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Collocated, Multi-Disciplinary, Collaborative Designspace

An overview

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Keywords: Collocated Multi-Disciplinary Collaborative Design (CMCD), Shared Understanding, Computer Supported Collaborative Work (CSCW), Group Activity, Design Space, Groupware

Abstract: This review identifies the research findings in the area of computer mediated, collocated, multi-disciplinary collaborative design. After a general look into this and related research areas, three influencing aspects of collaborative design are reviewed. Design activities, working together, and collaborative systems that fit into various work practices. Finally, we note missing points of research in the area of collocated, multi-disciplinary, collaborative design.

1. INTRODUCTION

The fragmentation of knowledge in the building industry has created symmetry of ignorance where no single professional has all the knowledge needed to design a complex facility (Kalay, 1999). Collaborative design is performed by multiple participants representing individuals, teams or even entire organizations, each potentially capable of proposing values for design issues and/or evaluating these choices from their particular perspective (Mark, et al 2002) and act towards mutual understanding and maximizing outcomes that satisfy not only their respective goals, but also those of other participants (Achten, 2002)

Architectural design and construction projects are unique not only both artistry and engineering involved, but the multi-disciplinary partners and the collaborative process in which spaces are designed. This uniqueness is a major challenge for the application of information technology, as it typically leads to loosely structured, strongly decentralized and at the same time weakly integrated IT environments, in which information requirements are not likely to be known beforehand (Hannus et al., 1995; IAI, 1999). Most computer applications in this context are based on single machine architecture, and single user interface. Moreover, they are designed for use in the detailed phase of a design and construction process. Contrastingly, design practice in real life involves more than one designer and requires harmonious interaction between designers and systems. Collocated Multi-disciplinary Collaborative Design (CMCD) introduces many other issues to be taken care of for a successful collaboration. Shared understanding, information orchestration, coordination and cohesion, multi-user interaction and interfaces, and media etc., are some of the areas researchers have focused in the recent years. Collaboration is an enabling force but it is also a restrictive force (Kalay, 1999).

1.1 Research Focus

IT supported collaboration is being developed rapidly to integrate the existing knowledge islands that are established in between different building processes as well as various individuals of expertise. It has been realized that attempts made at the earlier stage of building process (planning and design stages) will be more effective to attain better mutual understanding, integration and collaboration among the clients, architects, engineers and other interested parties. Existing design approaches and their supporting (ICT) tools do not provide sufficient support for collocated teams especially in the early stages of the building development process, which is often chaotic. The *CMCD space* aims at a ubiquitous design environment for a shared understanding of the design task, the process and the multi-disciplinary roles of design team members in a natural and fluent design conversation. This project also takes an insight into the effect of collocated synchronous teamwork on the design outcome and also on traditional design practices.

2. RESEARCH AREAS

How collaboration researchers have approached these problems depends on how they envision the design process and how they see the computer's role. As a result, research projects vary in focus and scope. Some focus on how software can support the CMCD activity and produce better products (Technical perspective). These typically look at how data can convey information between team members; file formats, data organization and information flow during the design process. Another way of looking at it comes from design theorists (Theoretical perspective), who propose group processes and methodologies to support group dynamics. An emerging research area of Computer Supported Collaborative Work (CSCW) looks into how individuals in a CMCD team can work together and how computers can support group activities (Social perspective). Therefore, different research perspectives lead to different findings and systems. Collaborative design systems and related areas are illustrated below.

