



Introduction

The Role of Objects in Design Co-Operation: Communication through Physical or Virtual Objects

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This special issue concentrates on the role of objects in design communication. We use a wide definition of the term *object* to encompass all sorts of physical and electronic artefacts, that can convey meaning in interpersonal communication, but have an existence beyond a single act of communication. These can include sketches, technical drawings, and computer models, as well as mock-ups and previous products. Researchers have for a long time been aware of the importance of representations and reference points in the generation and representation of designs, and have often studied particular types of representation, for example sketching (see Purcell and Gero, 1998, for an overview of research on the role of sketching in design). Designs are strongly influenced by the representations in which they are expressed. However in research on design communication the role of objects has sometimes been regarded as secondary to other aspects of collaborative design such as verbal communication, interpersonal relationships or organisational structures. However some sociological analyses of the development and transmission of ideas have recognised that information-carrying artefacts play an essential role as independent entities; this insight underlies Actor Network Theory (Latour, 1987). An understanding of the roles various kinds of objects play in design processes is crucial to the development of effective CSCW systems for design. Computer mediated communication can restrict communication through objects, or provide alternatives to it, but it can also enhance it. For the design of all CSCW systems it is necessary to consider whether the systems support the use of objects to convey meaning in the same way as they do in face-to-face communication, or if the systems provide effective alternative ways to convey the same information. One major theme of CSCW research has been the understanding of how objects can be used remotely in the same way as in face to face communication, and building systems to make remote collaborative designing as similar as possible to face-to-face collaboration. A number of important prototype systems have been developed at Xerox PARC (for instance, Bly and Minneman, 1990; Tang and Minneman, 1990; Moran et al., 1998). Such tools can sometimes enable

the users to do things that would not be possible in face-to-face collaboration, for example making marks and gestures at the same place at the same time. The impact of the CSCW systems on the social and organisational processes affects the communication through and with objects in fundamental ways. Changes in how objects can and can't be used to convey information, and thus the roles they can play in the design process can influence the consequences of technological changes to communication and might ultimately determine the success or failure of CSCW systems.

Looking at the objects generated or referred to during a design process enables us to study not only how a product is developed, but also how it is influenced by the objects themselves. Objects are reference points for explanations and externalisations of thoughts. Objects can be used to represent a typical element in a space of possible designs, or to describe the extremes of a design space (Eckert and Stacey, 2000). When design ideas are communicated through objects, each object represents a space of possible interpretations. Within these spaces the designers can negotiate over further developments to the design. Objects play an essential role both in communication and joint designing by designers who share expertise and experiences, and in communication between people who have radically different skills, experiences and responsibilities, as well as different sets of concepts and mental representations with which they think about problems and designs – what Bucciarelli (1994) terms different *object worlds*. The objects that mediate communication across these divisions between different ways of thinking about designs – what Star (1989) calls *boundary objects* or what Vinck and Jeantet (1995) call *intermediary objects* – are understood differently by the different participants, who find different meanings and implications in them for their own areas of responsibility. Many design processes depend on the different participants interpreting boundary objects not in the *same* way but in *compatible* ways. But there are often no guarantees that they will, and serious problems can arise when interpretations don't match, and designers stray from their colleagues' intentions (Eckert, 2001). A design specification is a boundary object, as is the sketch given by an engineering designer to a toolmaker; Stacey and Eckert's paper in this issue discusses another classic boundary object, the technical sketches knitwear designers pass on to knitting machine technicians.

By designers expressing their ideas with a combination of words, sketches, and gestures (Bly, 1988; Tang, 1989; Minneman, 1991; Neilson and Lee, 1994) as well as references to other objects or shared experiences (Eckert and Stacey, 2000), and their colleagues responding to what they see, interpreting vague or ambiguous objects, and then negotiating over their intended meaning, new ideas can be derived and problems with existing designs can be found. New types of intermediary objects can also be created by the participants and involved as elements of the participants' argumentation during negotiation as Boujut and Blanco show in this issue. The content, form and structures of the objects themselves biases the design

process and the product itself in many subtle ways, as all the contributions to this special issue show.

