What Happened to Collaborative Design?

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Abstract: *In this paper we present the results of a comprehensive literature survey on the development of collaborative design. We reviewed 324 papers on collaborative design, taken from various sources (conferences, journals, and PhD-theses). We grouped the papers based on common themes, and in that way derived a classification of themes through the last 25 years (1983-2008). Each category is described, its development, and key publications are identified.*

Keywords: *Collaborative design.*

Introduction

One of the first research publications mentioning the term "collaborative design" is Jones (1983). As Jones puts it: "Creative collaboration is perhaps the main challenge of our time. *Before computing* it was not possible, in principle, at the scale at which we now operate and organize, the scale of billions and at the scale of everyone's minds. *It is bound to be difficult* but it is, I believe, the hidden question behind the quest for lifelong designing" (italics by authors of this paper). Computing is seen as a crucial technology to support collaboration, and Jones also notes that it will be hard to actually achieve collaboration. The latter is supported by Kvan's (2000) seminal paper, in which he observes that "…most of the time when people think they are working collaboratively they are actually co-operating and, even more important, compromising… In short, working together, even effectively, is not necessarily collaboration, nor should it be."

In this paper we present the results of a comprehensive literature survey on the development of collaborative design. In the survey we reviewed 324 papers on collaborative design, taken from various sources (conferences, journals, and PhD-theses). We grouped the papers based on common themes, and in that way derived a classification of themes through the last 25 years (1983-2008). Each category is described, its development, and key publications are identified.

Developments in collaborative design

The first papers mentioning collaborative design describe it as a desired state of affairs which is seen as something that is potentially possible rather than established fact. A breaking point occurs in 1993-1994 when the first systems for collaborative design are reported. Up until 1997 most of the efforts are aimed towards technological solutions for collaborative design, and only in 1997 and onward there is a steady reflection on what collaboration actually is. The peak of publications on collaborative design lies in the period 2001-2008 in which 88 papers were published (27% of the total output). In recent years we can observe that the output is in decline (in 2006, 24 papers; 2007 19 papers; and 2008, 7 papers). Based on the literature review, we came up with the classification shown in Table 1 below. Figure 1 shows the chronological order of the themes and the number of papers in each year.

Category	Sub-category	First paper	Number of papers	Last paper
Support (40%). 129 papers.	3D Virtual Environments	1996	23	2007
	Asynchronous applications	1993	6	2007
	Synchronous applications	1993	10	2002
	Comprehensive systems	1992	31	2008
	Community participation	1996	12	2006
	Tools	1995	47	2008
Methodology (11%). 36 papers.	Case studies	1995	16	2007
	Research methodology	1994	20	2008
Theory (13%). 43 papers.	Design management	1994	23	2008
	Kind of design	1983	20	2006
Model (9%). 30 papers.	Design modelling	1993	10	2006
	Information modelling	1997	7	2004
	Knowledge modeling	2002	4	2007
	Representations	1988	9	2004
Technology (11%). 37 papers.	Multi-Agent Systems	1994	12	2006
	Technology	1998	25	2007
Education (13%). 43 papers.	Pedagogical models	1994	20	2007
	Virtual Design Studios	1994	23	2007
Other (3%). 6 papers.	Other	1998	6	2006

