Designers' secret cameras: Report on the Symposium on Computational Models in Design and Planning

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1. Introduction

In his book 'Vermeer's Camera', Philip Steadman (2001) elaborates the argument that the famous Dutch painter Johannes Vermeer used artificial aids (a camera obscura) to study, explore and create his paintings. Of course, the use of artificial aids in painting was not unusual. But the idea to use a lens, as an aid for the exploration and creation of paintings, was 'both novel and prestigious': the camera enabled the artist to not only improve his drafting abilities and accuracy, but also to study and explore his synthesis well before its realization. Steadman's view raised controversy, because the use of the camera obscura implied for some the diminishment of the creativity and skill of the great painter. Ironically, today, computational aids such as Computer-Aided Design (CAD) systems, or Computer-Aided Planning systems are criticised as to their ability to support and enhance high-level human abilities and processes, such as synthesis and creativity. One can say that computers and computer constructs are the counterparts of Vermeer's camera: they constitute the present 'lens' through which to see and study the world. The development and use of artificial constructs as autonomous entities and/or as complements to human physical or mental abilities is one of the most appealing and controversial 'symptoms' of human civilisation - especially in domains such as design and planning. However, this endeavour has always been accompanied by controversy.

Research that involves the development of computational models to address design and planning questions has naturally been growing in various dimensions. On 7th September 2002 a symposium was organised in CASA with the intention to explore the scope and role of computational paradigms employed in different domains and investigate common or conflicting perceptions. The invited speakers and panellists all came from different scientific backgrounds and traditions, representing different research interests that cover areas from artificial intelligence and complexity science, to design and decision support systems, computer aided planning, computer aided design, design science, urban modelling etc. Nonetheless, they have all been showing the same interest to exploit the computational power in order to support design and planning activities. This interest creates a plethora of challenges and 'traditions', but also conceals various fallacies and hidden opportunities worth exploring.

More specifically, the participants in the panel discussions were invited to explore and challenge a series of questions around two main themes: 'Modelling design and planning phenomena', and 'Tools to enhance design and planning activities'. The goal for the symposium was not necessarily to provide answers, but rather to find the appropriate questions that need to be asked in order to support common research on computational models in design and planning. A more detailed description of the questions and themes that were posed to stimulate the discussion can be found on the symposium website: http://www.casa.ucl.ac.uk/katerina/symposium/.

2. Themes, assumptions and resolutions

The themes of the symposium were a product of constructive discussions with the participants and other contributors, prior to the actual meeting, and were structured with two main working assumptions/propositions put in place. The first assumption was related to the kinds of paradigms that are employed to nourish research on computational models in design and planning. We can generally identify two kinds of paradigm: the first focuses on the development of computational models and tools to support design and planning processes, and the second focuses on the development of computational models that can emulate and reproduce design abilities. Taking this into consideration, the main assumption formed was that in order to understand the role and scope of computational models we need to explore the relation among humans and computer models, and investigate design and planning as processes that emerge from their interaction. This kind of research emphasises two main questions: the question of where design and planning abilities lie and under which conditions can they be evoked, simulated or supported; and the question of what functions and behaviours should computational models incorporate as a basis for establishing a complementary working relation with humans.

The second assumption that drove the formation of this meeting was that design and planning could be seen as two reconcilable activities. If design and planning as notions, processes or disciplines are concerned with similar questions then we could possibly identify new routes for common research and new paradigms for the development of computational models. The suggestion in this case was that in order to establish a common route of research, a definition of the notion of 'plan' and its role in design and planning processes is required. To this end, discussion was triggered around the question of what is design and planning and what kind of computational techniques are appropriate for each of these processes.

2.1 Paradigms for the development of computational models

As mentioned above, there can be identified two alternative paradigms for the advancement of research on computational models in design and planning. As Ray Wyatt noticed (in the discussion forum), the first kind of research usually emphasises questions of how modelling can support humans as they plan and design (the focus is on models *for* design and planning); and the second, emphasises questions of how people plan and design (the focus is on models *of* design and planning). Yet, this led us to opt for a third research paradigm that effectively focuses on the elaboration of computational constructs that can formulate designs and plans by working together with humans. To this end, the discussion was driven toward the investigation of roles, characteristics, and functions of computational models (current or potential) employed in design and planning tasks. In particular two questions were explored:

a) Can computational models exhibit design and planning abilities and how?