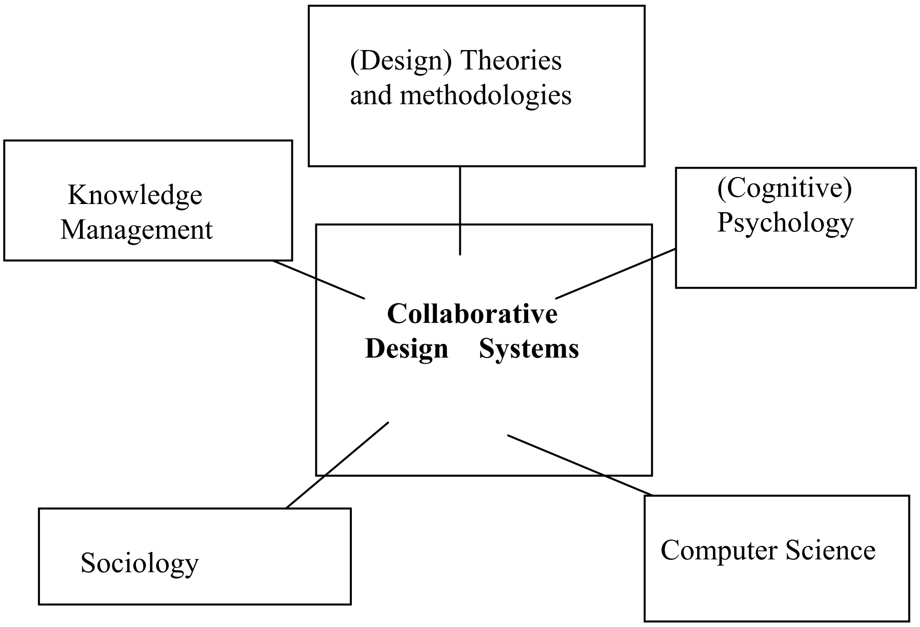

Figure 1. MD Collaborative design systems and related areas.

(Design) Theories and methodologies: In design research, there are several streams of research. Three important streams can be identified (Stempfle, 2002): normative, empirical and the design-as-an-art stream. In the normative stream, researchers have proposed systematic approaches to design in order to obtain optimum results. Design theories and methodologies provide the fundamental understanding of the entities and process of designing.

Many frameworks to support collaborative design and its group dynamics and processes have been proposed. Examples are: Reflection-in/on-action (Schon, 1983/87) for group reflection that can lead to a reconstruction of the meaning of the social situation and provides a basis for further planning of critically informed action; Experiential learning (Kolb, 1984) and further development of this idea has led to the notion of groups and companies transforming themselves into learning organizations; Design as a game (Habraken and Gross 1988) for control distribution and territorial organization; Design as a crystallization process (Friedl, 2001) to support exploration and clarification of the problem. As design activity is seen from various angles by design researchers, new methodologies have to address all of the above-related areas and look at design as a technical, social, and cognitive process. Protocol analysis (Cross, N., 1996) and case studies are major methods used as research methodologies by design researchers.

Cognitive psychology: Cognitive psychology is an interesting area to work at with respect to creative processes. In architecture, product design, and software design domains, attention has been directed for the past 10 years to designing as a cognitive process and to the cognitive skills and limitations of the individual designer. Cognitive activities within a (multi-disciplinary) group are different than the cognitive activities of one individual solving a problem alone. This is because one must consider not only the cognitive activities of an individual, but also the cognitive activities that result from group interaction (Tommarello, 2002). Although the phrase *team cognition* suggests something that happens inside people's heads, teams are very much situated in the real world and there are a number of activities that have to happen in that world for teams to be able to think and work together. This is not just spoken communication. Depending on the circumstances, effective team cognition includes activities such as using environmental cues to establish a common ground of understanding, seeing who is doing what, monitoring the state of artifacts in a shared work setting, noticing other people's gestures and what they are referring to, and so on (Clark, 1996). All this works so well in face-to-face settings because people easily maintain a sense of *workspace awareness*. Workspace awareness is defined as the up-to-the-moment understanding of another person's interaction with the shared workspace (Greenberg, 2002).

Computer science: The technical perspective of research is mainly about introducing new computing components and infrastructures. Collaborative computing utilizes networking, communications, concurrent processing and windowing environments. With the advent of the Internet and World Wide Web, and the availability of object-oriented technology, major CAD developers have come up with new generation CAD tools that can handle information sharing such as AutoCAD (Autodesk). Other systems include ArchiCAD for teamwork (Graphisoft) and Microstation Project Bank (Bentley Systems). These systems focus on how a pattern of workflow can be implemented on the existing platform and how the CAD file formats can be shared or published over a network for collaborative use to replace the traditional view of CAD as individual desktop processing with a radical view of CAD as collaborative computing. In the recent years, several initiatives have been launched to develop XML-based schemas for pan-industrial data communications and information exchanges over the Internet.

Sociology: It is clear that teamwork is a social process (Cross, 1995) and therefore relies on social interactions. Within a CMCD environment, in which team members from multiple expertise work together supported by information services and a computing infrastructure, design occurs as a social process of reaching a "shared understanding" (Toye, 1995) of the design problem, the requirements and the process itself. Some of the social roles of designers might include (Cai, 1999) discussing basic concepts and achieving consensus, defining the item meanings and criterion in the team, acquiring the knowledge and experience during the interaction, changing the goals and intentions, and adjusting the positions and attitudes of designers in the team. Social interaction and team behaviour during the design process are significant determinants of the success of collaborative design (Bucciarelli, 1994).

