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Virtual Environments for Collaborative Design: Requirements and Guidelines from a Social Action Perspective

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The paper is concerned with the design of virtual environments for collaborative design (VECD) - a particular class of collaborative virtual environments (CVEs) that focus on supporting design activities. VECD are becoming essential collaboration platforms for many designers and their clients, in a wide range of design domains including product, interior, architectural, automotive design etc. However, the contemporary design considerations of VECD are mainly driven by systematic approaches that do not reflect upon knowledge regarding requirements that stem out of everyday collaborative design activities. A consequence is that they do not yield methodical guidance to designers of VECD applications. This paper takes a social action standpoint for the purposeful identification and organisation of collaborative design activities; proposes guidelines at multiple levels of abstraction for the design of VECD; and finally, applies these to a case study development of a specific VECD for interior space design. The paper provides practical aids to designers of VECD so that they incorporate requirements about collaborative design early in the development lifecycle.

Keywords: Collaborative virtual environments; theory of social (communicative) action; interior space design; virtual reality; collaborative design

1. Introduction

Design today is considered a complex process that becomes meaningful within socio-cultural contexts (Krippendorff, 2006). In this sense, design is seen to emerge from a collaborative social practice and in turn is believed to give meaning to new forms of socialisation. Thus, the activity of collaboration and social change is considered an important factor for the evolutionary transformation of our society. According to Kvan et al (1997) the use of technological apparatus to support collaborative design practices, is not a new proposal, but is considered an inherent human objective. During our era of computerisation and in terms of collaborative design activities, new interests emerge by the use and

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exploration of computer assisted design tools, communication, coordination and cooperation tools as well as virtual environments. The research in computer supported collaboration (CSC), computer supported cooperative work (CSCW) and in extent, virtual environments (VEs), collaborative virtual environments (CVEs) and virtual environments for collaborative design (VECD) focus their analysis on technological factors and social processes that affect groups, organisations and communities that purposefully choose to interact and collaboratively design over the electronic medium.

Today, VEs in the domain of Virtual Reality are considered the designed, real-time computer generated, interactive, immersive and three-dimensional environments that try to produce to their participant users a sense of presence (from existence to symbiosis) in an alternative, simulated environment (a metaphor from reality or fictional) with spatial characteristics, often by the use of specialised hardware (Stavrakis et al, 2007; Steuer, 1992; Heim, 1993; Stanney, 2002; Burdea and Coiffet, 2003). Building on top of VEs, CVEs are considered the designed virtual spaces that attempt to provide alternative grounds for symbiotic collaboration in terms communication, coordination and cooperation and other forms of interaction and knowledge sharing. A special category of CVEs are VECD which offer supplementary functionality to their users in terms of collaborative design activities. These activities are usually observed by the systems designers and employed to the designed system to reflect user requirements.

The notion of the design of CVEs and VECD is a twofold concept and in our understanding refers both to the systematic design of VECD, and also to the underlying tenets and systems of beliefs that penetrate the methodological practices that support the processes of designing such environments (design and design thinking). Similarly to Brooks (1999), we are to infer that although technological advances in VR are often capable in supporting specific human needs, in terms of interacting and collaborating in VEs, there are still inadequacies at the methodological level of the design of VECD that restrict their realisation in actual design contexts. Specifically, there is a plethora of research works that focus on systematic/instrumental (bottom-up) approaches of systems design, without, at the same time, being informed from methodological (top-down) theoretical positions that situate the design context of VECD within an actionalistic, socially informed, interplay of design considerations. On the other hand, highly theoretical approaches make difficult the formalisation of their ideas and when formalised, offer little but overhead to the system designers who take all the responsibility to subjectively investigate their design context. Our position supports the idea that the design of VECD can be informed from reflexive methodological frameworks that provide to their VECD designers:

- a concrete but also reflexive theoretical position that describes the current state of the social setting,
- formalisation mechanisms (i.e. matching to techniques and other level design processes),
- guidelines that can provide rapid development processes on specific contexts. If needed, these guidelines can be redefined by the VECD designers in terms of the theoretical framework.

Designers can decide which way they prefer to follow in this framework - bottom–up or top-down - depending on their current state of interpretation of the design context. Towards the development of such a theoretical framework, we propose that an instance of it, a formalisation, is the analysis of the users' collaborative actions (including instrumental, communicative, discursive and strategic) by the use of the theory of Communicative Action (Theory of Social Action) (Habermas, 1984). Thus, the paper presents an understanding of collaborative design activities from the perspective of the theory of social action that is operationalised for the design of VECD in terms of relevant guidelines that can be taken up by application designers. Furthermore, it presents a case study development of a VECD in the area of interior space design that demonstrates the applicability and practical value of the proposed approach.