The questions of how objects are used in design communication and how CSCW systems can facilitate communicating with and through objects were the focus of a workshop at Coop 2000 in Sophia Antipolis in the South of France, entitled: *The role of objects in design co-operation: communication through physical or virtual objects*. Earlier versions of all the papers in this special issue were presented at the workshop; they were substantially rewritten in the light of the discussions at the workshop and reviewed again for *Computer Supported Cooperative Work*. The motivation of the workshop and this special issue was twofold. We aimed to increase our understanding of how design processes are influenced by the representations in which design ideas are expressed, and vice versa, by analysing the multiple functions objects can have in different communication scenarios; and to explore the implications of communication through objects for CSCW systems. We aimed to stimulate debate by bringing together researchers with a variety of perspectives and theoretical viewpoints, with experience of a variety of design-driven industries.

The workshop brought together about 15 researchers from all over the world who have applied ethnographic methods to study design processes. Most of the participants were primarily interested in engineering design, but between them they have looked at a wide variety of domains from software design to textiles. Ethnographic studies are a powerful tool to understand the richness of design as a social activity deeply embedded in the context of each participant's personal experience. Ethnographic studies try to take a holistic view of the situation they are studying. Studies have particular purposes which guide what ethnographic researchers do and think about, and analyses adopt particular focuses and viewpoints; however ethnographic fieldworkers try to look at everything that is going on in a culture or organisation and try to be open to all the factors that influence what is happening. Hypotheses and hypothesis-driven representations of data are necessary for the ethnographer to develop analyses of significant events, but they are not fixed and are changed in the light of new observations. This contrasts ethnography to other methods of empirical studies that are undertaken to test a particular hypothesis or solve a given problem. For example many empirical studies are solution-oriented case studies, where researchers go into companies applying their methods or tools to identify or solve practical problems. Other studies focus on one particular aspect of designing, such as the cognitive processes involved in design thinking, or on one level of description such as the channels of information transmission in an organisational structure. While these approaches can be highly successful and can lead to a deep understanding of the cultures they are studying, they run the risk of misunderstanding the work situations, leading system developers to build tools that do not address the real needs of practitioners. However in a field as complex as design where hundreds of people undertake thousands of tasks, broad hypothesis-driven studies are an essential means to understand macro-processes, which can

not be observed in an ethnographic study, which is limited to looking at one of many design activities (for example, project review meetings, or the activity of a given team). Other methods allow the researcher to integrate data drawn from a much larger number or wider range of activities than it would be possible to observe. Ethnographic studies can produce detailed descriptions of complex design situations and are very valuable in giving a deep insight on real world design, but translating this understanding into practical tools can prove problematic.

The choice between an ethnographic approach and another way to study design processes is however often not governed by the scale of the problem, but by the philosophical bias of the researchers. Traditional solution-focused research on design processes sees design primarily as a structured activity consisting of a succession of logically connected stages governed by the structure of the underlying product, where individual and collective behaviour is analysed with reference to a rational model. An increasing number of cognitive studies focus on collective design behaviour, especially on the argumentation processes in face to face communications (Martin and al., 2001). Most ethnographic research is undertaken from a viewpoint centring on social interactions, seeing design as a social process where a product emerges from negotiation between individuals who each bring a personal perspective and experience, and who have complex power relationships with their colleagues, rather than as the emergent result of a range of individual activities. Comparing the findings of ethnographic and other studies can be very valuable, both by challenging the assumptions underlying different approaches, and by showing convergence on a richer and more solidly grounded understanding of design.

In complex fields like design it is difficult to compare or integrate analyses that are based on different theoretical perspectives or use different units of analysis, but different perspectives can enrich our understanding by shedding light on different aspects of the phenomenon. This special issue includes papers from different perspectives. Each paper explains the theoretical context it is coming from. The papers by Stacey and Eckert and by Subramanian and al. are good illustrations of this pluralistic approach where ethnographic work is combined with other approaches. The work of Boujut and Blanco shows that modification of hypotheses during the course of fieldwork and constant interaction with the practitioners in the observed companies allow real collaboration between researchers and practitioners. Glock's work is a good illustration of what a fine-grained analysis of the verbal exchanges can contribute to the understanding of the role of the context and the importance of the interpretative work of the designers.

