective of visual impression.

For example, Krippendorff's (2006) product semantics approach focuses on the user's subjective impression of the product's meanings. The approach takes into account the relationship between the user's cognitive models and the perceivable features of the concerned product. By a sequence of activities, semantic considerations are incorporated into the design process. Some of the activities include establishing the semantics to be communicated, outlining the attributes to be expressed, and searching for the manifestations to project the semantic considerations with regard to shape. This approach is centred on symbolic associations and meanings and is governed by the design features during the design process.

2.2 Conceptual design

The problem-solving perspective is in the focus of most of the aforementioned approaches. The problem solved by the design need not be a pressing societal requirement, but rather a perceived gap in a user's experience (Ulrich, 2007). In recent times, studies focusing on creativity (Dorst and Cross, 2001; Jin and Li, 2007) have shifted their focus on the processes of concept generation. These processes include concept processing and combination, which are typical in the early stages of design.

For example, Shah and Vargas-Hernandez (2002) implemented the objective measures of idea effectiveness. They developed outcome-based metrics from the point of view of both design and cognitive psychology, thus contributing to the identification of key ideation components of design methods.

Such methodologies reveal the importance of concept formation and convergence with respect to creating a successful conceptual design (Liu et al., 2003), however, not clarify how ideas are structured and formed from the diverse concepts; this gives rise to the question of how this gap in the design methodology can be addressed. The convergence is necessary in order to correctly ascertain the aspects of concept formation of the designed artefact.

2.3 Framework

According to the framework of this study, 'meaning' can be defined as what an artefact represents for the user. The meaning element is the most basic part of the meaning. The 'structure of meaning elements' (SoME) is the relation between the various meaning elements of an artefact. Therefore, the meaning of the artefact includes meaning elements and the SoME (see Figure 1).

We refer to the term 'concept' as a design concept with an abstract notion. The framework of meaning elements is derived from the understanding of 'notion' as an abstract idea or mental image, which plays a part in the use of reason or language. In this study, we explore concept formation of design as the process of building the SoME. The conceptual design can be conceived as the dynamic creation of the SoME by the designer. A set of single meaning elements are put together in a way that it forms a particular whole meaning of an artefact (Georgiev et al., 2010b). In other words, during the conceptual design, the meaning of the artefact—a Beetle car in this case—is structured from the meaning elements of 'car', 'friend', 'ladybug', and 'cute' to the meaning elements of 'eco', 'difference', 'car', and 'happy', and the structure of the latter constructs the meaning of the whole entity, that is, 'Beetle car'. The whole meaning of the artefact can be represented as 'a different car that is ecological and which makes me happy'. The conceptual design is a process of exploration and evaluation of the meaning elements as a part of the SoME. The conceptual design results in a design concept with a structured meaning in the form of the Beetle car.

The outlined framework refers to the SoME in a sense that is different from the structure of meaning discussed by Osgood, Suci and Tannenbaum (1957). While Osgood et al. refer to the structure of meaning as the way these meanings are mentally represented and hierarchically connected, the framework of the

SoME in this study refers to the way meanings (meaning elements) are mentally represented and structured in conceptual design.

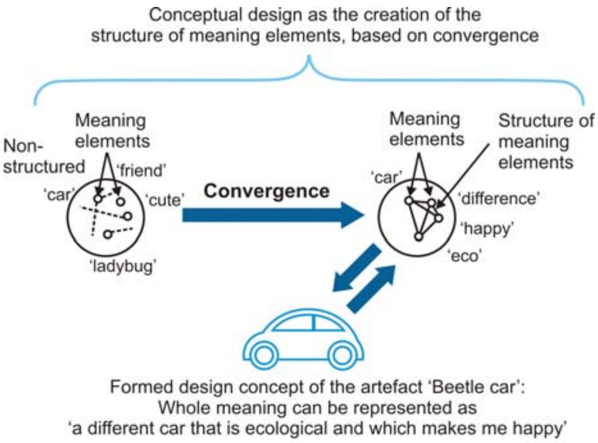

Fig. 1. Understanding conceptual design as the creation of the 'structure of meaning elements', based on convergence, using the example of a Beetle car (adapted from Georgiev et al., 2010b)

3 Aim and Methodology

The aim of this study is to investigate the convergence integrated into conceptual design in a case study, by using the described design methodology. Moreover, we aim to investigate how this convergence relates to the creativity of the generated concepts in design.