The paper is structured as follows: Section 2 presents a review of related works in the area of computer supported collaboration in virtual environments focusing on the methodological positions embraced; it also presents the background of this approach, i.e. the theory of communicative action and the social action framework. Section 3 explains typical collaborative design actions from the perspective of the theory of social action and contributes to the conceptual understanding of the basic activities and

requirements of collaborative design as social actions. Section 4 outlines the proposed approach for the design of VECD and presents a set of guidelines and tools by which these activities can be supported – at various levels of abstraction – by CVEs. Section 5 presents the development of a Desktop VE for the support of collaborative design in the area of interior space design on the basis of the proposed approach, illustrating that the proposed approach is applicable and informative to the design of VECD. Finally section 6 presents the conclusions and future work. This paper is a revised and extended version of the paper presented in (Vosinakis et al, 2007).

2 Related work and backgound

In this chapter we review current literature regarding the most challenging approaches for the design and development of CVEs and VECD. These approaches can be categorised by their underpinning paradigms, ranging from rationalistic ones that focus on technical achievements, to hermeneutic ones which are socially oriented (Stavrakis et al, 2007; Avis, 2003); we specifically refer to instrumental, structured-methodical, structured-methodological and post-methodological approaches. We further present an overview of the theory of communicative (social) action, on which we rest the proposed approach.

2.1 Review of design approaches to collaborative virtual environments

Instrumental design of VECD is accomplished with little account on explicit or formalised development methodologies, placing emphasis in programming and solving technical issues. Research works of current literature that focus on these fragmented, yet important, views in describing the design of VECD include works from a variety of different disciplines (Computer-Aided Design - CAD, Computer-Supported Cooperative Work - CSCW, CVEs, networking, Artificial Intelligence - AI etc). Briefly, these approaches tend to solve: technical issues of systems (3D scene representation/rendering, networking, hardware development) or technical issues for users (navigation, awareness, embodiment, communication, modelling and manipulating 3D geometry, project and asset management etc.). In many cases it is assumed that these are the major concerns around collaborative design. Examples in the area of VEs and CVEs include the MIVE (Stuerzlinger, 2002) for object manipulation, Ishii and Ullmer (1997) research on tangible interfaces, (Zeleznik, 1996) sketch system, (Oh and Stuerzlinger, 2004) virtual lego system, DIVE (Frecon, 1998), MASSIVE (Greenhalgh, 1995) and CAVERN (Leigh 1997) for networking CVEs and numerous other projects.

Structured-methodical VECD design approaches, focus on the identification of phases and stages that are thought to inform the management of systems development when followed in sequential order (i.e. waterfall model). On the other hand, methodological approaches aim to fulfil the gap left from the limitations of structured-methods. To do so, they propose that user factors and other contextual investigations should be performed in order to inform the way designers/developers should approach the design of systems. These approaches function as feedback mechanisms that take contextual information and adapt it to the design processes and design thinking. Examples include SESAME and in extent Covid (Stuerzlinger, 2006) which are built to support collaborative design activities.

Within this context, structured-methodological approaches that inform the design of VEs and can provide interesting grounds for the design of VECD, are also the evaluation frameworks presented in Bowman et al (2002). Central to the design of these processes is user involvement and systemic planning that tried to present a ‘holistic’ view regarding the complexities of human design activities. Kaur was one of the first researchers that focused in developing a comprehensive methodological view of VE design (Kaur, 1998). In her PhD thesis, she outlines three main areas that VE design should look at in terms of usability: *Development Activities* (requirements specification, system design, interface design, implementation, evaluation), *Classes of VE* (single-user, multi-user, real-world model, desktop, abstract, immersive, augmented, projected), *Design Considerations* (usability, cost, ergonomics, reliability, utility, health & safety, motivation). Based on this idea, Kaur provides a reflexive theoretical model that VE

designers can employ to effectively produce and mainly evaluate VE for usability. In addition, DesignWorld (Maher et al, 2005) is one of the first VECD prototypes on the area of architectural design. The methodological considerations towards the design of DesignWorld have confidence in guidelines that describe conceptual design activities and criteria for the design of collaborative support systems in supporting concurrent data access for designs in the CVEs. The study that informs the system designers of DesignWorld for the activities of the design participants is based on Protocol Analysis (Ericsson, 1984)(Cross et al, 1996). DesignWorld's implementation is an interesting pragmatic approach to VECD design. It provides valuable information for the design activities followed within a specific context of designers, but its results can hardly be used by other system designers in different contexts due to that system designers would need to use Protocol Analysis (or some other type of ethnographic method) in order to extract their own data. This approach can be complemented by the use of a theoretical framework of social action that provides a ground for researching social practices.