The meaning of this question is two-fold: it involves investigating the different perceptions maintained within the different disciplines about what design and planning abilities consist in, but it consequently also involves investigating which of these abilities *should* and *can* be modelled. The discussion around this question revealed a tendency to see design and planning abilities as abilities that are not uniquely identified with human reasoning and action. It was discussed, for example, that although no intentional designer can be recognised in cities, they could nonetheless be considered as designed artefacts; and that there exist computational mechanisms and intelligent software entities which can produce designs without the input from a human expert.

This discussion can be traced in more detail around phenomena such as emergence, self-organisation and evolution in design and planning tasks. *Emergence* is conceived to be the quintessence of complex systems, a form of global order created from the interaction and self-organisation of simple units in a local scale. In the study of cities from a complex systems perspective, the actors engaged in the formation and transformation of the urban landscape, are viewed as agents that interact with each other and with their environment, in much the same way as ants interact to build their nests. Peter Allen (1997: 71-71) discusses the evolutionary nature of urban systems and its impact on the meaning of human intervention and decision making as follows: '…in a complex system of interdependent entities the decisions made by individuals, or by collective entities representing certain localities, lead to the emergence of large scale structure, which is not anticipated in their thinking, and which later will in fact determine the choices which are open to them'. In his key presentation Juval Portugali discussed a tentative definition of design that distinguishes between *engineering design* and *self-organised design*. Roughly, according to this view, engineering design is a purposeful process that aims to satisfy some specific goals or constraints, while self-organised design is a process whose targets are formulated in time through the interaction of the multiple participating agents and parameters, and cannot be defined in advance nor be predicted. The difference between engineering design and self-organised design is that the first is intentional and the second is not.

The notion of emergence of unpredictable behaviours and structures however, is also relevant to the notion of *creativity*. In design, creativity is commonly defined as the ability to generate 'surprising and innovative solutions' (Gero and Kazakov 1996) that could not have been anticipated before. Taken that we agree on the importance of emergence and creativity in design and planning tasks, in any form they are demonstrated, the question arises: *is it meaningful to try to model them, and moreover, can we indeed do it*? Much of this discussion was instigated by Peter Bentley's presentation. His work in *evolutionary design* proclaims a reality where artificial systems may indeed generate creative solutions, with or without interaction with humans. The argument towards evolutionary design systems is that, particularly in the conceptual/preliminary stages of the design process, they can be effective in generating novel, better and even 'surprising and innovative' solutions starting from little or no knowledge about the way the design requirements maybe satisfied (Bentley 1999: 39). Paul Coates presented another 'breed' of evolutionary systems for architectural design, developed based on the paradigm of *stigmergy*. Such systems are inspired from the behaviour of termites that achieve coordination and regulation of their building activities without direct communication, but through modifications of the environment. The key in this case is the fact that individual behaviour modifies the environment, which in turn 'fights back' and modifies the behaviour of other individuals (Carranza and Coates 2000). Creativity here is also related to complex behaviour, the ability to learn and the emergence of unpredictable structures, which can be inherited (or simulated) by computational systems. *But, is computational modelling, or the scientific method in general, the correct way to approach design and planning phenomena such as creativity and emergence?*

Bauke deVries represented a reluctance to build creative systems that comes from two basic objections. The first is that complex behaviour, and consequently creative behaviour, is indeed elusive of comprehensive understanding and analysis, leaving us with an intrinsic inability to build creative systems without oversimplifying our definitions and goals (what Ian Parmee expressed as the danger of 'trying to fit a square ball into a round hole'). In a similar way, Thomas Kvan expressed the view that creativity exists in everyday life and starts from *ideas* rather than from functions or well-defined goals. There is no evidence that computational models can create ideas but we can develop tools to support and enhance designing, without losing the joy that derives from its complexity. This shifts the focus from the construction of creative design systems to the construction of systems that we can *learn from.* Kvan (2000) has also argued that particularly in multi-participatory design processes, social structures may be developed among the participants (such as compromise) that are fundamental for reaching innovative solutions. This argument may implicitly challenge the idea that creativity could be reproduced computationally or even that human-computer interaction could foster such tasks. The second objection relates to an understanding of creativity as the *unintended use of ordinary resources* (tools, materials, methods or design systems). This raises a question in relation to how we see the working relation between humans and tools. We will come back to this question later.

Other views expressed in the symposium include creativity seen through the prism of *rules and constraints* (Philip Steadman) or as *the creation of new relations* (Lidia Diappi). Rivka Oxman emphasised the meaning of *ideation* focusing on computational models that facilitate the mapping of concepts and their relations. Dino Borri in his presentation identified creativity as a *social phenomenon*, pointing out that in the urban planning domain, creativity is associated with a great number of people who interact and share resources to transform decisions and spaces reflectively. He investigates creativity as exploring and building the new, through the transformation of memories. To this end, intelligent computational agents can be employed as vehicles to support the sharing and mobilization of memories through reactive adaptation.

