CREATIVE DESIGN SITUATIONS

Artificial creativity in communities of design agents

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Abstract. This paper presents the outline of experiments with a behaviour-based computational model of creativity in design called *Creative Design Situations*. This model aims to allow the study of social creativity through the computational implementation of a community of creative design agents.

1. Studies of Creativity

Whilst the study of creativity in general has been a topic of interest in various disciplines, our current understanding of this distinctive human ability to create and innovate is still fragmentary (Runco and Albert, 1990). In design research, creativity has been the focus of a number of research efforts (Gero and Maher, 1989; 1993). However, there is still an inadequate comprehension of sufficient aspects of design creativity. This paper suggests that new approaches are needed to gain further insight into design creativity, particularly as a social phenomenon.

It is suggested that before trying to improve creativity, it is essential to know more about it, how is it produced and recognized, where and under what conditions does it occur, when does it start and finish, and what promotes or hinders it (Runco and Albert, 1990).

2. Experimentation

One feasible way of building a more complete understanding of the creative phenomena is by manipulating and experimenting with the presumably numerous kinds of factors and processes that have been related to the occurrence of creative solutions throughout the research literature (Runco and Pritzker, 1999). This research presents a way of experimenting with creativity when seen as a complex system (Mataric, 1993), an approach that has yet to be better understood and applied in this kind of studies, and which could provide an important contribution towards the formation of a theory of creativity.

Under this view, the occurrence of creativity can be considered as consisting of emergent behaviour of a system that is not directly proportional to the sum of its parts. Thus, such difficulty to clarify the exact causes and conditions under which the creative event takes place has often caused it to appear surprising and inexplicable to some researchers (Gardner, 1993). This controversy could suggest, amongst other things, that creativity takes place in relation to certain system states within a multifaceted set of causes and possibilities, whose results are surprising only when the complete historical sequence remains inaccessible.

As with other complex systems such as the evolution of species or metazoan formation, the development, coherence, and persistence of creative systems could depend on extensive interactions, the aggregation of diverse elements, and adaptation or learning (Holland, 1995). And as in the study of such complex adaptive systems (CAS), general principles could rule creative behavior, principles that research needs to disclose. The next section sets the foundations for a behaviour-based approach to experimentation with creative systems.

3. Behavior-Based Model

Artificial Life, an example of behavior-based experimentation, is described by Langton (1989) as the synthetic approach to biology. Rather than take living things apart, it attempts to put living things together, in this way arguing that certain phenomena are most appropriately treated by a synthetic approach where a logical form is abstracted from the natural problem and implemented in a computer program that serves as a laboratory to experiment with the determination of collective behavior.

A behaviour-based study of creativity in design uses insights from artificial life to explore the dynamics of interacting information structures, not by attempting to 'explain' creativity as a kind of computer program (and in this way avoiding the quandary of computers being considered alive, intelligent, or creative) but rather by supporting informational universes within which dynamic populations of individuals engage in a form of creative behaviour (Pattee, 1996). Figure 1 illustrates a behavior-based approach to modeling creativity in design. From the modeling of behaviors in the microscopic dimension emerges the synthesis of collective behaviour of interest in the macroscopic dimension.

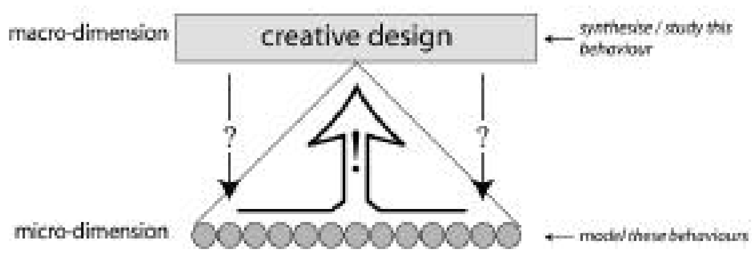

Figure 1. Behaviour-based bottom-up approach to modeling creativity; after Langton, 1989.

In artificial life models, the behaviour of animats is studied by focusing on aspects of individual conduct and the ensuing dynamics at the collective levels. Reproduction, forage, migration, climate changes, and other phenomena are abstracted from real animal species, implemented in experiments, run, and their results analyzed thus potentially providing insights into animal behaviour (Cliff et al., 1994) and robot design (Steels, 1990). Correspondingly, behaviour-based models of creativity need to address aspects of individual and collective human behaviour in simplified computer programs that facilitate the study of their occurrence and interaction; that is the aim of this approach to the modeling of creativity presented in the following section. Table 1 compares the behaviour-based approach to the knowledge-based modeling of creativity.

TABLE 1. Approaches to the computational modeling of creativity

Behaviour-Based Artificial Creativity	Knowledge-Based Artificial Creativity
Aims to reproduce creativity in order to study it	Aims to study creativity in order to reproduce it
From synthesis to theory analysis	From theory analysis to synthesis
Assesses soundness of theories	Assesses soundness of results

4. Creative Design Situations

This section presents a model of creativity in design called Creative Design Situations (CDS). This aims to serve as an experimental framework by which different insights and various thought experiments can be implemented in computer applications that facilitate the exploration of hypotheses potentially associated with creative behaviour in design. The CDS model is based on a possible set of socio-cognitive components that have been correlated to the occurrence of creativity by relevant studies that characterize this as a multidimensional phenomenon in which genetic, cognitive and social levels interact (Findlay and Lumsden, 1988).

