The Theoretical Framework for Creative Visual Thinking

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Introduction

Although designers during design process can form mental images in their heads, the majority of them do much better when those images are out in their internal worlds, in the form of drawings on paper or monitor screen. Therefore the main work of creative visual design is done through the dialogue with graphical outputs, which is very difficult to handle in a formal way. It is often simplified and perceived as *seeing* and *doing*. Understanding of this dialogue helps us to learn about constructive power of perception that has profound implications for creativity design [1]. This paper is an attempt to present a formal coherent framework for creative thinking which includes this dialogue, where human visual perception is treated as a dynamic process. The framework will be called a *creative visualization system*.

The paper deals also with other important aspects of creative design: *constructive perception* and *semantic convention*. The former is based both on external graphical information and on the constructive mental process. The latter governs the process of designing in which the designer creates drawings. In this paper the constructive perception is treated as a composition of a perceptual action (normal seeing) and a functional one (visual intelligence and imagination). Whereas the semantic convention is defined as a binary relation between constraints on graphical representations and constraints determined by designer's requirements.

A manner in which the designer thinks about design problems with graphical outputs is the next essential aspect for creative design. There are two major categories of thinking: *divergent* and *convergent* [2]. Divergent thinking is imaginative and intuitive. This ability has been associated with skill in the arts and it has been interpreted as an open-ended approach seeking alternative. This types of thinking is based on abduction and it is typical in an inventive design when a number of unknown design concepts is sought. Whereas convergent thinking is associated with science. It requires deductive and interpolative skills. The convergent thinking is

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logical and rational. Taken as a whole, design is a divergent task. However, during the process of creative design good designers are able to develop and maintain several lines of thought, both convergent and divergent. The proposed framework, in the form of the creative visualization system, enables one to handle both types of thinking in a formal way [3, 4].

Design Actions and Domains

Recent frameworks for creative design focus on dynamic character of the context in which designing takes place. The process of design is described by means of actions defined with the help of both an *internal world* and an *external world*. The internal world is built up inside the designer in terms of concepts and perceptions, while the external world is composed of graphical representations outside the designer [5].

Actions

During the design process designer's actions connect his/her internal and external worlds. The following four types of actions are distinguished [6]:

- *physical* actions—drawing, copying and erasing elements of graphical outputs,
- *conceptual* actions—finding requirements and setting design goals,
- *perceptual* actions—discovering visual features of drawings, such as for instance spatial relations between visual elements, and
- *functional* actions—associating meaning with features discovered in the perceptual actions and valuation of drawings.

This classification of actions makes designer's dialogue with drawings easier to characterize.

Domains of Creative Visualization

To unify the description of the considered designer's dialogue three components are distinguished (see: Fig. 1):

- a domain $\boldsymbol{D_T}$ of *design tasks* related to formulation of design problems in terms of requirements,
- a domain $\boldsymbol{D_A}$ of *physical design actions*, and
- a domain $\boldsymbol{D_V}$ of *visualization sites,* which consists of drawings along with a surface on which they are drawn.

Design process presented in the context of these three domains can be described with the use of two environments: an internal and external worlds.

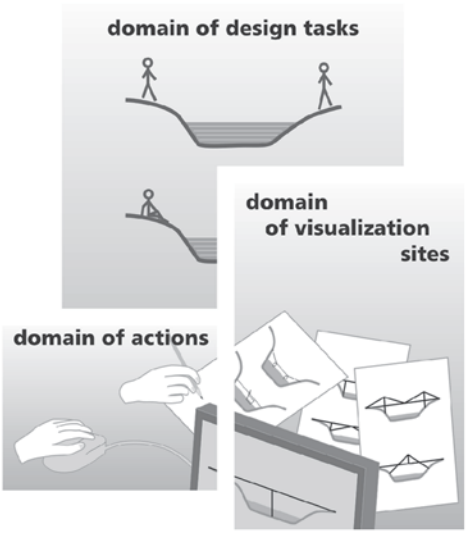

Fig. 1 The do-mains of creative visualization

The domain of design tasks is related to the internal world and is modified during the design process. At the beginning it contains only initial requirements, while later the devised requirements are added. When the designer determines design goals and requirements then conceptual actions are undertaken. Physical design actions of the domain of actions are related to the external world. The domain of visualization sites in the external world is associated with undertaking perceptional actions in the internal world. The remaining actions constructed in designer's brain are induced by perception which strongly determines the course of designing.

