Transforming shape in design: observations from studies of sketching

Miquel Prats, The Design Group, The Open University, Milton Keynes, MK7 6AA, UK
Sungwoo Lim, Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK
Iestyn Jowers, Department of Mechanical Engineering, University of Leeds, Leeds, LS2 9JT, UK
Steve W Garner, The Design Group, The Open University, Milton Keynes, MK7 6AA, UK
Scott Chase, Department of Design, Manufacture & Engineering Management, University of Strathclyde, Glasgow, G1 1XJ, UK

This paper is concerned with how design shapes are generated and explored by means of sketching. It presents research into the way designers transform shapes from one state to another using sketch representations. An experimental investigation of the sketching processes of designers is presented. Connections between sketches are defined in terms of shape transformations and described according to shape rules. These rules provide a formal description of the shape exploration process and develop understanding of the mechanics of sketching in design. The paper concludes by discussing the important phenomenon of 'sub-shape' and suggests that a computational mechanism for detecting sub-shapes in design sketches might augment explorative sketching by providing important opportunities for manipulating and generating shape in design.

Keywords: drawings, conceptual design, shape transformations, shape rules, computer-aided design

In creative design, free-hand sketches are frequently used to record ideas for later use and to rapidly explore design alternatives. A key benefit of sketching, in fields such as product design and architectural design, is that it assists designers in the development of various characteristics of design ideas such as form and shape in a low-cost, fast and flexible way. Studies of design suggest that designers proceed by cycles of see-move-see (Schön and Wiggins, 1992). *Seeing* concerns a process of reinterpretation of design elements in a sketch and *moving* concerns transformations of the reinterpreted design elements. This two-way conversation between designer and representation – the maker and the made – commonly results in the generation of sequences of related sketches in which design elements are repeated,

Corresponding author:
Miquel Prats
m.prats@open.ac.uk

www.elsevier.com/locate/destud
0142-694X $ - see front matter *Design Studies* **30** (2009) 503–520
doi:10.1016/j.destud.2009.04.002

recognised and manipulated (Prats et al., 2006). Some research has focused on the patterns and associations that designers see in their sketches (Liu, 1995; Suwa and Tversky, 1997), and it has been suggested that such patterns are valuable externalisations of designers' cognitive processes (Lawson, 2006). However, there has been little research into the mechanisms used to transform design elements in sketches. Our research goes some way toward this goal.

The challenge of developing computational tools to support sketching in the early stages of design has produced significant interest in the design research community (Saund and Moran, 1994; Gross and Do, 1996; Leclercq, 1999). CAD (Computer-aided design) tools have proven to be highly effective for supporting down-stream design tasks such as analysis or manufacture and it is believed that they could also be valuable in the exploration of design alternatives, possibly by suggesting new paths of exploration to designers (Woodbury and Burrow, 2006). However, the mechanisms necessary to fluidly explore design alternatives are not readily afforded by current computational design tools. As noted above, reinterpretation of conceptual representations is a vital aspect of design exploration and CAD has traditionally struggled to support this because of the precise and structured geometry through which it works. There can be an inconsistency between patterns and structures that are perceived in a CAD model and the transformations that are afforded by the formal geometric structures used to construct the model (Scrivener, 1982). In order for CAD systems to support the early stages of design this inconsistency needs to be resolved. In particular it is necessary to explore mechanisms that can assist designers in recognising and transforming perceived design structures, regardless of method of construction.

This paper primarily outlines an experimental investigation into the sketching of architects and industrial designers. The investigation was particularly concerned with the developing form of design concepts, and the shape transformations that led to this development. Analysis of the data produced led to the definition of a set of shape transformations commonly used in sketching. The transformations are formalised according to shape rules that explicitly describe connections between sketches and allow for a better understanding of sketching in design. We also include speculation on how this knowledge might assist the development of a computer-based mechanism that might scrutinise designers' sketch outputs and lead to interactive and automatic manipulation, and perhaps even the generation of shape conjecture. It is proposed that the key to this development lies in understanding 'sub-shapes' manipulated in sequences of design sketches.

1 Sequence of sketches

Sketching is a common activity in a range of design disciplines. Although the styles of sketches may differ between different disciplines, the role that