Studies of Creativity and Innovation in Complex Social Systems

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Submitted to the workshop 'Design out of complexity'
University of Central London, 2nd of July 2005

Number of words: 2789

1. Designers and Social Change

When designers shape the built environment, they have the potential to trigger cycles of change in our societies. Designers that do so, are regarded as creative practitioners, and users or consumers of their artefacts are described as adopters of these solutions in a process of diffusion of innovations. Recent instances of design artefacts that have transformed important activities include portable music players and digital cameras. Some of these products and their designers are ascribed a creative value by different stakeholders of a social system, including adopters, critics, and peers. Design research has been largely circumscribed to studies at the individual level, and in general to the generative processes of design. From such a viewpoint, it has been difficult to isolate the characteristics of creative products and practitioners. The study of design as part of complex social systems is a territory relatively unexplored that provides an alternative approach to the study of creativity, innovation, and design (Sosa and Gero 2004).

This paper presents a number of computational models of social aspects of design that we have explored in recent years. Firstly, Cellular Automata (CA) models have been used to explore the processes of aggregate group formation and periodic transformation. Secondly, social network models have been applied to the study of small group processes, in particular team brainstorming. Thirdly, multi-agent systems have helped to understand key factors in the interaction between designers, adopter social groups, and a shared body of knowledge. After reviewing some aspects of these systems and the type of insights obtained, this paper proposes a new line of inquiry of creativity and innovation in design based in the modelling of complex social systems.

2. Cellular Automata: Complex Social Systems

Cellular Automata (CA) models have been developed in recent years to explore a number of social phenomena including urban segregation (Schelling 1971), demand-supply economic systems (Epstein and Axtell 1996), social influence (Axelrod 1997), and innovation diffusion (Goldenberg and Efroni 2001). In general, these types of CA yield the same types of output: emergent patterns of coordination in decentralised systems, which can be explained by the ergodicity of such systems (a tendency of recurrent random walks in one and two-dimensional spaces) (Liggett 1999). However, one has to doubt whether such simplistic models really capture anything relevant about social systems. After all, their potential to generate emergent patterns has been used to proclaim a novel kind of scientific inquiry (Wolfram 2002), and is used in general terms to explain chemical, physical, and biological phenomena alike.

Criticisms of using these systems to explain social dynamics can be made at two levels. Firstly, the representation of units of behaviour has remained largely limited to a two-dimensional rectangular or hexagonal grid of equal height and width. Small variations in the shape, size, density, and arrangement of these units can have significant effects on the emergent patterns. Secondly, emergent CA patterns may be useful to replicate reactive behaviour determined by environmental cues such as ant foraging (Bedau 2000), but social agents can be assumed to build models of the social state, and therefore bottom-up linear emergence may be insufficient to represent social phenomena (Conte et al. 2001). Instead, lateral and circular emergence between individuals and groups becomes necessary, rendering CA models of limited use to explain social systems.

Nonetheless, CA may be useful to explore general dynamics of aggregate systems including social aspects of design (Sosa 2005). Our results illustrate, for example, that a combination of majority imitative behaviour and occasional dissent of a minority is likely to facilitate the spread of new ideas (Sosa and Gero 2002). When at the local and group levels imitation exists, the result is convergent structures or status-quo. When at the local and group levels unrestricted dissent exists, no group formation supports social coherence. Our CA models have shown that ratios of up to 10% of dissent in a society may support group formation and cyclic transformations (Sosa and Gero 2003).

3. Social Networks: Modelling Group Brainstorming

Social networks provide a promising framework to the study of complex systems in small groups (Arrow et al. 2000). We have applied social nets to study the empirical observation that individuals are more creative than groups –based in the notion that a higher number of original ideas are generated when people work separately than when they work in teams (Paulus 2000). This effect is often attributed to 'ideational productivity loss', which may include a number of cognitive and social factors (Paulus and Nijstad 2003). We have used a social net model of idea generation in a simple computational brainstorming experiment to inspect ideational productivity in independent individuals (nominal groups) and in teams (real groups) (Sosa and Gero 2005).

Our simulations capture a basic mechanism of production blocking, a factor associated to ideational productivity loss in groups. In this system, independent designer agents (nominal groups) consistently generate a larger number of unique solutions to a simple open-ended problem, than designer agents working collaboratively (real groups). Nominal groups (independent individuals) generate around 50% more distinct solutions, and up to 70% more explorative behaviour than real groups (teams).

In addition, the model is used to evaluate the role of group influence in different types of teams in order to understand how agent interaction can result in production blocking. Brainstorming simulations are conducted to gradually explore the range from groups where agents have no influence over each other (as in nominal groups), to the type of groups where every agent is equally likely to influence the rest of the group (as in real groups). Results show that as the scope of influence of ideas between team members increases, the total number of unique solutions decreases. The significance of these results is in the shape of the trend. The number of unique solutions rapidly decreases when influence between members of a team is increased above zero. In other words, a minimum amount of influence in a real group causes a sharp fall of production of unique solutions.

This system illustrates in a simple simulation the basic mechanisms of group influence that could support blocking in ideational productivity loss. This suggests that the mere sharing of conceptual structures in brainstorming sessions can explain a significant decrease in the number of novel solutions produced.