The research in this special issue is far from being purely descriptive. Both Boujut and Blanco and Stacey and Eckert are concerned with the question of how to achieve more effective representations of design ideas, that serve as more effective objects for mediating design communication. Most of the work presented in the special issue has produced computer tools or other proposals for practical action to improve design processes such as organisational changes.

Drawing on three longitudinal case studies Subrahmanian et al. show the role that objects play across an entire organisation when participants from different object worlds have to interact. They extend the concept of boundary objects, which are understood differently by different groups and act as an intermediary conveying information between them, to what they term *prototypes*. They use the term 'prototype' more-or-less in the sense of a central or primary exemplar of a category; they define it with respect to the concept of boundary object emphasising the necessity for engineering designers to achieve at least partial agreements about how to conceptualise and classify the objects they share. This enables the designers to classify the design and make sense of it as one of a kind they know. The case studies show that as design processes change through evolving technology or new organisational structures, groups have to negotiate a new understanding of their boundary objects, with shared mental models and context.

Boujut and Blanco discuss the role of an object at the interface between experts from different fields of expertise working simultaneously on a specific design problem. They illustrate how negotiation is conducted around intermediary objects and show how design is influenced by the information that is afforded by a representation and the bias it carries. Not only does an object influence the design process by the information that it carries, but also by the information it does not contain. When information can not be derived from an object, such as manufacturing information from early sketches, the underlying ambiguity can lead to misunderstandings or useless debates. Boujut and Blanco propose to enrich CAD representations by symbols that have a meaning for the participants of the design team and that allow them to record information directly onto the model. They show how it is possible to tailor specific intermediary objects (or boundary objects) during design.

The theme of information that an object holds or does not hold is crucial in Stacey and Eckert's discussion of the effects of ambiguity in design representations in asynchronous design. While ambiguity can sometimes help designers in coming up with new design ideas and facilitate negotiations in design teams, it can have very adverse effects in design hand-over situations, as their study of the knitwear industry shows. In this industry incomplete, inaccurate and inconsistent representations are handed over to other team members without much further explanation. The recipients interpret this information based on their own experience and generate designs that do not reflect the original creators' intentions. The term ambiguity is often used to mean both vagueness and uncertainty, as well as the availability of two qualitatively distinct interpretations; Stacey and Eckert argue that the ambiguity of the word 'ambiguity' confuses analyses of the role of uncertainty in design. They present a typology of forms of uncertainty, and argue that ambiguity and vagueness can often be removed by specifying the designer's intent in terms of precision, commitment and confidence. The paper concludes that ambiguity should be avoided in design hand-over situations through clear specifications or the annotation of the boundary objects.

These two papers conclude that objects are not only good means for analysing design situations, but when they well specified are powerful tools for improving design communication.

The scope of possible interpretations of design objects lies at the heart of Glock's fine-grained analysis of a communication protocol of two engineers working jointly on a the conceptual design of a handheld medical scanner. He describes the social process of both designers interacting with the sketch and re-framing their problem in many different ways prompted by a reflection on the sketch and additional issues that emerge in a conversation arising from the sketch. Glock states that the designers' interpretative work is rooted in an enculturation process that is fed by both interactions with other designers and the material available in the design situations. He then stresses the importance of the reflective process (Schön, 1983) that might be stimulated by making transparent practices visible through the researchers' reconstructive interpretation.

All the papers in this special issue are primarily descriptive giving a holistic picture of the roles that objects can play in design communication within different design situations. Glock addresses joint design by engineers sharing the same expertise, and shows how objects spark their creative process. Boujut and Blanco look at team members with different expertise who interact frequently through fact to face meetings and can use objects as a way to support information flow to avoid problems that could have arisen. The limitation of communication through objects is shown by Stacey and Eckert, who show problems arising from the (mis)interpretation of ambiguous information in asynchronous design communication. Subrahmanian et al. analyse the changes in the role of individual objects in the context of an entire organisation as organisations and technology change.

All the papers show objects to be powerful and influential means of design communication. Communicating with and through various kinds of objects enables designers to express information impossible to convey in words, avoid misunderstandings and recover from communication breakdowns. As several of the papers in this special issue conclude, focusing on the objects used in design communication enables researchers to track these aspects of communication processes and analyse the forms that design information takes and the processes by which it is expressed and interpreted.

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