Whatever the merits of these approaches, designers still face increasing uncertainty and complexity. In a similar context of analysis, many researchers in different areas of systems development found that they could not be served by an either single 'soft' or 'hard' methodological approaches (Miles,1988)(Avison 1990). Hence, research practices divert their focus into a search for multi-methodologies (Avison 1990)(Bell, 2003). Post-methodological VECD design reconsiders the concepts and usefulness of instrumental development methodologies and theoretical frameworks, altogether. The functioning of methodologies in real world situations led designers to reject those that they personally considered either overly complex or single-dimensional and return to the multifaceted approaches for VECD. COVEN is a project that explores the requirements and supporting techniques for collaborative interaction in scalable CVEs without using any specific pre-existing methodological frameworks; only a posteriori evaluation mechanism. COVEN's analysis of collaborative activities is based on empirical, ontological observations: embodiment, subjective viewing, spoken interaction and collaborative way-finding. Another example of post-methodological design of CVEs is the reflexive theoretical multi-methodological framework of Stavrakis et al (2007). Influenced by the critical pluralism of Mingers and Gill (1997) and the pragmatic pluralism of Taket and White, (2000) they provide an actionalistic framework for multi-methodological practice in the area of VED. This framework provides a starting point for informing designers of VEs, CVEs and VECD on the collaborative design of such platforms in terms of three notional systems: situation representation, intellectual resources, design system. These can be mapped to: system designer collaboration, participant (user) designer actions, hardware requirements and theoretical model incorporation. An instance of these design actions (participant designer collaboration) is presented in this paper from the perspective of the theory of Social Action (Habermas, 1984).

2.2. Theory of Social Action: An Overview

The paper provides an understanding about collaborative design actions from the perspective of the theory of communicative action (also referred as theory of social action). The theory of social action is a comprehensive critical theory of social reality that has been developed by the German political philosopher Jurgen Habermas (1984, 1987). The theory offers an epistemological perspective about the nature of human actions in social reality; thus is may be employed in order to provide an understanding about the reach of support of scientific methods and tools that aim to support these actions.

According to the theory, social action is both instrumentally oriented, because people are interested in using tools and controlling physical artefacts and socially oriented, because the social actions are interpreted by others in order to be understood in the specific social context of interaction. Social actions may be oriented towards common understanding for reasons of collaboration with others or not, for example to deliberately violate established norms in order to strategically influence other actors (Agerfalk and Eriksson, 2006).

Ngwenyama and Lyytinen (1997) have operationalised the theory of communicative action into a social action framework that outlines a set of social action categories and the rules and resources needed to support them in everyday activity. The social action framework assumes, develops and explains four basic types of actions that interchangeably occur in society:

- Instrumental action: Instrumental action is goal-oriented focusing on the control, manipulation, and transformation of physical artefacts; the enactment of this type of action is dependent upon technical knowledge and tools.
- Communicative action: Communicative action is concerned with achieving and maintaining common understanding among participants engaged in coordinated action; it is enacted via language and other forms of symbolic interaction.
- Discursive action: Discursive action is oriented towards developing or restoring the background conditions for collaborative action; i.e. when questions are raised about the actions of a design participant in a group process, the mode of interaction may shift to discursive action. Discursive action unfolds through critical debate and argumentation which forms the basis for joint decision making and agreement.
- Strategic action: Strategic action is oriented towards influencing and transforming the behaviour of participants or the group in order to achieve advantage. Means for exercising strategic action include social and material resources that contribute to the generation of power and dominion of some actors by others, such as charisma, social status, authority, and items of exchange value (time, expertise, money, etc.).

Ngwenyama and Lyytinen (1997) have used the social action framework to discuss the primary action types that mainstream groupware technologies target, and they provide a taxonomy of groupware from this perspective. Their taxonomic view of groupware is useful for understanding technical possibilities. However, taxonomic views in general do not encourage designers to think about new designs of systems that can support particular situations of collaborative activity and work. Thus, the approach taken in this paper extends the work of Ngwenyama and Lyytinen (1997) by applying the social action framework to a particular problem context: that of the design of a particular class of collaborative systems (i.e. virtual environments) for a particular application area (i.e. collaborative design).

The framing of social activity as a distinctive (but not mutually exclusive) set of social actions that is provided by the theory of social action provides a conceptual framework that can guide the analysis of specific social actions and tools that can be used to support them. Any type of collaborative activity can be considered to entail each one of the aforementioned categories of social action; for example the set up and conduction of a collaborative project may include: a) strategic actions about the terms and conditions of participation and the overall scope and objectives; b) discursive actions about negotiating and refining the overall project objectives into specific tasks, responsibilities and outcomes; c) communicative actions, which involve cooperation about (at least temporally agreed) tasks such as coordination about the write up of a project deliverable; and d) instrumental actions, which involve the actual project development with the use of appropriate tools and resources such as writing software code using appropriate software development kits.