Types of Designer's Dialogue

Our study on creative design starts with the presentation of two types of designer's dialogue described in the context of the domain of tasks, the domain of visualization sites and the domain of actions. First, sketching, which commences design process is discussed and then the process of computer aided visual designing.

Sketching

Sketching is one of the best ways to absorb design ideas (Fig. 2). During drawing pictures there exists the need to pass an idea from mind to hand and to eye [2]. The mind in which the designer tries to formulate of design problems is related to the domain of design tasks. The hand symbolizes the domain of actions consisting in

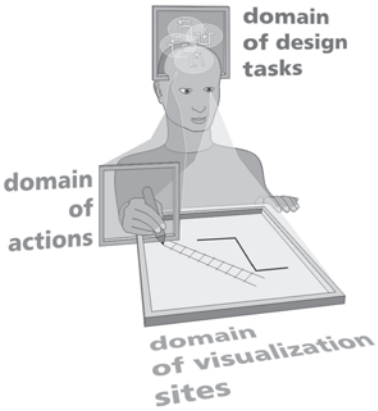

Fig. 2 The process of sketching

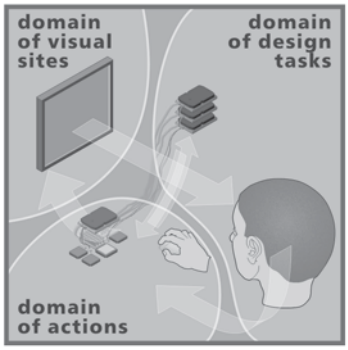

Fig. 3 Computer aided visual design

making drawings with a pencil or a pen. The eye is associated with designer's visual perception of the drawings on sheets of papers belonging to the domain of visual sites. In actions of drawing stimulation and perception are tightly intertwined [7].

Computer Aided Visual Design

The second example presents computer aided design process with the use of visualization. The domain of design tasks is related to formulation of design problems by the designer with the aid of computer system (see: Fig. 3).

Actions are aided by computer tools, for instance graphical editors or functional-structure editors. The domain of actions is about drawings with the use of a mouse, a tablet or a programming language. The results of performing physical actions are displayed on the monitor screen which belongs to the domain of visualization sites. Expression drawings on the monitor screen with the use CAD—tools has to respect the semantic convention between designer's requirements and requirements on graphical outputs.

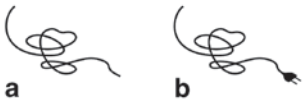

Fig. 4. **a** A random irregular scribble, **b** The same scribble with addition of a plug shape becomes a flex

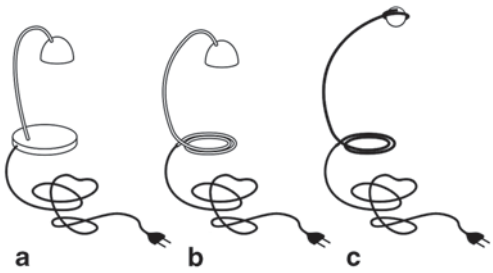

Fig. 5 The phases of designing lamp

The Fundamentals of Creative Design

Constructive perception and semantic convention are fundamental aspects of the creative design which can be described in the context of the considered three domains.

Constructive Perception

A composition of a perceptual action and a functional one can be seen as *constructive perception* which combines normal seeing with visual imagination [5]. The constructive perception connects the domain of visualization sites with the domain of design tasks, i.e., the external world with the internal one. Moreover it can stimulate a conceptual action in the form of a devised requirement added to the domain of design tasks.

Example 1 The following exercise allows one to understand how the constructive perception of lines with one simple shape visual added can be used as part of a creative design process (compare: [7], pp. 216–217). Let us make a simple scribble without thinking about representing anything (Fig. 4a). Let us add a shape of a plug to transform this meaningless scribble into an electric wire (a flex) shown in Fig. 4b. An irregular looping line can be seen as a looping flex.

This exercise can be a source of inspiration for drawing a piece of equipment, for instance a lamp connected through the flex to an electricity supply. The first attempt of adding a classical lamp is shown in Fig. 5a. After the perceptual action searching for similarities between design elements the lamp shape is modified (see: Fig. 5b). The final solution is presented in Fig. 5c.