Table 1
Classification of developments in collaborative design

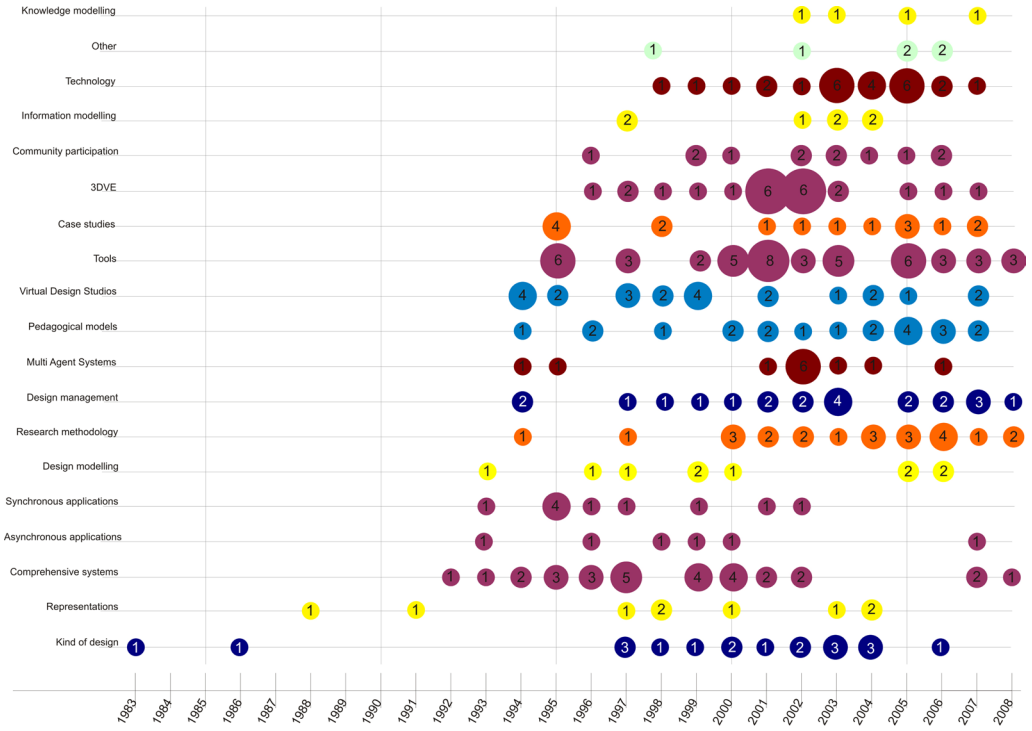
Support

Support denotes all kinds of applications and tools that are intended to stimulate, cause, or assist collaborative design. Support is by far the largest category. It appears that much of research in collaborative design is done by building systems which are assumed to support collaborative design. Research in this area is very much technology driven and less based on a theoretical approach. Most of the work in this area started in the period 1992-1993.

3D Virtual Environments: are all those systems that use some kind of spatial virtual environment to support collaborative design. This development is very much dependent on open systems or formats to exchange and display in real-time virtual environments. Therefore it is closely linked to developments in virtual reality and the Internet. Early works from the mid-nineties onwards mostly consisted of systems based on UNIX graphics workstations using 6DOF input devices and Head-Mounted Displays or CAVEs. (Davidson and Campell (1996)) With the availability of cheaper hardware, mostly screen-based PC-systems where developed in the nineties and early 2000nds. These works particularly focused on synchronous and asynchronous discussions, redlining and collaborative geometric modeling based on the Virtual Reality Modeling Language (VRML) and the External Authoring Interface (EAI) standards that had been implemented in many standalone applications or based on web-browser plugins (Jung et al (1999), Han and Turner (2001) and Conti et al (2001)). This trend was succeeded by the use of proprietary game engines such as first-person-shooters which harnessed the built-in multi-user and visualization capabilities (Hoon et al (2003), Sallkachat, and Araya (2003) and others). Most recent publications from this field considered in this review use the popular SecondLife platform for the purpose of collaborative design applications, mainly in educational environments. (Maher et al (2006) and Hoog et al (2007))

Asynchronous applications: concern all systems

Figure 1
Chronological order of the developments in collaborative design



that support collaborative design activities which are performed at different times by design team members. Together with synchronous applications and comprehensive systems, they form the first wave of collaborative design applications. In the early works, such asynchronous systems consisted of accounts on remote machines shared by several teams and individuals (Wojtowicz et al (1993)) using the File Transfer Protocol (FTP), file naming conventions and email broadcasts to share the work. Later works introduced hypermedia databases referred to from shared Hyper Text Markup Language (HTML) and bulletin systems (Martens et al (1996)) and more structured repositories by e.g. emphasizing hierarchical access rights management (McCall (1999)).

Synchronous applications: concern all applications that support collaboration by design team members that takes place at the same time. Prominent examples of such systems are remotely shared whiteboards and more domain-specific shared CAD systems (Jabi and Hall 1995, Khedro 1995, Qian and Gross 1999).