3.1 Methodology

The processes of exploration, synthesis, searching and finding of meaning elements are critical for design achievements, from the creativity viewpoint (Finke, 1996; Nagai and Taura, 2006). Usually, the search and evaluation of meaning elements in the conceptual stage of design are dependent solely on the ability of the designer. The design methodology employs the following procedures for the searches and evaluations of meaning elements (Georgiev et al., 2010b) (Figure 2). Input stage involves the set of meaning elements derived from the design task; Stage B entails building the SoME using searches and evaluation of convergence; and Stage C involves the generation of the SoME.

The steps are as follows: (Input) Deriving the set, which is the starting point of the initial meaning elements that relate to the design task and the abstracted meaning elements from the task; (1) Performing searches with these meaning elements by using a semantic network; (2) Visualizing a semantic network of related 'searched-for' meaning elements; (3) The designer selects new meaning elements from this neighbourhood network; (4, 5) Evaluating new meaning elements based on the convergence (average degree of relations between the meaning elements). The last stage (Output) represents formed design concept.

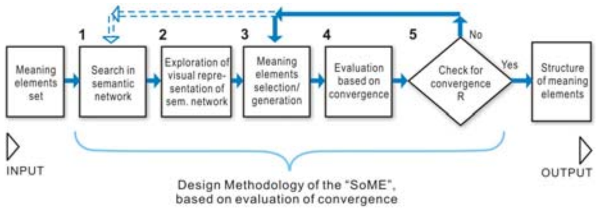

Fig. 2. Stages in the design methodology which focuses on convergence of meaning elements (adapted from Georgiev et al., 2010b)

3.2 Tools

In order to implement the initial stages, the tool we used to perform the search was WordNet's (WordNet 2.1) Visuwords 2.02 (Visuwords 2.02) visualization (in the stage 2). WordNet is an explicit, complex knowledge-based representation of the human mind in form of concpet network (Miller et al., 1990). As computational structures, these networks represent the field of meaning and can be used to model conceptual associations (Boden, 2004).

In our case, the search, however, is limited to the representation of the network neighbourhood of the semantically connected words. The process of evaluating the structure of meaning elements (stage 4) is based on the measures that have been implemented in WordNet::Similarity (WordNet::Similarity 2.01). Similarity by path is the most general measure, and it is based on the principle of counting the semantic distance between concepts (Pedersen et al., 2004).

The methodology uses this method as the evaluation criterion (stage 5) for the set of meaning elements (Georgiev et al., 2010b). Here, we define convergence, *R*, as the average value of the similarities, *S*, derived from the shortest path in the WordNet database, of a limited set of meaning elements (see Equation 1). The number of meaning relations between individual meaning elements is *n:*

$$R = \frac{1}{n} \sum_{i=1}^{n} S_i \qquad (1)$$

4 Case Study

We conducted an observational case study on the SoME using the methodology described above. The four-session experiment was conducted with three subjects (designers A, B and C, practicing engineering, industrial and media designer respectively). We evaluated the stages and results of the process of building the SoME and extending the use of convergence in the conception process.

The language stimuli were used in this case study. The approach is similar to studies on the idea generation process in design (Chiu and Shu, 2007; Segers et al., 2005). The process begins when the subject is assigned the word pairs and then tasked to design a new concept; the combined words are considered to enhance the creative ideas in design.

