The Roles of Sketches in Early Conceptual Design Processes

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Abstract

Design sketches are believed to play essential roles in early conceptual design processes. Exploration of how sketches are essential for the formation of new design ideas is expected to bring important implications for design education and design support systems. Little research has been done, however, to empirically examine the ways in which designers cognitively interact with their own sketches. Using a protocol analysis technique, we examined the design thoughts of an architect from the following point of view; how he drew depictions, inspected depicted elements, perceived visuo-spatial features, and thought of non-visual functional or conceptual information. The findings suggest that design sketches serve not only as external memory or as a provider of visual cues for association of non-visual information, but also as a physical setting in which design thoughts are constructed on the fly.

Introduction

Designers typically use less rigid forms of diagrammatic or pictorial representations, such as freehand sketches, in early conceptual design processes. It is widely believed that sketches play an essential role in the formation of creative ideas. Research on the roles of sketches in design processes is expected to lay the foundation for design education in the effective use of sketches and for the development of computer tools to support sketch-based design.

Relevant to this is a more general question. That is, why and how do diagrammatic or pictorial representations facilitate people's problem-solving or decision-making? The ubiquity of these representations in our everyday life, e.g. in public signs and icons, maps, textbooks, advertisement and brochures, intensifies the significance of the pursuit of this issue. Newell and Simon (1972) discussed how these representations serve as an *external memory*. Externalizing intermediate results of inference as visual tokens reduces memory load. When some of the results need to be available for furthering inference later in problem-solving, people have only to visually revisit the corresponding tokens.

Recent research has revealed more active roles of external representations. Inspecting representations allows visuo-spatial information to naturally emerge in perception (Koedinger & Anderson, 1990). Emergence of visuo-spatial information sometimes occurs in unexpected ways, because externalizing a set of ideas forces a specific organization of elements (Stenning & Oberlander, 1995). The visuo-spatial information extracted will, in turn, make a central contribution to inference in two ways. First, it is used for inference as its major component. This is the case where the information extracted corresponds to a meaningful predicate in the domain, for example, "equalness" in size in geometry proof problem-solving (Gelernter, 1963), and "adjacent" arrangement of components of a device in physics problem-solving (Narayanan, Suwa & Motoda, 1994). In these cases, external representations serve as a *spatial model*, providing a concrete appearance of the problem-structure and thereby encouraging people to attend to particular predicates.

Second, the visuo-spatial information extracted becomes the *visual cues* for association or reminding of abstract concepts, functional issues, relevant past experiences, or problem-solving strategies. Larkin and Simon (1987) discussed that proximity on a diagram could be a good guide for solvers to decide what to infer next. Petre (1995) discussed that indentation, alignment, white space, and symmetricality in the notation of programming language help people understand the structure of programming components and their functional relationships.

These views, especially the view *as a provider of visual cues*, apply to design sketches as well. Arnheim (1977) enumerated many examples in which forms of architecture, e.g. shapes, sizes, and spatial arrangements of elements, carry abstract meanings, functions and psychological effects on people for which the architecture is designed. Suwa and Tversky (1997) suggested that experts' tendency to maintain a successive chain of related thoughts is attributable to the ability to use visual cues for association of functions. Further, designers tend to associate a visuo-spatial feature with one concept at a time and then with another afterwards (Goel, 1995; Goldschmidt, 1991). This act, called re-interpretation, is believed to be involved in the formation of creative ideas.

Design sketches have another important characteristic. They are not something given to designers at the beginning of a task, but something which designers dynamically produce from scratch during the process. By putting ideas down on paper and inspecting them, designers see new features and relations that suggest ways to refine and revise their ideas, and thereby are driven to draw again. Schon and Wiggins (1992) discussed that this sort of interaction with sketches is the essence of early design processes.

Little research has been done, however, to empirically examine how designers cognitively interact with their own sketches. What we mean by cognitive interaction is a whole