Comprehensive systems: concern all systems that support the complete process of collaborative design, not just one single isolated aspect. Early system prototypes often were based on the idea of peer-to-peer connected workstations using technologies such as application sharing with design session annotation capabilities on top of existing proprietary applications and protocols (Rutherford (1995)). As the World Wide Web began to gain traction, many of these comprehensive systems used database-backed web servers to store multi-media information in project contexts and expose them via

web-interfaces. Examples of such domain specific groupware applications include the works of Woo et al (1997) and Jabi (2000).

Community participation: concerns all system that involve current or future inhabitants or users of a building or urban environment. Most community participation systems are based on experiences gained earlier with comprehensive systems. Since community participation is often based on Internet access for users, it is also dependent on developments in Internet. Community participation comes in two flavors: to inform the community about earlier made plans without giving them a mandate for change (earliest example Kaga et al. (1999)), and enabling systems that allows the community to make changes to a plan or design (earliest example Smith 1999). In particular in the latter case, authors note that there are marked differences of effectiveness between different age groups in the community (for example Shen et al. 2002). Esther is a notable system aimed to support self-builders in Chili (Donath and Gonzalez 2003).

Tools: concerns all applications that support a particular isolated aspect which is seen as important to collaborative design. Examples of such tools focusing on specific task include web-enabled process modeling and management tools (Lee et al (2001)), and distributed constraint modeling and checking systems (Lottaz et al (2000)).

Methodology

Methodology concerns all aspects how to research collaborative design. This is either studied through case studies (how collaborative design actually is done) or by investigating the research methodology itself.

Case studies: concerns all research on collaborative design based on practice or the effect of the application of a particular system. The main method in such studies is observation. A good foundational study, drawing important conclusions about collaboration in the area of Group Support Systems, is presented in Nunamaker et al. (1995). A comprehensive early case study concerns the development of the VRML 2.0 specification (Ando et al. 1998). Laepple et al. (2005) show how through careful selection multiple cases can be analysed. Nevertheless, case studies are methodologically problematic to generalize from, because they are always specific to a project, a technology, and a group of users. They are very useful in a development trajectory when they support a cyclic understanding of a problem.

Research methodology: concerns the various ways collaborative design can be investigated. Since it involves multiple design team partners, its investigation is more complex than study of a single designer. In particular since 2000 there has been a steady stream of publications on the research methodology of collaborative design. As early as 1994, Franz (1994) outlines an overview of research perspectives that are predominantly technical and systematic that tends to ignore the more context and interpersonal aspects which play a role in collaborative design. Protocol analysis is the dominant research method. Because of its combination of observation and systematic analysis, it connects very well with the tradition of case studies (e.g. Gabriel (2000)). Limited experimental setups can reveal basic structures of collaborative design thinking (Schnabel 2004). Questionnaires appear to be the third most used methodology (e.g. Garner and Mann 2002). They are well-suited to gain a broad overview but have limited power to reveal deeper issues.

Theory

Theory denotes all contributions that aim to describe the nature of collaborative design. This area focuses either on the way collaborative design may or should be managed, or how it distinguishes itself from other types of design.

Design management: concerns all papers that look at specific ways collaborative design is managed and controlled. Very often, management is not a direct concern in our field, which is quite technology oriented. For example, through the capture of design rationale (e.g. Cerulli et al. 2001),

a technological solution is proposed for what is essentially an interhuman problem (Sebastian 2005). A recurrent problem in collaborative design is how to get team members to actually collaborate. Many management papers identify the need for a team building phase preceding the actual design process. In the same spirit, most CAAD oriented papers propose a game-approach to achieve this goal (e.g. Brown and Berridge 2001).

Kind of design: concerns all publications that describe collaborative design as a specific kind of design, opposed to other types of design. Although everyone agrees that something special happens in collaborative design (communal effort, with participants caring about each others contribution), there is no consensus how this may be achieved (Achten 2002). There is an unspoken faith that technological solutions may remove the bars that block collaborative design. Tom Kvan is one of the few researchers who repeatedly argue and demonstrate the rarity of collaborative design in architectural practice (e.g. Kvan 1997).

Model

Model concerns all formal approaches to create models of collaborative design. These models are in particular intended to provide theory-based tools for information and knowledge modeling; what kinds of representation are appropriate for designers, and how the design itself should be modeled

Design modelling: concerns all papers that describe ways how to model the design so that it is (more) appropriate for use in collaborative design. In particular simultaneous modification, version management, and history representation are important issues in this aspect. The works of Rosenman and Gero (1996) and Khemlani and Kalay (1997) are representative examples for capturing and maintaining multiple, parallel aspects of artifacts for domain-depended views.