Semantic Convention

Designer's requirements can be treated as constraints on expected design solutions. Forms of visual constraints on the drawings in the domain of visualization sites are different from forms in which the designer expresses requirements related to the design tasks. When taking physical actions the designer encode information about the object being designed in the fictional depicted world. He/she also deals with visual organization of the drawing, which includes form, proportion, line, shape and so on. The correspondence between constraints on drawings and constraints on designer's requirements determines a *semantic convention* which relates constraints on graphical representations to designer requirements.

A System of Creative Visualization

In this section creative design is described in the framework of the system of visual design. The system has three major components, including a domain of design tasks related to the imposed design problem and a domain of actions connected with the process of drawing in terms of physical actions, and a domain of visualization sites being about perception. Each of the three domains is defined with the use of the notation of classification, i.e., is described by a pair containing a set of objects to be classified and a set of types used to classify the objects [8].

The Domain of Design Tasks

Design task can be posed in terms of the design solution expected. A design solution describes a certain situation which is classified by types.

A domain of **design tasks** *is* a triple $D_T=(T, \Sigma_T, |-_T)$ consisting of a set T of objects to be classified, called *design situations* of D_T, a set Σ_T of objects used to classify the situations, called *types* of D_T, and the relation $|-_T$ contained in $T \times \Sigma_T$, called a *belonging* relation.

If a design situation $t \in T$ is classified as being of type $\sigma \in \Sigma_T$, we write

$t \,|-_T \sigma$ and say *t belongs to* σ Design situations are classified by design requirements in the form of expressions or sentences of the *propositional logic.*

Example 2 Let us consider the very simple example of the domain of design tasks. Its role is only to provide insight into the nature of this domain.

Let T be a set of decorative elements with rotational symmetry.

$\Sigma_T = \{\sigma_1, \sigma_2\}$ contains two types in the form of the following sentences:

$\sigma 1$: design has four-fold rotational symmetry,

$\sigma 2$: design is in the shape of a circle.

Fig. 6 Three de-sign situations

Three design situations of *T* shown in Fig. 6 are classified by two requirements expressed by sentences σ_1 and σ_2. Element t_1 in Fig. 6a is not either of type σ_1 or of type σ_2, whereas element t_2 in Fig. 6b is of type σ_1. Fig. 6c presents element t_3 which is both of type σ_1 and of type σ_2.

The Domain of Visualization Sites

Drawings are graphical representations which designers use in their external world. An arbitrary surface on which a drawing is made along with this drawing is called a *visualization site*. Two different drawings on the same surface, e.g., on the sheet of paper or on the monitor screen determine two different visualization sites. A visualization site is itself a situation in the external world, and as such it belongs to its own domain of classification, just as a design task situation does.

A domain of **visualization sites** is a triple $D_V=(V, \Omega_V, |-_V)$ consisting of a set *V* of objects to be classified, called *visualization sites* of D_V, a set Ω_V of *types* used to classify the situations, and the *belonging relation* $|-_V$ contained in $V \times \Omega_V$.

Visual perception plays an essential role for the domain of visualization sites. If a visualization site *v* is used to find a design solution *t* then *v signals t* and we write $v \rightarrow t$. *Signaling,* denoted by $\rightarrow$ is a binary relation from *V* to *T*.

As it has been considered, the semantic convention relates constraints on graphical representations to designer requirements. Therefore, types of Ω_V that classify visual sites must be related to types Σ_T that classify design situations. The semantic convention is expressed as a binary relation => from Ω_V to Σ_T. The constructive perception is described by two relations, signaling and semantic convention, which together form a mapping from the domain of visualization sites to the domain of design tasks. The designer discovers information σ related to the design situation *t* from a visual site *v* only if $v \rightarrow t$ and there exists ω such that $v |-_V \omega$ and $\omega => \sigma$.

Example 3 Let us come back to the Example 2 and assume that after drawing the flex shown in Fig. 4b the process of designing a lamp has been continued with the use of the computer with the visualization site being a monitor screen. Usually the design process is started with an empty monitor screen (initial visualization site). Each drawing (Fig. 7) being a step of a design solution leading to a final drawing is treated as a different visualization site and constitutes a different design situation.

Fig. 7 The visual sites signaling the task of designing a lamp

The Physical Design Actions Domain

The last of the three domains describes. physical actions treated as a certain kind of events in the external world that start with an initial situation and result in another situation.

A domain of **physical design actions** $D_A = (A, \Delta_A, |\!-\!A)$ consists of a set A of physical actions to be classified, a set of types used to classify the situations, and the *belonging relation* $|\!-\!A$ contained in $A \times \Delta_A$.