The goal in the case study was to integrate the convergence process into the designers' thinking process. This goal was initiated when the subjects were assigned the word pairs and then tasked to design a new concept. The assigned meaning element pairs (word pairs) are mentioned in Table 1. The selected pairs had varying degrees of convergence. The four word pairs ranged from being highly converged ('computer'–'ski') to very low converged ('violin'–'sea') (Georgiev et al., 2010b).

Table 1. Convergence of pairs of the meaning elements used in the study

Pairs	Convergence of pairs
(1) Computer–Ski	0.2 (High)
(2) Cat–Piano	0.1429 (Intermediate)
(3) Helicopter–Blanket	0.1 (Low)
(4) Violin–Sea	0.0769 (Very low)

5 Results

The subjects followed the outlined methodology unhindered until the design concept was formed. In every session, a check to evaluate convergence was conducted one or two times.

The design concepts that were formed are illustrated as a process in Table 2. Participant A formed the following design concepts:

(1) *'Ski device for an impaired person, controlled by a computer. Person is in a bobsleigh-like seat and is using a computer to direct the ski';*

(2) '*Cat-shaped educational table for kids. Have keys that play explanations for different aspects of cats' behaviour, habits';*

(3) *'Helicopter cargo net can be made as a blanket using tangled threads and knots. It is easy to produce and very strong'*; and

(4) *'Design of a wave-shaped violin with different elements also shaped like a wave'.*

Whereas, participant B formed the following design concepts:

(1) *'A ski device mounted on a car's back tyres, while the front tyres use textile like chains. This simple mounting device is useful in deep snow';*

(2) *'A foldable piano-like instrument which uses harmoniously resonating plates. When folded, it is compact and light';*

(3) *'A sling-like entertainment vehicle: A person wearing a protective suit is launched from the vehicle and then caught in a glove-like device'*; and

(4) *'Public transportation on ropeways with individual transformable capsules having beds'.*

Participant C formed the following design concepts:

(1) *'Skier is a user of digital technology, who interconnects digital ideas'*;

(2) *'Key learning system for pianist, which uses whips'*;

(3) *'Wind toy that meets east and west, tradition and technology. Small helicopters and blankets are circling over the bed'*; and

(4) *'Hydro-phonic fiddle, which plays different notes using bow'*.

Table 3 and Figure 3 use meaning elements from the last column of Table 2 to present a comparison between the convergences of the input and output designs with regard to the meaning elements. The convergence of meaning elements in the output (formed concept) of the design is higher than that in the input in most of the cases. This difference is greater in the cases of input with low convergence.

Furthermore, the resulting design ideas were evaluated by two experts on the criteria of originality and practicality (Table 4). The first—originality—is concerned with the quality of being new and original and not derived from something else with, and the second—practicality—is concerned actual use rather than theoretical possibilities. This method has been used in other studies as well (Finke, 1996).

Table 2. Main steps to find meaning elements

Pairs	Main steps involved in finding meaning elements (Designer A)			
(1) Computer–Ski	**Computer →** **Ski →**	Computer → Water ski →	Computer → Wedel →	**Computer** **Ski /** ***Disabled***
(2) Cat–Piano	**Cat →** **Piano →**	Whip → CAD / *Tail* Piano keyboard→ Holder	Sound *Cat shape* → Keyboard →	 *__Cat__-shaped* **Key**
(3) Helicopter– Blanket	**Helicopter →** **Blanket →**	Vane / Cargo helicopter→ *Shield*	Sky hook Hook Blanket	**Hook** ***Net***
(4) Violin– Sea	**Violin →** **Sea →**	Chinrest → Wave →	Chin → *Shape* →	 ***Shape*** **Wave**