Knowledge management: The main objective of the research in this area is to develop instruments for collaborative design that support the management of knowledge. Excessive data and information generated from a building project is always a recurring problem in the building industry (Christiansson., 2002). In order to deal with such mass amount of data, the concept of product modeling has already been implemented for several years. A product model is useful to integrate all necessary relevant data for all of the computer-supported phases throughout the life cycle of the product into a single model. However, the complexity of the model often reduces the accessibility, navigability and retrievability of the associated data (Eastman., 1998). Another problem with product models is that a commonly agreed standard for the structure and definitions in these models is still lacking. Several attempts have been taken to arrive at such a standard, with international efforts by ISO in the STEP (Standard for Exchange Product data model) projects and by the IAI in the Industry Foundation Classes (IFC).

In other projects on product development and knowledge management systems, the major issues are the coordination of activities, capturing the generated process knowledge, and managing the data in different stages of the design. Design activities create huge amounts of potentially valuable content in the form of documents such as e-mail messages, drafts, project plans and reports, proposals, decision documents, research notes and many other forms. However, design teams typically use such documents once and then lose them, despite the savings they could realize by reusing them.

All the above areas are informative for CMCD research aim. In order to adequately support CMCD, we need to provide an environment, which supports both the individual work and also group work. In this paper we look at three aspects that are of influence on CMCD sessions. Firstly, in the section on Design activity we focus on task work and actions that are taken to complete the tasks. Secondly, in the section on Working together we focus on teamwork; actions that a team takes in order to complete the task as a team. And, finally, in the section on Collaborative Systems we focus on various types of systems (environments) and interfaces that fit into different work practices.

3. DESIGN ACTIVITIES

During a design session, elements of activity are seen in various ways by researchers. They can be distinguished as content related activities and process related activities.

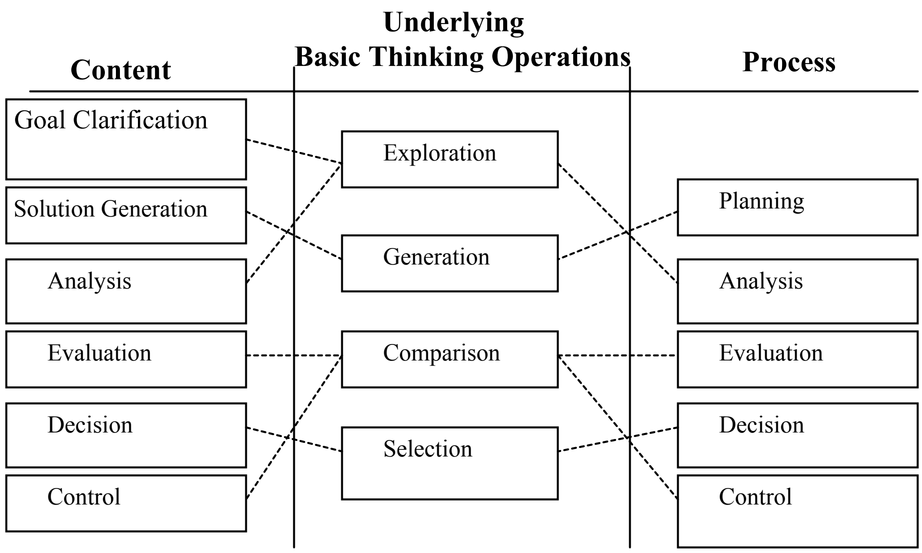

Figure 2. Generic step model of Design team activities (Adopted from Stempfle, J., et al 2002), also see (Baya, 2001).

The above model applies basic thinking operations such as exploration, generation, comparison, and selection to design teams. Authors state that the first two thinking operations, exploration and generation widen the problem and solution space, and the later two, comparison and selection narrow the problem and solution space.

