

Visual Reasoning and Knowledge in the Design Process

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Abstract: In design studies, information-processing and reflection-in-action paradigms were mainstreams in describing designing, but there seemed to be a discrepancy between design practice and their descriptions on the interactions between visual aesthetic reconstruction and conceptual knowledge transformation. This study took the viewpoint of the visual design reasoning theory where abstract, conceptual knowledge and perceptually-based knowledge were interlinked. The major purpose was examining the design process using visual design reasoning to discover the essential features of design activities. The minor purpose was exploring the utility, representation, and categorization of design knowledge and its interaction with sketches. The methodology was protocol analysis, the most frequently applied method in design thinking research. Incorporating with content-oriented coding scheme, this study analyzed the cognitive process of designers, including the use and application of perception-based and meaning-based knowledge, and importantly the interactions between them. Three main findings were: first, a strong connection between sketches, perception, and functional references illustrating the design knowledge of perception-based and meaning-based. Their interactions via sketches establish the design process as a visual reasoning process. Secondly, revisiting existing sketches bridges different design stages to a continuous design process of visual reasoning to maximize designers' effort. Third, the design process of visual reasoning itself is a way to obtain design knowledge. The implementation in design education and computer-aided design are drawn.

Key words: *Visual Reasoning, Design Knowledge, Sketches, Protocol Analysis*

1. Introduction

Sketches made by designers during the design process play multiple roles for both designers and the design process [1]. They serve as an external memory to augment the limitation of human cognitive abilities. Further, sketches act as the medium that designers use to communicate with themselves and others, and also as the triggers that enable designers to reason on a design problem [2-7].

It is the last role that reflects an increasing recognition that a perception-based view of design sketches is not sufficient to describe their roles in design. We proposed that this type of conceptual thinking process relates directly to sketches and visual perceptions. The increasing insight of this type of thinking process comes from our better understanding on the roles of sketches, and their relationship to different parts of the design process.

The essential relationship between sketches and the design process was highlighted by Schön & Wiggins [3].

The kinds of seeing and their functions in design and the relationship between seeing and the appreciative system were related to the functional references attached to the sketches themselves. The dialectics between figural reinterpretation and non-figural functional references in design sketches was proposed to describe the same idea [2]. The inappropriate dichotomy between analytic and synthetic thinking processes was discussed to emphasize that design visual reasoning was not equivalent to vision, but was a production of thought via visual imagery [4]. Designing therefore was considered essentially as the interplay between two types of knowledge - abstract, conceptual knowledge and perceptually based knowledge. Visual and spatial reasoning are the cognitive processes that link these two types of knowledge [8].

1.1 Visual reasoning

Visual reasoning is the cognitive process that links abstract, concept knowledge and perception-based knowledge [9]. It refers to the drawing of inferences from visual representations to abstract knowledge. Consequently, sketches are different from images such that sketches physically reflect conceptualizations of the visual reasoning process [9]. Through research on children's drawings, sketching maps, and geometric design, Tversky [9] proposed that drawing are representations of reality and can provide insights into conceptualizations [9]. The representation, segmentation, and orders of depictions reveal the organization and components of the underlying conceptual elements. Drawings are thus clues to conceptualization of mental domains. Studying the segmentations and orders of sketches in the design process, therefore, provides insights into the operations and schema of design conceptual modules.

These ideas constitute our hypothesis that the conceptual design process using sketches is a visual reasoning where sketches are the media amongst perceptual and conceptual knowledge, enabling the design process to happen.

1.2 The inter-linkages in the design process

The design research community has been addressing the interactions between different cognitive levels in the design process, including physical, perceptual, functional, and conceptual [10]. Sketches were described as visual cues for their association with functional issues, and as the physical settings in which conceptual thoughts were constructed on the fly in a situated way. The roles of sketches in design were triggers and connectors. Similarly, the design process has been categorized as a mixture between sensor-driven processes and goal-driven processes to emphasize the inter-linkages and dependencies amongst these four cognitive levels [11].

The design process is therefore a conversational and iterative process between a designer's internal ideas and external sketches. Design sketches serve as instantiations of emerging ideas and inspiration of new ideas [2, 4, 12, 13]. They benefit designers in reasoning about non-visual elements via the designer's functional references in visual depictions. The functional references and corresponding design knowledge are articulated through sketches to advance the design process [10, 13].

A designer drew to externalize his/her concepts, and these depictions sometimes provided visuo-spatial emergence back to the creator. At this instance, the depictions were associated with the designer's perception, not only passively representation. Furthermore, most of the sketches drawn by designers pertained to some meanings in design, for example, an arrowed line illustrated a view from the front window to the garden. Some sketches however did not stand for any specific meanings. These were designers' incubators of inspiration through arbitrary doodling and graffiti. They were perceived as what they were on the paper without any additional perceptual or functional information. The sketches pertaining to some functional meanings were therefore associated with