3. Viewing Collaborative Design as Social Actions

The situation of typical collaborative design actions in the aforementioned social action framework provides an understanding about generic requirements that CVEs should address from a particular perspective.

In terms of collaborative design, typical objectives of **instrumental actions** include the introduction, control and manipulation of tangible objects that are required for design, such as:

- Drawing sketches – designers typically draw design concepts or artefacts in sketches that gradually develop to more elaborated forms. (Bilda et al, 1998; Do, 2005)

- Constructing a landscape or (context) background (e.g. architectural plan) – in particular cases of collaborative design there is a need to situate the designed artefact within an environment such as a landscape.
- Filling in the design brief – the design brief documents important elements of the design process. (Ryd, 2004)
- Producing a prototype (e.g. rapid prototyping) – besides sketching, it is often required to produce prototypes, usually in cheap materials. (Yang, 2005)
- Creating mock-ups, models and artwork – depending on the problem domain other forms of prototypes include mock-ups, models and artwork.
- Orienting tangible resources into the design work space – these actions are relevant when the object of collaborative design is the design workspace itself, e.g. in the case of architectural design or interior space design.

In terms of collaborative design, typical objectives of **communicative actions** include face-to-face, written and verbal communication among design participants aiming at consent about design goals, such as:

- Meetings, presentations and short verbal communications that may be required to understand the progress of a design project.
- Mail exchanges that provide specific required and background information about the design project.
- Interviews of key people (such as intended users or end-customers) about their opinions about particular concepts or ideas, for example as part of market research.

Typical objectives for **discursive actions** in collaborative design are related to goal and process orientation of design participants, such as:

- Expressing high-level descriptions of requirements – clients need to express their requirements in order to denote their preferences or concerns about aspects of the design.
- Introducing ideas – designers come up with ideas on the basis of clients' requirements and concerns that may be imprinted in various kinds of physical artefacts.
- Expressing concerns about the progress and direction of the design.
- Applying methods for design, e.g. scenario-based: storyboarding – various methods can be employed to illustrate basic principles of the design concept and/or artifact.
- Applying methods for evaluating and validating solutions, e.g. design rationale (Moran et al, 1996) – again, there are various methods that can be employed to evaluate and validate design alternatives.

In terms of collaborative design, **strategic actions** are related to the exercise of influence or power among design participants and may include actions such as:

- Negotiating initial conditions for collaborative design – design participants may wish to alter the initial conditions of a design project later in the process to gain advantage (e.g. a higher budget or to impose a particular solution respectively).
- Considering particular design constraints as unavoidable – any design project has constraints that may be considered as unavoidable to serve personal goals and desires.
- Imposing access restrictions to tangible objects and resources – access and sharing of information and resources about a design project may be critical for participants or groups that wish to conceal information from others
- Expressing expert opinions – in cases where expert knowledge is considered an asset for the design process, the expression of expert opinions may guide the behaviour of other design participants towards the goals of the expert.

The record of these identified typical collaborative design actions is (certainly) not an exhaustive one – it is not possible to enumerate all possible actions that occur in any human activity, neither at an abstract level of analysis nor at more specific contexts. The situation of these collaborative design actions in the

social action framework can be of value to the designers of VECD in order to inform their practices towards purposeful new developments in the area that do not rely alone on the collaborative technology at hand. In addition, this understanding can be complemented, refined and contextualised by in-situ research methods that can identify specific requirements for particular applications.

4. Virtual Environments for Collaborative Design: guidelines for development from a social action perspective

Following the discussion of collaborative design from a social action perspective, our aim is to enhance the design and implementation requirements of virtual environments for collaborative design by exploring the tools and techniques that can support the identified actions and by proposing a set of design guidelines. Specifically, we decompose a VECD into four distinct interaction spaces, each of which attempts to map the respective category of social actions into a 3D visualization and interaction model. As a consequence, we present a new paradigm for designing and implementing VECD, according to which, the set of tools and techniques that will be part of the application is guided by the social actions that the application is aiming to support and by the specification of the respective interaction spaces. It is envisaged that the approach can be employed to:

- Provide insight to designers of VECD about the types of actions that could/should be supported by the available tools;
- Guide the selection and/or development of new collaborative tools and metaphors and
- Inform the evaluation of VECD in terms of the level of support that is achieved for the social actions of concern.

In the context of a CVDE, the 3D space usually models a complex scene consisting of static geometry, dynamic objects, and user embodiments (avatars), which navigate and interact with the environment. In the proposed approach, the environment is examined as the sum of the following interaction spaces:

- the *instrumental space*, in which users design the artefact,
- the *communicative space*, in which users communicate with each other,
- the *discursive space*, in which users form and modify their requirements and express new ideas, and
- the *strategic space*, in which user roles and their dynamic manipulation is supported.