If situation $a \in A$ is classified as being of type $\delta \in \Delta_A$ we write $a \; |\!-\!A \; \delta$ and say *a belongs to* δ.

The System

Summing up the discussion on the three design domains and relations between them, a visual design system is defined.

A **system of creative visualization** is a 5-tuple

$$\boldsymbol{CV} = (D_T, D_V, D_A, \Rightarrow, \rightarrow), \text{where}:$$

- D_T is a domain of design tasks,
- D_V is a domain of visualization sites,
- D_A is a domain of physical design actions,
- $\Rightarrow$ is a semantic convention, and
- $\rightarrow$ is a signaling relation.

The system ***CV*** allows one to define essential elements of creative visual designing.

Creative Visual Designing

Studies of designers, artists, and scientists have identified some common elements of creative visual thinking. Looking at the stages of the creative process from a generalized point of view, four steps are distinguished [1]:

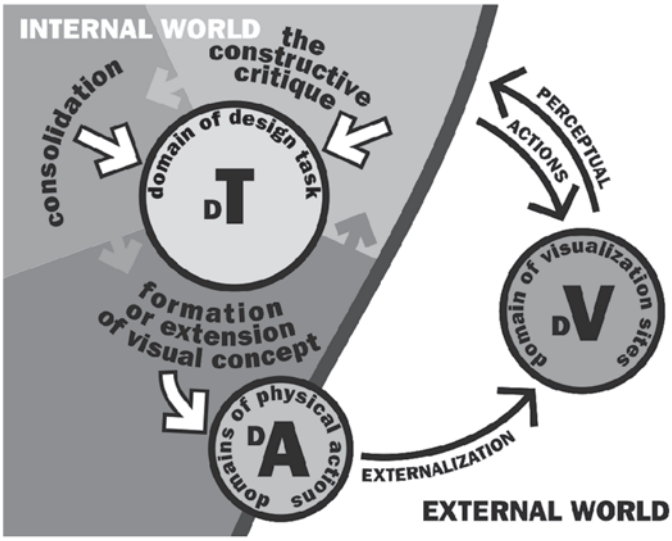

Fig. 8 Creative visual thinking

Fig. 9 Emergent shapes

1. formation of the visual concept—depending on the application, a free or stereotyped graphic idea is proposed,
2. externalization—a visualization site is created,
3. the constructive critique—constructive perception is used,
4. consolidation and extension—new requirements are formulated on the base of conceptual actions.

Figure 8 presents creative visual thinking in the framework of the system of creative visualization. The visual concept is forming first by means of types $\sigma_1, \ldots, \sigma_n$ expressing design requirements of the domain D_T. Then these types are transformed into types of actions $\delta_1, \ldots, \delta_k$ allowing one to determine a sequence of physical actions $a_1, \ldots, a_m$ of the domain D_A for drawing an appropriate graphical representation on the visualization site.

One of the element of the process of the constructive critique may be the *emergence* of new shapes. The designer discovers a new shape (which had not been consciously constructed) related to the design situation from a visual site.

Example 4 Let us consider the scribble shown in Fig. 9a. An example of emergent shape drawn white line is presented in Fig. 9b. The perceptual action allows the designer to notice this shape, while the functional action associates it with shapes

Fig. 10 Designing a lamp

of a lamp. This association becomes a new inspiration in creating a form of a lamp (Fig. 10) and enables the designer to formulate a devised requirement σ* (a new type of Σ_T).

Let ***CV*** *be* a system of creative visualization. We say that **emergence** occurs in ***CV*** if:

- The sequence of physical actions realizes a fact $\omega^* \in \Omega_V$ on the visualization site.
- According to the semantic convention ($\Rightarrow$) an element ω* of Ω_V can be transformed into a new type σ* of Σ_T

Occurring emergence is an example of the convergent thought. The process of designing shown in Fig. 5 is an example of the divergent thought. Both convergent thought and divergent thought stimulate consolidation and extension in the process of creative visual thinking.

Conclusions

Nowadays, visual designer environment plays an essential role in creative visual designing. The proposed system of creative visualization shows different aspect of visual design process. To develop this system, which is necessary, in the one hand for deeply understanding the fundamentals of creativity, and in the second hand to devise new visual tools, a higher level of abstraction had to be used. The new framework for creative design allows one to hold concepts from different disciplines (engineering and psychology) in a formal way and shows influence of different perspective on the design theory.

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