Goal clarification: communicative acts dealing with goal space
Solution generation: proposals and solution ideas concerning the design task
Analysis: questions and answers concerning the solution space
Evaluation: positive and negative evaluations concerning the solution space
Decision: decision for or against a solution idea
Control: control of the implementation of a solution idea

Process related activities: These are stated as 'team handling activities'.
Planning: proposals concerning the group process (how to proceed)
Analysis: questions and answers concerning the solution space
Evaluation: positive and negative evaluations concerning the solution space
Decision: decision for or against a solution idea
Control: control of the implementation of a solution idea

According to various experiments conducted on multidisciplinary team activity (Steele, 2001), it can be seen that, in terms of time-spent undertaking each activity, the most prominent are generation and evaluation, which in total account for approximately 40% of design time. As such, it is apparent that the interdisciplinary teams spent up to 60% of the design time undertaking activities other than generating and evaluating concepts. From research studies (Simon, 2001), it is apparent that there is some form of dependencies between activities to be performed. Conflicts often arise due to various dependencies. On the other hand, sometimes designers pick the next activity to be addressed at random, simply because he/she recognized that it had to be visited. Iterations across the activities of the CMCD phase are also reported. The concept of iteration-within-iteration has been proposed by researchers (Hickling, 1982), which represents whirlpool process of activities for problem solving and decision-making.

Apart from the above-mentioned activities, some activities are seen as unclassifiable activities within the conceptual design phase (Austine, 2001). Time spent on social interaction and team maintenance fall into this area.

4. WORKING TOGETHER

When design spaces are distributed and activities are asynchronous, teamwork is often understood as coordinated work. In such a context activity can be seen as private. Collocated activity goes a step further to include co-construction of team decisions and artefacts (Olson, Carter et al, 1993). Multi-disciplinary design teams consist of experts with different qualifications and backgrounds who collaborate on a common project. During the design process, individuals in the design team interact together to build a shared reality. Interactions among designers occur by sharing ideas, resources, and representations (Milad, 1995; Kalay, 1997; Chiu, 2002).

In a collaborative design process, designers perform both social roles and technical roles. The former is conducted in the social interaction process and the latter is conducted in the technical decision-making process. In most situations, designers' roles change while perspectives evolve. Social roles of the designers might include: discussing concepts and achieving consensus; acquiring knowledge and experience; creating new ideas and inventing methods; defining the item meanings and criteria for design; and so on. On the other hand, some of the technical roles include: gathering and analysing requirements; deciding on overall functions of the product; mapping functional requirements to design parameters; assigning values to design parameters; testing design concepts; etc.

The social character of design activities is not separated from the technical results. Rather, it is continuously present in meetings, discussions, arguments, and interpretations. Design can be seen as a "Social construction of technical reality" (Minneman, 1991). Traditional approaches such as data management approaches concern the product model and the design data. Activity manipulation approaches focus on dependencies of design activities and exchange of information among designers. The socio-technical design framework by Lu and Cai (1999) is based on the acceptance that collaborative design is a human-based, multi-disciplinary and socio-technical activity and modelled as a co-construction process. The lower plane in image 3 shows the design environment and the upper plane shows socio-technical co-construction. The design process model (DPM) and the conflict management model (CMM) are built to support both, the technical decisions and social interactions.

A CMCD project brings together various expertise from disciplines and knowledge that use discipline specific information formats, discipline specific modelling, analysis, and visualization tools for their part of work often unknown to the co- participant outside his/her own domain. While acting social and technical roles, designers join the design session based on their perspectives. In the socio-technical framework, a perspective is a combination of Purpose, Context, and Content; purpose with which a designer participates, a context within which a designer participates, and content that is relevant to the purpose and context.