Frances Brazier as an expert on another design domain, that of developing intelligent software agents that ‘move about over the Internet’ (Brazier 2000: 4), has discussed the challenges of *designing something that is going to change.* Intelligence agents need to be proactive, capable of learning and reasoning about their actions and actions of other agents, and able to adapt themselves according to the situation. In this sense, and if creativity is about open environments, adaptability and novel solutions, then such systems can be considered to be creative. On this last point Brazier also raised another question that is: *who recognizes creativity and how can we measure it*. This provoked a discussion around the notion of 'interestingness' as a measurement of creativity, clearly as elusive as the notion of creativity itself, and the challenging of creativity as a goal for design systems by shifting the focus on systems that are fit for purpose, good on what they do, or can be used to promote understanding.

b) What kind of functions should computational models for design and planning support incorporate, and what is the working relation between humans and machines?

The discussion mentioned in the previous section brings about the issue of functions and behaviours that computational models should encompass in order to effectively support and enhance design and planning. This should take into account the nature of design and planning but also the relation among humans, machines and the environment within which they operate.

John Gero principally stimulated this discussion with his key presentation. He described a framework for the modelling of design thinking based on the idea of *situatedness.* This understanding is founded on his Function-Behaviour-Structure (FBS) framework, which offers an abstraction of designing as an analysis-synthesis-evaluation-formulation and reformulation process. The principle that holds here is that 'where you are when you do what you do matters', pointing out the importance of the *constructive role of memory* and experience in design (Gero 1999). According to this view, designs emerge by using previous memories that are re-interpreted/re-constructed in the light of the current situation. This implies the need to develop tools and models that interact with their human or artificial environment and build their knowledge and action according to this interaction.

Jeff Johnson, as an advocate of the power of combining complexity science and design discussed the dynamic nature of design and planning. Most systems that we design, plan and manage (such as cities, road networks or buildings) are complex socio-technical systems, reflecting the actions and interaction of human beings within physical constraints (Johnson 2001). He argued that the multiplicity of parameters that take part in the design process and the fact that specifications and proposed solutions *co-evolve* in the context of human interactions also reveals the need to construct an appropriate *language* to represent complex systems. In this sense, a primary concern for the development of computational constructs should be the elaboration of a language that can represent the level of complexity found in design and planning processes.

Paola Rizzi also stressed the *social* nature of planning and the importance of making possible the participation of the people whose lives are affected by design and planning decisions. She shared her experiences in devising and using *simulation and gaming tools* for urban and environmental education and training. Such tools cannot only help us 'create would-be worlds' (as Jeff Johnson put it), capture emergent properties, and understand the workings of complex systems, but they can also help us communicate this knowledge to individual stakeholders and communities. Computational constructs may hence work more as tools 'to think with', as frameworks for communication and learning.

Ian Parmee on the other hand, discussed an alternative paradigm for decision-making support that uses the power of *interactive evolutionary systems* to support search, exploration, discovery, innovation and creativity in design tasks and enhance decision-maker's knowledge and capabilities. He argued that particularly when operating within ill-defined and uncertain decision-making environments, there is a need to evolve the problem space before attempting to solve the problem. Such systems support the exploration and extraction of optimal design information, which is then presented to the designer for analysis and evaluation. Therefore user knowledge can also be captured in further evolutionary search.

Evidently, different approaches to design and planning result in highlighting different aspects of support and focusing on different functions for computational models. In most of the cases, interactivity, adaptability, evolution and learning are critical abilities for computational models. These functions are used to support analysis, synthesis, exploration and generation of alternatives, rule extraction, prediction, evaluation and so on. Those different approaches reveal also different perceptions about the working relation between humans and machines. Traditionally, there is a deliberate attention on distinguishing between functions that are performed by humans, and functions that are performed by computers. This division of labour has its roots in the view that there are certain human abilities that cannot be duplicated by machines, and that on the other hand machines should be used for the tasks they can perform better than humans. As we have seen in the discussion about creativity, creative individuals and groups often require to wield control over the design products, thus framing the role of computational models to that of optimisers, collaborators, facilitators, or stimulators. With the advances in complexity science and artificial intelligence, the focus has often been in trying to embed abilities such as knowledge acquisition and learning within computational models, so that they are able to perform within unknown, ill-defined, or unpredictable environments. Interaction in this case is a process that forms both human and 'artificial' knowledge and in effect human and 'artificial' action. The boundaries between human and machine labour begin to blur, so that design and planning become abilities that are attributed to the human-computer interaction rather than to any of the individual parties.