Information modelling: concerns all papers that deal with the formal description of information that is generated/exchanged/presented during collaborative design. Much of this information is non-visual or non-geometric, meaning that it cannot be easily derived from the shared documents (2D or 3D). The trend of using semantically richer means of information modeling by introducing ontologies (also as a prerequisite of other AI-based systems such as Multi Agent Systems) is illustrated by van Elst and Abecker (2002).

Knowledge modelling: concerns all papers that deal with formal description of knowledge in collaborative design. Examples for extraction of knowledge from existing designs for the purpose of retrieval and reuse using knowledge bases are documented in van Leeuwen and Fridqvist (2002) and Ma and Milli (2003).

Representations: Representations concern all papers that deal with specific aspects how design, information, and knowledge are or should be represented to designers and third parties. Seichter (2003) has shown approaches to persevere the exploratory and fuzzy natures of sketches into the third dimension for design communication and collaboration.

Technology

Technology denotes all research that focuses on specific techniques which may be useful for collaborative design, but disregards the concrete application in form of a comprehensive system.

Multi-Agent Systems: concern all papers that deal with the notion of agency, and how collaborative design may be viewed or supported by multi-agent systems. The spectrum of MAS suggested for the support of collaborative design stretches from change monitoring and management systems where agents take assist designers of incorporating changes in multi-user environments (Maher et al (2003)) to agents representing and assisting users in complex negotiation tasks (Ren and Anumba (2002)).

Technology: concerns all papers that discuss one particular technology in isolation, meant to support collaborative design but without looking at its application in a comprehensive system. Examples for technologies that address specific problems in

collaborative design are Virtual Reality and later Augmented Reality that to enhance meetings, the facilitation of handheld devices such as PDAs or the use of Wiki systems as project collaboration tools.

Education

Education denotes all work that looks at teaching collaborative design, or the application of collaborative design in teaching.

Pedagogical models: concerns all papers in which is discussed how collaborative design is or should be taught. Similarly to the situation in design studio work, learning by doing is the predominant pedagogy (see the multiple instances of Virtual Design Studios). Gaming, as mentioned earlier, is seen as an effective step to get students start collaborating. A well-known implicit pedagogical approach are the Phase(x), Fake.Space, and EventSpaces projects that all explicitly take collaboration as basic model (Hirschberg 2003).

Virtual Design Studios: concern all papers that discuss implementation of Virtual Design Studios for learning and practicing collaborative design. Combined with the development of comprehensive systems, in this area most of the research and development efforts are invested. Hands-on experience through creating such VDS is important to appreciate the complexity of dispersed multiple-users in a design project (e.g. Wojtowicz et al. 2004). Very often however, the authors are happy when they have a system running, and there is not much more investigation into collaborative design. Chiu (1998) is a good example of continued reflection on the effects of VDS.

Other

Other concerns the category of publications that have something to say about collaborative design, but without explicitly dealing with any of the categories mentioned above. For all purposes of the current paper, these publications fall outside the area of collaborative design in architecture – therefore, we will not discuss them here.

Conclusions

Despite the many publications on collaborative design, it seems to be the case that there is still no agreement on a common definition what collaborative design is. Much of the work in the field is technology driven. By itself this is no problem, but there is a strong tendency not do any "reality-check" how much of the work is applicable in practice, or to see what the actual demands from practice are.

Although we have tried to be comprehensive, we are aware that the current set of papers is limited in scope. In particular, the papers are technology oriented and we probably lack publications from the managerial and psychological perspective.

It is taken as an article of faith that collaboration "is a good thing," but there is almost no paper that does not identify (non)technical problems, frustrations, and hindrances to achieve collaboration. Also, it seems to be difficult to keep collaboration up – if there is no continuous push from teachers and researchers, it does not sustain. Given the increasing amount of collaboration in practice, this is probably an indication that the pedagogical and institutional setting of universities in this respect is disconnected with practice. Even if professing otherwise, we are still teaching our students as individuals.

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