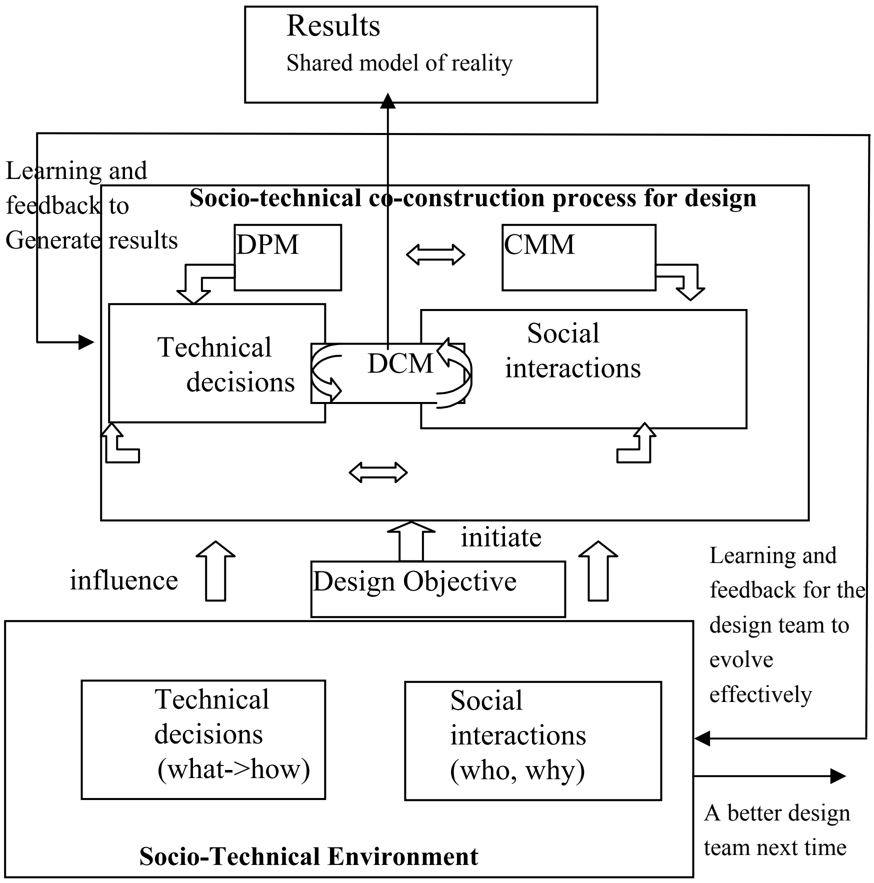

Figure 3. Socio-technical framework (adopted from Adopted from Lu and Cai, 1999)

5. COLLABORATIVE SYSTEMS

Collaborative systems are often classified on the basis of the time and space matrix. The variation for the time dimension depends on whether the participants in the collaboration act at the same time (synchronous) or at different times (asynchronous). The spatial or geographic variation is that the collaborators are either in the same place (collocated) or in different places (remote). A four-quadrant graphic is often used to show the possible combinations: synchronous -- collocated, synchronous -- remote, asynchronous -- collocated, asynchronous -- remote. Within each quadrant, we can consider a computer or technology-based system, which supports that activity. The matrix with illustrative examples is shown below. This paper focuses on the same time-same place (collocated synchronous) classification.

	Same time	Different time
Same Place	Electronic white board Electronic meeting room (Synchronous)	File management Bulletin board
Different place	Video conferencing Audio conferencing Data conferencing Instant messaging	Email Distributed databases Workflow mgmt systems Electronic bulletin boards

Figure 4. Collaborative systems in time/Space matrix (adopted from Baya, 1995, Milad, 2001).

5.1 Computer supported collaborative work (CSCW) and Groupware

CSCW is a continually evolving subject area, which has developed substantially since early 1980s. CSCW addresses the design and deployment of computer based technologies to support cooperation, collaboration, communication and coordination between members of groups, teams, organizations and more recently also between members of virtual communities (Grudin,1994). It combines the understanding of how people work in groups with the enabling technologies of computer networking, and associated hardware, software, services and techniques. CSCW as a research field developed as a result of the realization that single-user; human computer interaction design methodologies and perspectives were not adequate for the design of multi-user technologies and settings. (Banon and Schmidt 1989)

On the other hand, Groupware are computer-based systems that support groups of people engaged in a goal and that provide an interface to a shared environment.

Groupware is often used to specifically denote the technology that people use to work together, whereas CSCW refers to the field that studies the use of that technology. CSCW is the scientific discipline that motivates and validates Groupware design.

5.2 Groupware

Multi-disciplinary design work happens in two design spaces; individual spaces and shared spaces. They often work within their own individual space on discipline specific sub-objects and integrate them into a whole object from time to time. During this process, they shift their focus frequently between the individual and the shared workspaces. They maintain their own individual space while at the same time dynamically access the shared space in order to check the integrated status and to exchange information about the progress.