2.2 Design and planning activities

The second assumption that drove the formation of this meeting was that design and planning could be seen as two reconcilable activities. Although research on the development of computational tools in the design domain is in practice quite disconnected from research in planning, cross-exploration of the assumptions, views and definitions employed could form a fertile basis for discovering new routes for common research as well as new paradigms for the development of computational models.

In the symposium, differences between different types of design and planning were discussed (for example the difference between 'engineering design' and 'architectural design', or the difference between 'classical planning' and 'intelligent planning') but also differences and dissimilarities between designing and planning. If we try to compose a generic definition of what is involved in designing, as was expressed by the participants, we would identify a focus on designing as a *purposeful*, *constructive self-organising*, *evolutionary* and *exploratory* process. It is a process that aims to satisfy a goal, but without having a complete or pre-defined definition of this goal, or problem (see also Smithers 2002). Planning on the other hand (especially in the

Artificial Intelligence sense) is perceived to be a process of developing the appropriate *sequence of actions* that will lead a system from the current state to a desired one. Planning however, also involves dealing with ill-defined goals and multiple objectives, as well as with uncertainty about the current situation and the anticipated effects of actions.

An important question for urban planning in particular is to acquire knowledge about the behaviour of the system to be planned. This was supported by the presentation of Dino Borri and was the core of the discussion that followed Lidia Diappi's presentation. She expressed the view that in urban planning modelling various techniques are used (ranging from Cellular Automata, to Genetic Algorithms and Multi-Agent Systems), but which still leave us without a theory about the city. She highlighted the need to extract 'rules of change' from the available information, particularly through the use of Neural Networks (NN). The discussion showed that the question about whether Neural Networks are the appropriate approach for planning is indeed very much related to our perception of what planning is and what is required to support it. For example John Gero challenged the fitness of NNs for planning purposes because they cannot easily be used for extrapolation, and planning as a process 'is about extrapolation'. On the other hand, the constructive pattern recognition or 'pattern formation' ability of connectionist systems was found to be a key for building cognitive design models as well as a key for the study of cities as complex self-organising systems (Portugali 2000). However, the need to acquire or extract knowledge about system behaviour as a basis for decision-making seems to be a common feature also in engineering design (Ian Parmee).

It seems that although planning is perceived to be different from designing, they are both concerned with a process of *learning* about current situations, needs, constrains, beliefs and expectations, but also with a process of exploration and *problem formation*. In a similar way, we can also identify a common interest in techniques and tools to extract and represent knowledge about the system in hand (a city or a building), as well as knowledge that reflects the multiple views, preferences and objectives expressed by the many participants in the design and planning processes. Moreover, the multi-participatory and social nature of design and planning brings into play the need for interactive tools that facilitate participation and co-operation.

To our investigation of common and differing features in design and planning, the notion of *plan* is of crucial importance. An interesting investigation of the notion is found in Hopkins (2001:34-42) who suggests that a plan works in five ways: as a design (a fully worked out outcome), a vision (image of possible outcomes), a strategy (set of decisions that set a contingent path), a policy (if-then rules for actions) and an agenda (a list of things to do). However, the relation among designing processes, plans, and the system to be designed, varies across disciplines and according to the nature of the system to be designed. In certain domains, like for example in intelligent buildings and behaviour-based robotics (Brooks 1999), there is no clear division between the development and the implementation of a plan. In the context of urban development on the other hand, plans are very much seen as part of the problem they attempt to solve. In this sense the development of a plan is also seen as an interactive and adaptive process rather than a fixed product imposed from the top. Despite similarities and differences, we feel that what remains from all these examples is that in order to be able to formulate robust theories about the kinds of computational models needed to support and enhance design and planning abilities, we need to have a clear and workable perception of what a plan is (Alexiou and Zamenopoulos 2002).

3. Conclusions

The different presentations delivered in the symposium covered a wide range of alternative paradigms for the development of models and techniques that can be employed to support design and planning tasks. Both 'traditional' and 'avant-garde' perceptions were reviewed and challenged. And, as should have been anticipated, we did not come up with any conclusive answers to most of the questions raised; but we did come up with some crucial questions. Our view is that in order to further advance research on the development of computational models to support and enhance design and planning activities we need to identify and understand: 1) Where do design and planning abilities lie? How is it possible to understand design and planning phenomena that are not attributed to an intentional designer or planner? 2) What is the working relation between humans and machines? How is it possible to develop systems where design/planning abilities are totally distributed between humans and computers? 3) What is the relation between design and planning and what is the nature of plans? How can the notion of plan be elaborated to support the development of computer aided design and planning systems?

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