4. A Multi-Agent Framework of Design

In multi-agent based simulation of social phenomena the components exhibit more complex behaviours. We have defined a framework of social agency based on the DIFI view of creativity (Feldman et al. 1994). This model includes a small number of competing designer agents, a social group of clients or adopter agents, and a cumulative repository of design solutions or artefacts that represent the design domain. This architecture supports experimentation with the types of interactions between system components, which have been described in general as transmission from domain to individual, variation from individual to field, and selection from field to domain, drawing from evolutionary systems (Feldman et al. 1994). In this framework, social agency implies that agents adapt their behaviour to continuous changes triggered by the generation of new solutions and by an iterative process of social influence (Sosa and Gero 2004). This generative-evaluative coupling has been explored by manipulating some of the characteristics of social interaction and observing consistent effects on design behaviour and domain configurations (Sosa and Gero 2003).

In relation to individual differences, our studies suggest that their role in triggering group changes may be less significant than often assumed in the creativity literature. Of similar or higher importance can be situational factors such as the environmental conditions that support individual behaviour as well as the conditions that determine the group impact of such behaviour. In our models, the introduction of new values by an individual into a society is self-regulated indirectly by the occurrence of sufficient external conditions and by the stochastic aggregate behaviour of the group. Our studies also suggest that an increase of individual traits need not be proportional to the effect of individual behaviour. For individual abilities of designers to adequately account for effects at the group level, differences between individuals would need to be considerably high.

These types of experiments illustrate the idea that causality cannot be conceived as linear in complex systems (Wagner 1999): whilst initial individual differences stabilise over time due to contingencies modelled as stochastic processes, the inclusion of learning mechanisms further lessen the strength of initial individual differences. Thus, when designers are considered as part of a social system, more than individual isolated characteristics can be expected to matter. This reinforces the notion that the role of instruction, support and practice is at least as important as innate talent in determining performance (Ericsson and Charness 1995). These studies show the insufficiency of individual differences as predictors of innovative outcomes when individuals are considered not in isolation but as part of a dynamic group.

In relation to the social group –or field-, the social forces acting on the creative individual can be classified in two periods, i.e., the earlier period in the production of ideas and the later period in their dissemination and evaluation (Gruber and Wallace 2001). Arguably, the main insight derived from our studies is the principle that the same individual design behaviour can generate solutions that are regarded as creative within one social setting but not within a different one. In other words, macro conditions may provide the bases for particular generative processes, or they may facilitate particular effects on evaluative processes. The strongest evidence for this principle is the extemporaneous recognition of creativity. Whilst design artefacts remain unchanged, the social and cultural conditions may evolve to the point where evaluators are ready for such solutions.

Lastly, in relation to the material culture –or domain-, our studies reveal a comprehensive role of domains in the link between individual behaviour and social change. The environment from which individuals retrieve existing information, and into which societies incorporate changes, may exhibit significant qualitative and quantitative differences depending on a number of factors, most of which have been only marginally addressed in the literature. A prevalent assumption is that creativity can be estimated from the creator's total output or from the number of works commended by experts (Gardner 1993; Simonton 2003). However, individual differences are only one of the factors that determine the quantity and quality of a domain. A combination of situational factors is likely to determine the output and distribution of prominence across competitors. Situational effects may characterise cases where different individuals independently make the same contributions (i.e., simultaneous invention).

5. Understanding Creativity

The implications of our computational studies point towards a promising line of inquiry focused on the complex relation between designers, societies, and culture. New types of questions are possible with an alternative understanding of creativity and innovation as part of a complex system. The most important theoretical construct that frames this interaction is the notion of "design situations". It has been recognised for a long time that as a result of the dominant individualistic focus in the literature, important questions have been underemphasised, specifically the study of 'creative situations', defined as 'circumstances conducive to creativity' (Amabile 1983).

A design situation represents the combination of individual and external factors as construed by the designer. Based on the factors explored in our studies, a situation in design can be defined as the confluence of individual and external conditions within which behaviour is determined. The key idea when considering creative situations is that the observed output is likely to take place as a combination of individual and external characteristics. This is true in two ways: a) a range of individual differences are likely to generate the behaviour of interest and b) a range of behaviours are likely to generate the effects of interest at the social level.

Our research has identified a set of interactions that can be expected to occur between individual and situational factors in creative design. The long-term goal is to capture the details of naturally occurring situations. This can be done by matching field and laboratory studies with computational modelling (Morone and Taylor 2004). For instance, our studies of gatekeeping suggest that social groups with weaker ties tend to distribute prominence in assessments made by experts. This could be used as a hypothesis in the design of laboratory experiments or historiometric studies. Likewise, during the evaluation of design artefacts strong individual preferences yielded higher satisfaction levels, less artefact differentiation, and higher scores for domain entries. These issues can be inspected in control and experimental groups of generative and evaluative processes.

Laboratory and field experiments are convenient to test the veridicality of these types of frameworks as explanations of human behaviour. In addition, computational models can provide new ideas for the design of 'in vivo' and 'in vitro' tools of inquiry. One basic type of experimentation focuses on evaluation: where equivalent artefacts are given to equivalent evaluation groups to assess their creativeness. The aim of these studies would be to investigate in human groups the foundational idea that creativity is a property of systems and varying different system components or the way in which equivalent components interact can generate quantitative and qualitative different results.

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