We will examine each of these spaces in terms of design and availability of tools and techniques to support them and provide a number of guidelines for their design and implementation.

Instrumental actions occur inside the environment when users are creating and modifying the design artefact. In terms of 3D interactions, users should be able to identify and select dynamic objects in the environment and to change their geometry and appearance. Therefore, the instrumental space should offer tools to create new forms in 2D or 3D, to insert, copy and delete objects in the environment, to select and apply geometric transformations (translate, rotate, scale) on them, to group objects into more complex ones or to ungroup them, to change their form, etc. The dynamic objects of the instrumental space should be the elements that compose the artefact (e.g. 3D models) or any rational abstraction of it (e.g. sketches). Furthermore, the manipulation of the dynamic content could be enhanced with processes that assist an inexperienced designer or help a professional to speed up the design, e.g. constraint based manipulation (Fa et al, 1993; Salzman et al, 2001), batch processing, etc. The appropriate interaction support of such an environment depends heavily on the form of design and the intended users' tasks, but it is generally accepted that effective environments need to provide intuitive interactions based on real-world metaphors, where possible, and to consider the performance limitations as well.

The communicative space should provide a multitude of means for communication, ideally without cancelling the metaphor of the shared space (Tromp et al, 2001) and co-presence, which are the main advantages of virtual reality technology over other collaboration media (e.g. e-mail and videoconferencing). Synchronous communication can be supported by instant text messages visualized

inside the 3D environment and spatially related to the speaker, or by spatialised audio, provided that the system is running over a fast network. The support of asynchronous communication is equally important in a collaborative environment, since it allows the coordination of actions. It can be supported by posting text messages or images in shared boards or in special interest positions inside the environment and by tools that allow users to sketch in order to communicate concepts.

A great deal of emphasis should be put on awareness so as to allow the observation and evaluation of other users' actions. Embodiments should be designed in a way that the interpretation of their current action is as unambiguous as possible, which depends on the design artefact and the actions identified in the instrumental space. Human-like avatars are not always the most appropriate solution, especially when working with different scales (e.g design of a furniture item versus design of a building). If possible, they should also allow for a form of non-verbal communication, such as facial expressions in the case of anthropomorphic embodiments (Guye-Vuillème, 1999) or deictic gestures. Furthermore, given that a CVE is a space where visibility is inevitably limited, there should be support for peripheral awareness, i.e. the ability to notice other users and to perceive their current state even if they are not in the user's field of view. It can be activated using textual or sound annotations concerning events or using a mini-map for global perception of the environment and the users. Finally, an important feature that can enhance communication in virtual environments for conceptual design and can aid the process of agreement on principles and concepts is the ability to share viewpoints (Valin et al, 2001), i.e. to observe the content for another user's point of view. A number of design issues concerning user embodiments in collaborative virtual environments is presented in (Benford et al, 1995).

Discursive social actions can be supported by enhancing the means for collaborative argumentation. First of all, the inclusion of personal working spaces and the ability to copy the content of the shared space to the personal and vice versa will allow the construction of hypotheses by the members of the team without affecting the progress of the actual object of collaboration. Actions such as confirmation or expression of concerns about the work progress or the plan of actions can take place with the aid of tools that let users quickly evaluate the current concept and comment on it. In the discursive space, such tools could superimpose diagrams and design concepts on the working environment, visualize semantic associations between elements (e.g. places, objects, embodiments) and attach comments on them (Jung and Do, 2000). Furthermore, the environment could support and visualize different levels of abstraction for the same concept(s) in order to aid the sharing of ideas and scenarios. Thus, the discursive space should attempt to visualize and let users interact with the possible abstractions that can be used to argument on the design artefact, and which should be spatially related to existing elements of the instrumental space.

Strategic actions inside a collaborative environment can occur if roles are supported, preferably visualized through the embodiments, and access to objects is related to them. In cases where roles need to be flexible, the system may support dynamic assignment and release of authorities upon resources. In the strategic space, such authorities could be visualized in order to be easily identified and/or manipulated inside the virtual space. A model for the support of roles and authorities in Collaborative Virtual Environments is presented in (Chunyan et al, 2005). According to our knowledge, current VECD do not offer any inherent support for strategic actions.

