Visual divergence in humans and computers

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Studies of design creativity have underlined the importance of divergent reasoning and visual reasoning in idea generation. Connecting these two key design skills, this paper presents a model of divergent visual reasoning for the study of creativity. A visual divergence task called ShapeStorm *is demonstrated for the study of creative ideation that can be applied to humans as well as computational systems. The model is examined in a study with human subjects, a computational stochastic generator, and a geometrical analysis of the solution space. The main significance of this task is that it offers a straightforward means to define a simple design task that can be used across research studies. Several scenarios for the application of* ShapeStorm *for the study of creativity are advanced.*

Keywords: creativity, sketching, computer models, solution space

Creative ideation is generally considered to involve divergent reasoning processes to generate original, useful and unexpected ideas (Maher, 2010; Schunn, Paulus, Cagan, & Wood, 2006). A majority of methods and techniques for idea generation prioritise quantity of ideas and suggest deferring evaluation; and research does suggest that more ideas generated in the early phases of the design process lead to more creative final outcomes (Yang, 2009). Divergent reasoning – the process of generating as many different alternatives as possible, is recognised as one core component of the design process. Visual reasoning has also been identified as an important function for design creativity (Goel, 1995; Kavakli & Gero, 2001; Shah, Millsap, Woodward, & Smith, 2012).

Divergent reasoning is usually assessed in linguistic rather than visual formats, and visual reasoning is often studied in relation to cognitive constructs such as perception, encoding and chunking, working and long-term memory, mental transformation and representation (Bilda & Gero, 2007; Shah et al. 2012). Connecting these two key design skills, this paper presents a model of divergent visual reasoning for the study of creativity. The aim of this work is to propose and demonstrate a design task or problem statement that researchers of

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design creativity can employ to study visual ideation. This type of assessment approach can be applied to humans as well as computational design systems, thus providing a foundational step towards the comparative study of human and computational creativity.

At present, studies of design ideation lack explicit and objective criteria to define the task or problem statement used in models and experiments. It is common practice in design creativity research to define significantly different design tasks or challenges for participants to generate ideas. General models of design ideation based on visual tasks are needed which can systematically guide human and computational studies. In other fields, classic problem statements are extensively used across studies although not without criticisms and caveats, i.e., the classic 'thumbs problem' (Taylor, Berry, & Block, 1958), the Remote Associates Test (Mednick, 1968), and the 'nine-dot puzzle' (Burnham & Davis, 1969), among others. The study of specialised assessment tools for specific design skills is an active research topic. The work presented in this paper aims to contribute an approach to be applied across research areas of creativity.

The way in which tasks are defined today can be problematic, and more so in studies of design creativity. The main problems include: a) design tasks are arbitrarily chosen and framed by the researchers making it difficult to compare results across studies; b) problem statements are framed in ad-hoc ways often excluding key information or constraints; c) tasks may or may not be partially structured, open-ended, and many require domain knowledge or refer to problem situations inspired by real world conditions, making it impossible to objectively assess performance, leading to d) strong dependence on domain experts to judge early ideas often poorly communicated in elementary representations; and e) early ideas that are produced in short sessions are, by definition, incomplete and some may contain subcomponents or partial aspects of merit that judges can easily oversee or inadequately reinterpret during assessment. Due to such lack of consistency in the study of design creativity, the constructs being analysed, the relevance of the findings and the validity of the claims remain problematic. It is difficult enough to systematically study the generation and evaluation of creative ideas, even more so when no basic agreement exists across studies.

This paper presents *ShapeStorm*, a model of visual ideation that captures key characteristics of design activity: no unique correct solution, adaptable problem formulation, combination of objective and subjective evaluation criteria, and exploration of solution space by visual reasoning (Goel, 1995). In addition, *ShapeStorm* is suitable for the computational study of design creativity and innovation, and it is suitable for a range of experimental conditions with human subjects. In the remainder of the paper, Section 1 presents a background analysis of tasks used across creativity research highlighting current

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