Shared workspaces not only provide flexible and effective visual communication but also have the advantage of allowing understanding another participants' model/design where design specialists do not necessarily have a shared vocabulary. (Milad et al, 1994). Small screens of individual computers are difficult to gather around, and simultaneous input is impossible with a single mouse or keyboard. Several systems in the exclusively shared space classification encourage a single focus of attention for the collaboration. For collocated systems, this is often manifested as a physical environment with a single display for the co-located team. These systems are also known as Single Display Groupware (SDG). SDG systems provide support for small groups collaborating around a single display by offering simultaneous, multi-user input. One of the earliest of such systems, Multi-Device, Multi-User, Multi-Editor (MMM) (Bardram, 1998) allowed up to three simultaneous user inputs, but did not support the option of private space for individuals. Each user had a "home area," a small window on the public space in which the user's name, cursor colours, and drawing mode was displayed.

Another example is the Tivoli (Clark, 1996) system, which is an electronic whiteboard application running on a live board around which the collaborators interact. The board is large enough for several people to work with, and the board is assumed to be the only room artefact on which participants' work. Shared drawing programs fall into this category such as SHDR, WSCRAWL 2.0, Groupdraw, and Group sketch, ArchiCAD. Some of the limitations of SDG are that by default all information is public, which could cause conflicts and frustration, and that it is not suited for modern GUI systems. On the positive aspects, SDG could enhance verbal and non-verbal communication. It could encourage peer learning and teaching.

5.3 Electronic meeting rooms

The advent of new computer technologies, wireless and mobile networking capabilities have allowed us to utilize technology in new ways. During the collaborative design process, often there will be a need to collaborate with others in various scenarios. In such scenarios, designers may want to take advantage of handheld computers, electronic tablets and tables, and wall displays. This not only requires communication between devices but also raises issues such as, how information will be distributed across devices, information structuring and what information is displayed where, how designers interact in such environments.

Xerox PARC's Colab (Stefik, Foster, et al., 1997) was a meeting room (co-located synchronous) that explored and supported public and subgroup interactions. Instead of a single display on which all the participants focused as in SDG, each participant had a PC that was networked over a local area network to all collaborators' PCs and to a large display(s) (Liveboard) of the room. The system supported the display of shared windows as well as private windows. Shared spaces could be seen and edited by every participant. Therefore, shared workspace has become a medium where all information and communication between the participants in the CMCD session occurs.

The idea of 'Roomware' is central to the i-LAND (Streitz, et al 1999) system. This approach to meet the requirements of flexible configuration and dynamic allocation of resources in integrated physical and information environments is based on a concept called roomware. The project aims to integrate several roomware components into a combination of real, physical as well as virtual, digital work environments to support dynamic teams who work in changing flow of activities. Flexibility and mobility were prime concerns of this project. i-LAND is aimed at providing spontaneous encounters and informal communication. ”Team meetings are not anymore conducted by meeting in a room but by providing an environment and a situation where encounters happen” (Streitz, et al 1999). The roomware components include an interactive electronic wall (DynaWall), an interactive electronic table (InteracTable), and mobile and networked chairs with integrated interactive devices (CommChairs).

Stanford's iRoom (Winograd, et al 2001), explores how in Architecture, Engineering, and Construction multi-disciplinary project teams can use such interactive workspace environment to support group tasks, such as project review, project planning, and decision-making. The iRoom project also facilitates spontaneously formed subgroups by allowing participants to physically move their PCs to facilitate face-to-face subgroup communication.

6. CONCLUSION

Design is an argumentative process in which designers do not prove a point but instead create an environment for a design dialogue (Simon, 1981) where the product is co-evolved. A product in a co-evolved process emerges through a series of interactions between the members of the design team negotiating for a shared understanding. In collocated collaborative design, communication tools or methodologies are not of central interest (as for distributed collaboration), because the designers communicate face-to-face and use graphical representations, physical models and verbal explanations. It is a highly interactive process. Representations in a design conversation are resources for action, reflection and documentation.

Architectural design can be understood in two broad ways, deriving from engineering processes (rational processes) and from creative processes (discovery processes). Most of the existing groupware applications either support only *content related activity* (generation, sharing) or *process related activity* (planning, decision making). These systems are very rigid in process, information structuring and user interactions. With this formal and rigid process, designers only exchange information and in some cases only explain to each other rather than think together, act together and reflect together.

In a design dialogue, an individual designer must communicate his ideas accurately and completely to others and understand responding communications to him. A *CMCD space must support the dialogue and the informal argumentative process between the designers and also between the designers and the system. It is an augmented space where designers can monitor progress, exchange information and learn about what others are* *doing and how this affects one's own discipline area.* It is believed that a system that can support a flexible interaction style and bring to view a dialogue between designers might benefit architectural design activity; a system that supports and simulates overall collaborative engagement.