The discussion presented above is summarized into the following set of guidelines:

1. Instrumental Space
1.1. Identify basic elements that compose the design artefact and any abstraction of it
1.2. Provide tools to support efficient selection and manipulation of basic and composite elements of the virtual environment
1.3. Based on user requirements and observations, assist user interactions by providing task-oriented manipulations
2. Communicative Space
2.1 Provide tools to support synchronous and asynchronous communication among design participants

2.2 Design user embodiments to support various types of awareness (workspace, task, peripheral, etc.)
2.3 Allow sharing of viewpoints among design participants
3. Discursive Space
3.1 Include personal and shared workspace, support transfer of content between the spaces
3.2 Provide tools that allow the introduction, visualization and manipulation of requirements and ideas
3.3 Allow for textual annotations and semantic associations on the elements of the instrumental space
4. Strategic Space
4.1 Identify user roles, rights and respective actions upon resources
4.2 Provide intuitive visualizations of roles
4.3 Allow for efficient assignment and adjustment of roles

Table 1: Guidelines for the development of virtual environments for collaborative design

5. Case Study: Development of a desktop CVE for interior design

To evaluate the practical value and applicability of the proposed approach we have designed and implemented a case study which is a Desktop VE for interior design. We present the process of identifying the social actions in the specific context of interior design and mapping them into the proposed interaction spaces. The case study has been implemented in Java using the Java3D API (java.sun.com/products/java-media/3D/) for the visualization of the environment.

5.1. Interior design as a social action

The purpose of interior space design is to enable design participants (e.g. groups of clients and/or designers) to gradually develop an elaborate proposal about the content of any type of interior space such as a house, an office, a restaurant or a conference room. Interior space design involves numerous decisions about style, form, content, furniture and other equipment arrangements and so on according to design principles and client preferences related to ergonomics, accessibility and aesthetics. In order to further inform our knowledge about interior space design actions, we have observed interior designers and architects during in their work settings as well as we conducted structured interviews after observation to validate our understanding of particular actions.

The interior space design activity usually starts with the elicitation of client requirements that requires intense communication among clients and designers. This communication varies depending on the firmness of client requests: when clients are quite firm about their requirements designers usually illustrate examples of styles, and artefacts, otherwise the communication takes the form of questions and answers. Having reached an initial perceived common-understanding of the requirements, designers have to elaborate these to a set of design alternatives, which will be iteratively evaluated and elaborated until a final design concept is agreed. During these actions of collaborative design, designers need to communicate the basic arguments for each proposal and how these correspond to the identified requirements; on the other hand, clients provide feedback, or might take on a more active stance by counter-proposing design ideas, elaborating or even revisiting the agreed requirements and so on.

5.2. Mapping actions into Interaction Spaces

The development of the interior space CVE has been based on the design approach outlined in the previous paragraph. Our aim was to implement an integrated system with inherent support for the four basic categories of actions. To achieve this, we mapped each category into the respective interaction space, in which we focused on the support tools for the respective actions.

Concerning the instrumental space, we have identified the main actions that take place in the interior space planning process as the following: constructing the apartment or room, furnishing it, and examining / exploring the concept. The tools designed to support these actions in the resources space are:

- Construction of apartment/room: construction and manipulation of walls, insertion of doors and windows on walls, insertion and modification of lights, modification of materials (colours, textures) on walls, floor and ceiling
- Furnishing: insertion and manipulation of furniture, grouping / ungrouping, alignment
- Navigation: exterior view / examination, inside view

The communicative space contains the user embodiments and the messages they transmit to each other. Concerning user representations, the solution of anthropomorphic avatars was not considered appropriate for all design aspects of this application area. The designers are expected to spend most of the time using the system in exterior view, and, therefore, a human-like representation is not adequate. However, users should be aware of others and especially of the tasks they are currently performing in order to coordinate the design activities. Therefore, we employed the solution of tele-pointers (3D arrows denoting the position of a user's mouse pointer) (Valin et al, 2001) to enhance awareness when users are in exterior view. In case they are navigating inside the environment and browsing the content users are represented with human-like models.

Synchronous communication is supported by instant text messages that are visualized inside the environment. Furthermore, users can post offline messages in a message board to communicate when they are not concurrently online. Finally, the communicative space allows sharing of viewpoints: a user may switch to another user's point of view to observe the content from her perspective.

Concerning the discursive space, in the case on interior space planning, client and designer will need to discuss about the design requirements and to relate them to the actual design concept. A client may express her requirements or concerns to the designer, a designer may propose a new idea, explain the concept or part of it, and both may wish to evaluate the concept against the initial requirements. In this space, users can express, visualize and manipulate their requirements, as well as relate them to the objects of the resources space. The tools designed to support user actions are:

- *Expression of requirements*: a user may draw an area on the ground and post an annotation in it, e.g. express her needs concerning the functionality of that area. Furthermore, she may use icons to visualize the class of furniture that she wishes to be included or not included inside that area.
- *Expression of concerns*: the system allows attachment of annotations on existing furniture or groups of furniture.
- *Proposition of ideas*: a user may draw shapes and regions related to existing furniture. Any transformation on furniture affects the respective annotations and sketches as well. Also, semantic associations (visualized as lines that connect them) may be inserted on two or more furniture to draw attention on them.
- *Evaluation of concept*: the concurrent visualization of requirements and resources space aids the quick, visual comparison of the existing concept to the expressed user needs.