The term *situation* is used in the CDS model to refer to the state of the design and the designing environment. What this notion encapsulates is that creativity is not an inbuilt property of a design (like its color or the material it is made from), but exists only as a function of a system composed by the interaction between the design and its environment. Such an environment can include the design agent, the evaluator, the context, the period of time, the means of interaction between agents, and any other aspect of interest in the study. Under this view, creativity transcends the individual reasoning process to include its *situatedness* (Clancey, 1991). As a result, it allows that the same design can be considered creative or not under certain circumstances, within certain periods of time, in relation to other existing designs, and by some evaluators, etc.

In descriptive terms, a Design Situation (DS) can be seen as a transitory worldview within which a design solution is generated or evaluated by the individual(s) found in that situation. A change of any given element that comprises a DS could yield a different relation between the design and its environment, and so a design could succeed or fail a creative assessment even if the object itself were left unchanged – since its situation did. A key role in a DS is played by the designer (a design agent), who may directly construct its DS or adopt an existing DS, or elements of it. Design agents that share a common DS are considered members of a community of designers. More formally, a DS can be defined by at least four essential components:

1. problem representation
2. design space
3. design processes
4. evaluation criteria

When a design agent constructs or adopts a DS, at least these four components are either implicitly or explicitly present significantly shaping the outcome and thus importantly play a role in determining its final creativity. Problem representation stands as a working formulation or interpretation that can either be individually constructed or socially accepted. This represents a bounded way of dealing with a potentially infinite set of possible descriptions of a problem, giving place to a subsequent space of possible designs (Gero, 1996) Design operations refer to the available means of transforming the problem representation during the design process. This is referred to as design skill or techniques. Evaluation criteria are part of a DS by providing the parameters against which design solutions are evaluated. These criteria are used to evaluate current solutions and serve as a point of reference for past as well as for the generation of future possible solutions. However, such criteria are not fixed but are part of the construction of the design situation. In sum, from a situated point of view, the eventual generation of a creative solution is associated to the change in the way of interpreting the problem, the design means available, the resulting set of possible solutions, and the new applicable evaluation criteria.

Under such a definition, a Routine Design Situation (RDS) is one within which a well-known solutions are generated, and is shared by a large number of members of a community. A CDS could be seen as a DS in formation that needs to be fully explored, the condition of its components, their new possibilities and limits, being better understood only through the synthesis of further design solutions. At a societal level, a CDS is increasingly adopted by individuals that shape or reshape their community. The CDS model suggests that the production of creativity in design is strongly associated to the situatedness of the design and that a Design Situation could move from routine to creative throughout time.

A design solution of a CDS does not originate from the same problem representation, is not contained in the same design space, generated via the same operations and measured against the same criteria as a routine solution.

In this sense, the idea of Design Situation stands as a construct to denote a design space that is constantly constructed and modified as part of the interaction with a changing environment, i.e. akin the problem-finding and problem-solving interaction suggested in the co-evolutionary model of design by Maher and Poon (1996). Further details of the CDS model are presented elsewhere (Sosa, 2001).

A feasible CDS experimental program contains the following basic elements: a population of individuals or design agents; a common environment; interaction mechanisms between such agents; a design task,; and a set of design solutions. In such an experimental program, different behaviours can be observed and manipulated. Of particular interest are the emergence, diffusion and exhaustion of a Creative Design Situation. Various questions can be explored in a CDS program: How can individuals introduce novelty into their society? How can a problem be reformulated by both innovators and assessors? How can a creative artifact become routine over time? What individual, social, and environmental conditions may facilitate or hinder creative behavior? What is the degree of innovation supported by a society? What roles may assessment and misjudgment play in the definition of creativity? How may a community continuously self-define what counts as creative? How can communities and cultures be formed and reshaped after a creative solution? How can the body of shared elements in a community be transformed? How can novelty be individually driven and socially demanded? In sum, what low-level creative components may take part in the emergence of group-level innovation? And ultimately, how might these findings guide new support and learning systems in design?

5. CDS Experiment Framework

Consider an experimental setting as follows:

- an initial representation of the problem formulation,
- a set of existing solutions that follow a series of design requirements,
- a population of design agents with individual means of interpreting, representing and transforming the object geometry,
- a design task consisting in the generation of solutions that conform to the interpreted design requirements and that are different to the existing solutions,
- individual mechanisms for interpreting design requirements as well as for generating and sharing new representations among design agents,

- a common environment with variables such as communication mechanisms, performance threshold, credit allocation, evaluation criteria, etc.
- an observer to track and graph individual solution generation and collective performance over simulated time steps.

In a multi-agent system of this kind, agents can be biased with different characteristics to facilitate the study of various emergent phenomena and their correlation to the design situation A key phenomenon of interest is the formation of communities of agents, i.e., groups of agents that share commonalities, and their role in Design Situations. The experiment should provide evidence for the development of Design Situations from routine to creative and back to routine, as well as the capacity of a population of design agents to produce and assimilate creative solutions. Other experimental settings include homogeneity and heterogeneity in populations of design agents, direct and indirect communication processes, incremental and non-incremental design processes, competition between different DS in formation and cooperative phenomena among members of a community.

The kinds of results that are expected from these experiments are the group level phenomena related to creativity that are observed by regulating individual and environmental characteristics, as well as the feedback from the societal level to individual decision-making, i.e. the agents' situation awareness. From these results, relevant abstractions can be elaborated to describe components and interactions of such in vitro creative system, principles that may contribute to a theory formation of creativity.

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