Pairs	Main steps involved in finding meaning elements (Designer B)			
(1) Computer– Ski	**Computer →** **Ski →**	Work → Compute → Travel → Movement →	Freelance *Factor / Cloth* Progress → Advance →	 **Ski** ***/ Snow*** **Car/wheel/*chain***
(2) Cat–Piano	**Cat →** **Piano →**	*Caterpillar* → Music/Sound → Key/Keyboard →	Tractor/Folding→ *Pantograph* Accord → Leg/*Plate/Tight*	**Fold** **Piano** **Plate**
(3) Helicopter– Blanket	**Helicopter →** **Blanket →**	Vane → Sky hook → Windmill/Sail → El. Blanket →	Rotor/Blade Rope/*Rail/Air* → Rescue/vehicle→ Wind generator Warm/*Glove* →	***Rope*** **Capsule** **Vehicle** **Bed**
(4) Violin–Sea	**Violin →** **Sea →**	Bow/Violinist → *Launch* → Float/ Shell →	 *Speed / Glide*→ *Flight / Fun* → *Glove / Hit* →	**Sling** ***Vehicle*** ***Glove / Suit***

Pairs	Main steps involved in finding meaning elements (Designer C)			
(1) Computer– Ski	**Ski →** **Computer →**	Thing/Object → Runner/Person → Calculator → *Interconnect* →	Snow → Fast → Chip/Microchip/ Cristal → *Digital* →	**Skier** ***User*** **Technology** Digital Interconnect / ***Ideas***
(2) Cat–Piano	**Cat →** **Piano →**	Whip/Vomit → Keyboard → Pianist →	Catty/Whip → Key →	**Whip** **Key / Learn** **Pianist**
(3) Helicopter– Blanket	**Helicopter →** **Blanket →**	Rotor/Blade → Chopper → Bed Covering → Comprehension Embracing	*Magic blanket* → *East/West* → *Mobile* →	***Tradition*** **Technology** **East / West** ***Toy /Wind***
(4) Violin–Sea	**Violin →** **Sea →**	Fiddle/String/Bow→ Body/Water → Hydrosphere →	Bow/String instrument → Hydrosphere → *Glass*	**Bow** **Fiddle** *Hydro-phonic*/**Water** **Glass**

Table 3. Analysis of convergence of the results

Pairs	Case	Input convergence	Output convergence
(1) Computer–Ski	A B C	0.2 0.2 0.2	0.15 0.1953 0.123
(2) Cat–Piano	A B C	0.1429 0.1429 0.1429	0.2 0.2083 0.1878
(3) Helicopter–Blanket	A B C	0.1 0.1 0.1	0.3333 0.2195 0.1415
(4) Violin–Sea	A B C	0.0769 0.0769 0.0769	0.25 0.1629 0.2195

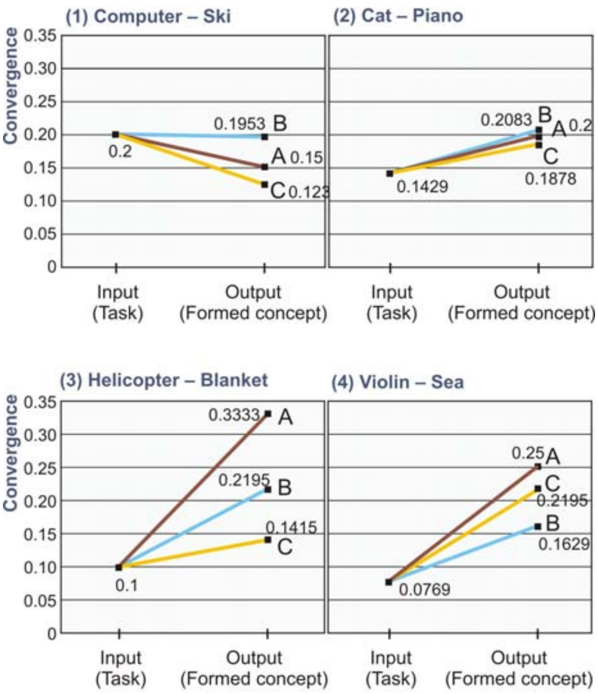

Fig. 3. Convergence of meaning elements

Based on these evaluations, we can observe rather week connection between convergence and creativity of the formed design concepts. Creativity evaluations (originality and practicality of the ideas) in cases (2)A, (3)B and (4)B,C (see Table 4) exhibit considerable convergence. On the contrary, in cases (1)A,B,C and (3)A,C the convergence is or negative, or very weak or very high. We think the 'computer'–'ski' case was an exception, due to the high initial convergence.