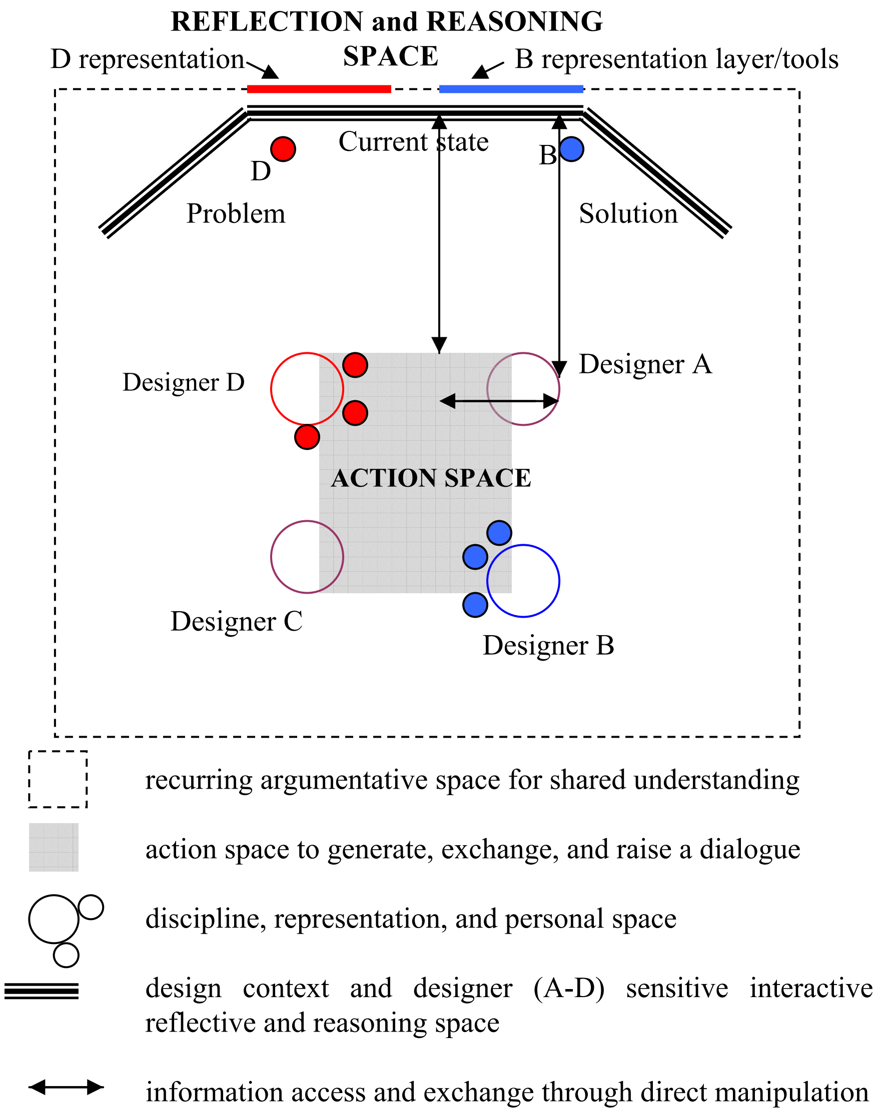

Figure 5. The proposed concept in outline.

6.1 A Scenario

The CMCD aims at promoting collaborative conversation in the form of a playful and constructive experience. The CMCD consists of an action space and a reflection space. Action space is an interactive horizontal shared space where users generate, structure, exchange, and transfer information within personal, shared, and external sources and raise a dialogue for an argumentation by means of tangible interaction. The reflection space is a context sensitive and designer/discipline sensitive interactive wall display. It displays representations of all disciplines of the current design state while focusing on the design context and also holds the recorded sequence of the design process (time line) where designers can visit any point of the sequence from time-to-time to reflect and reason. While reasoning and reflecting, displays are updated to accommodate the designer(s) 'in charge' and provide means to menus and tools to suit the conversation and reasoning. It supports sub-grouping and parallel conversations, layering of various representations that are of natural practice in a collocated design session. This project is in the phase of literature review at the moment.

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