Table 4. Analysis of originality and practicality of the formed design concepts

Pairs	Case	Originality of the idea (1-5)	Practicality of the idea (1-5)
(1) Computer–Ski	A B C	2 2 2	4.5 2.5 1
(2) Cat–Piano	A B C	4.5 4 3	4.5 3.5 1
(3) Helicopter–Blanket	A B C	1.5 4.5 1.5	3.5 2 4
(4) Violin–Sea	A B C	3.5 4 5	3.5 2 3.5

6 Discussion

The addition of convergence in the methodology of building the structure of meaning elements (SoME), as described above, provides guidance and direction to designers in the conceptual design process. The assistance provided with regard to convergence in the conceptual design process allowed designers to find direction by themselves from the diverse generation of ideas.

The methodology led to the completion of concept formation in the conceptual design process with the assistance of an integrated user-derived convergence. The results indicated that the convergence was successfully integrated into the design methodology. Therefore, it can be said that adding a convergence stage in the concept generation process could help designers to create design concepts more effectively. However, this assertion needs further investigation. This study extends preliminary results regarding the construction of meaning in the conceptual design process (Georgiev et al., 2010b). Here we narrowed our focus on convergence and its connection with creativity of the formed concepts. This puts the results in new perspective. We added two cases of designers B and C, which allowed us observe how convergence can be seen in the perspective of creativity (originality and practicality of the ideas).

In this study, we dealt with one of the characteristics of creative thinking in design. Dissimilar concepts (thus, probably the divergence of concepts) are regarded as being connected to creativity (Finke, 1996; Wisniewski, 1997; Nagai and Taura, 2006). From the results of this study, a convergence is clearly expressed in the cases of more dissimilar pairs and the converged concepts are often with high originality (see cases (2)A, (3)B and (4)B,C in Table 4). Thus, convergence can probably be associated with the process of creative thinking. The abovementioned methodology may assist the exploration process involved in the creative thinking by (exploration process involved in the creativity) facilitating feedback on convergence.

In comparison with previous methodological approaches to the concept generation stage of the design process this study adds support of convergence. For example, the study of Segers, de Vries, and Achten (2005) showed that word stimuli affect designers in the early stages of architectural design. Word graphs were evaluated as being helpful in breaking the designers' mental fixations and enhancing creativity. In addition to the word stimuli, in our study, we supported the convergence of meaning.

The study of Chiu and Shu (2007) focused on verb stimuli in predefined tasks. Verb stimuli have been successfully used to solve functional problem statements. In another study, Chiu and Shu (2008) showed that conceptual stimuli with opposite relations played a role in solving functional problems. Thus, we can state that verb stimuli contribute to functional problem-solving tasks. Action concepts also play an important role in the creative design process (Nagai and Taura, 2006).

In this study we define only the meaning elements and the convergence between them, but not the task, which is why we focus on nouns. Various studies have outlined the importance of the conceptual processing of nouns for the generation of creative ideas in the early stages of design (Finke, 1996; Nagai and Taura, 2006; Wisniewski, 1997).

The limitations of the study are connected with the existing visual representation. The utility of the representation is limited by its general features. Excluding some of the information might improve the exploration process. Adding features that stimulate the convergence processes in conceptual design (providing suggestions by comparing the shapes of the two meaning elements and using 'shape of' constructions, e.g. 'wave shaped violin') can positively influence the design. However, the results indicated that the convergence was successfully integrated into the design methodology.

7 Conclusion

We introduced a formal approach to explore the SoME and evaluate the convergence in the conceptual design process. The results indicate that this methodology will help designers in the convergence stage of design. Moreover, the findings are step towards our comprehension and enhancement of creative processes in the conceptual design process. However, this case study requires to be further investigated, and the tools involved in this process require to be further developed.

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