The strategic actions of conceptual design are supported by the assignments of roles of design participants to the interior space CVE. The basic roles supported are those of the client and the designer. Each role can exercise access rights to the resources they own in terms of locking their position and orientation as well as by allowing others to collaborate with them in the same workspace. We find that there is no need for the development of more elaborated strategic actions, such as support for formal means for decision making, for the particular application of interior space design.

5.3. Use case scenario

The interior space CVE contains an integrated desktop 3D environment that includes all the aforementioned functionality. It can be used for the synchronous and/or asynchronous collaboration between clients and designers on developing design concepts for interior space planning. Users may

coexist and communicate in the shared space, express their requirements and ideas, create and reconstruct concepts, and provide feedback on them.

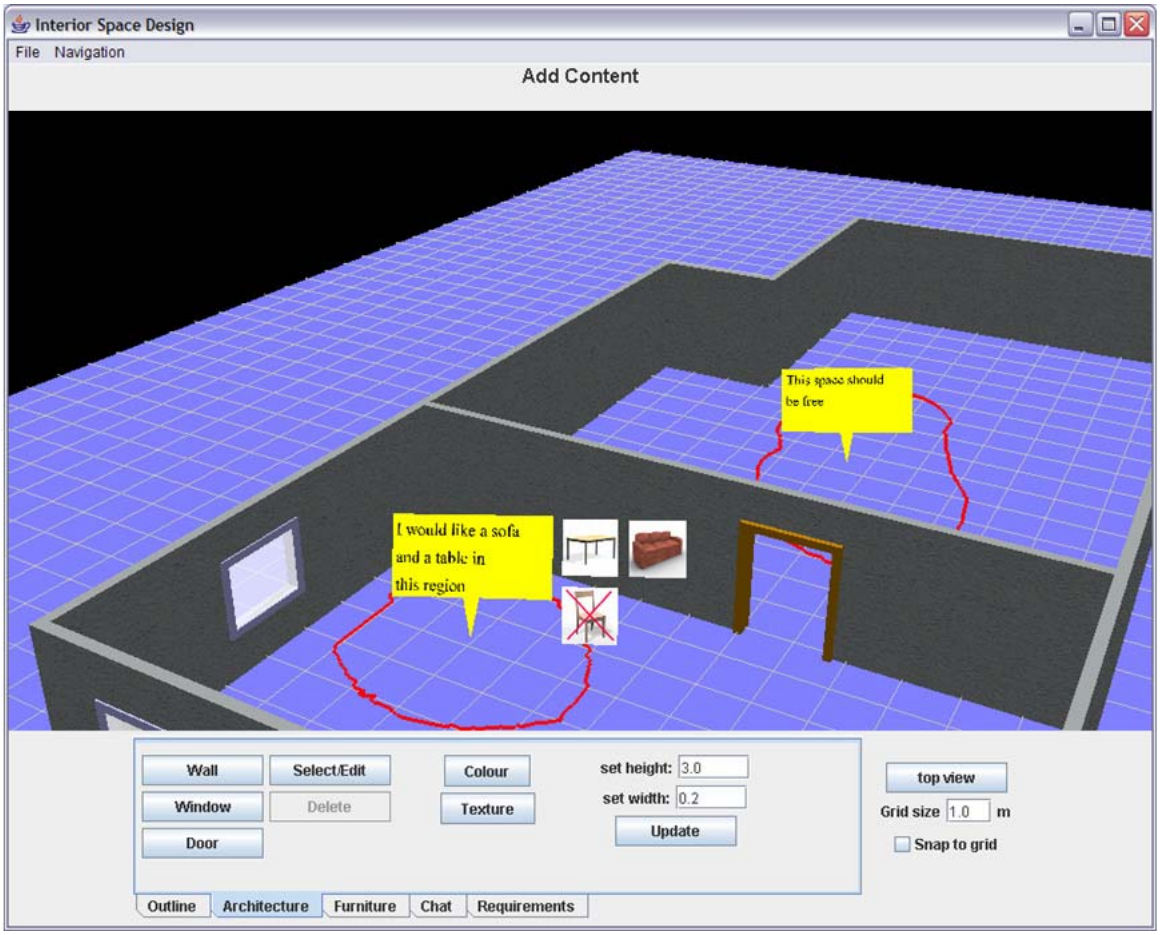

Figure 2. Visualizing Requirements

We present a typical scenario to demonstrate the use of the environment for interior space design:

- The clients log in to the interior space CVE and construct their house according to the architectural plan, which is scanned and mapped on the ground to assist the process. The environment offers a scaled surface where exact measurements are visible to allow accuracy during the creation and editing of the house. When the geometric model of the building has reached the desired level of accuracy, the clients add colours and textures to mach the actual space.
- Clients express their basic requirements about the way they would like their home to be designed. They mark areas inside the house where they explain their preferred properties or function (e.g. specifying empty space needed or room function) by posting annotations; they also visualize their wishes by using include and exclude lists: icons that display types of furniture (Figure 2).
- The designer is instantly informed about client requirements expressed in the 3D space and starts working by providing feedback in terms of proposing concepts on the basic of types of furniture according to these requirements. He inserts furniture and places them into the environment to match the clients' wishes (Figure 3) and also makes new proposals and discusses about the requirements using chat or manipulating the requirements space. He creates and saves various concepts.
- The clients review the concepts and provide comments on specific aspects of the design using annotations. They navigate inside the environment in first person view to evaluate the concepts and they ask for clarifications and express concerns about the design concepts (Figure 4)

asynchronously. They also arrange meetings inside the 3D environment with the designer to talk about concept proposals and to express their ideas.

- The designer and the clients interact synchronously with the content and exchange messages and sketches in order to review and improve the concepts.
- The conceptual design activity comes to an end as soon as a final concept is agreed by clients.

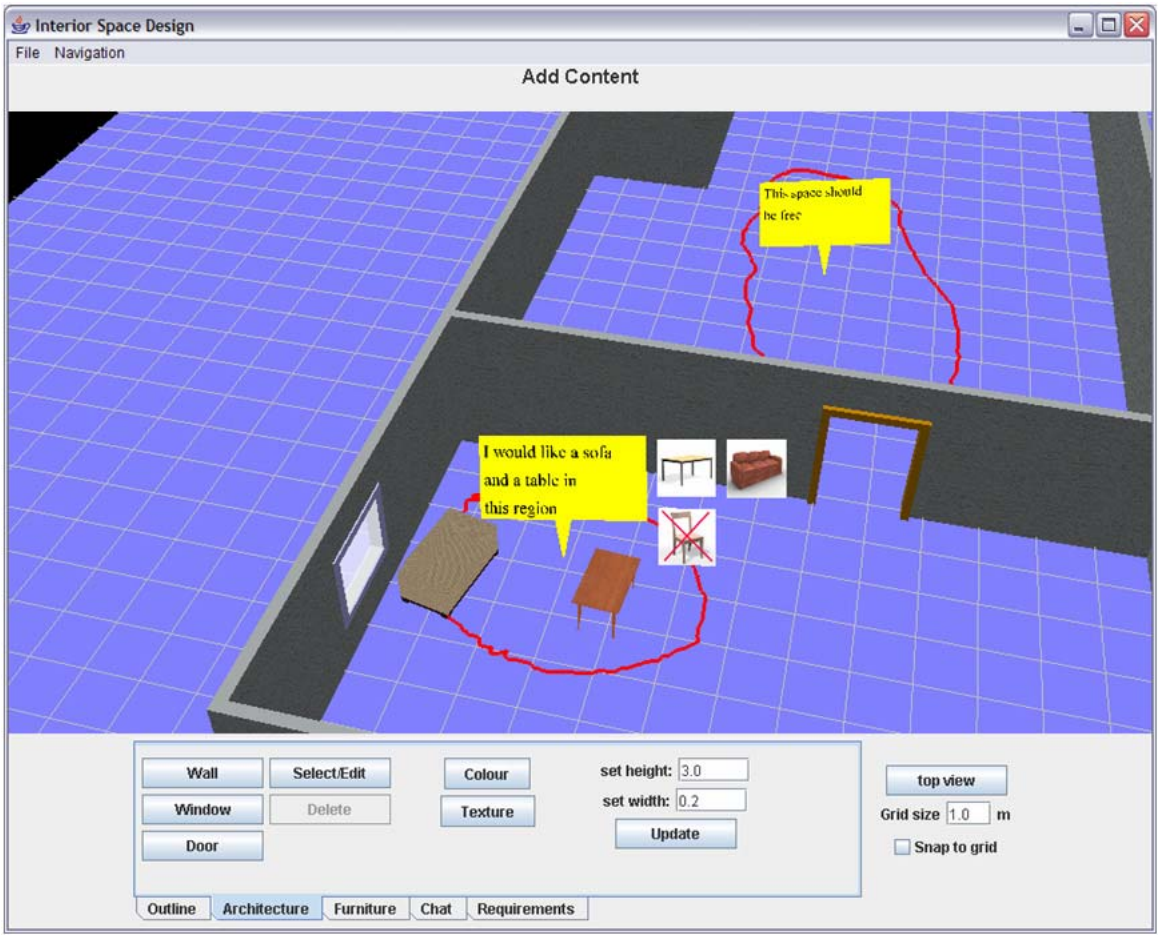

Figure 3. Creating concepts based on requirements

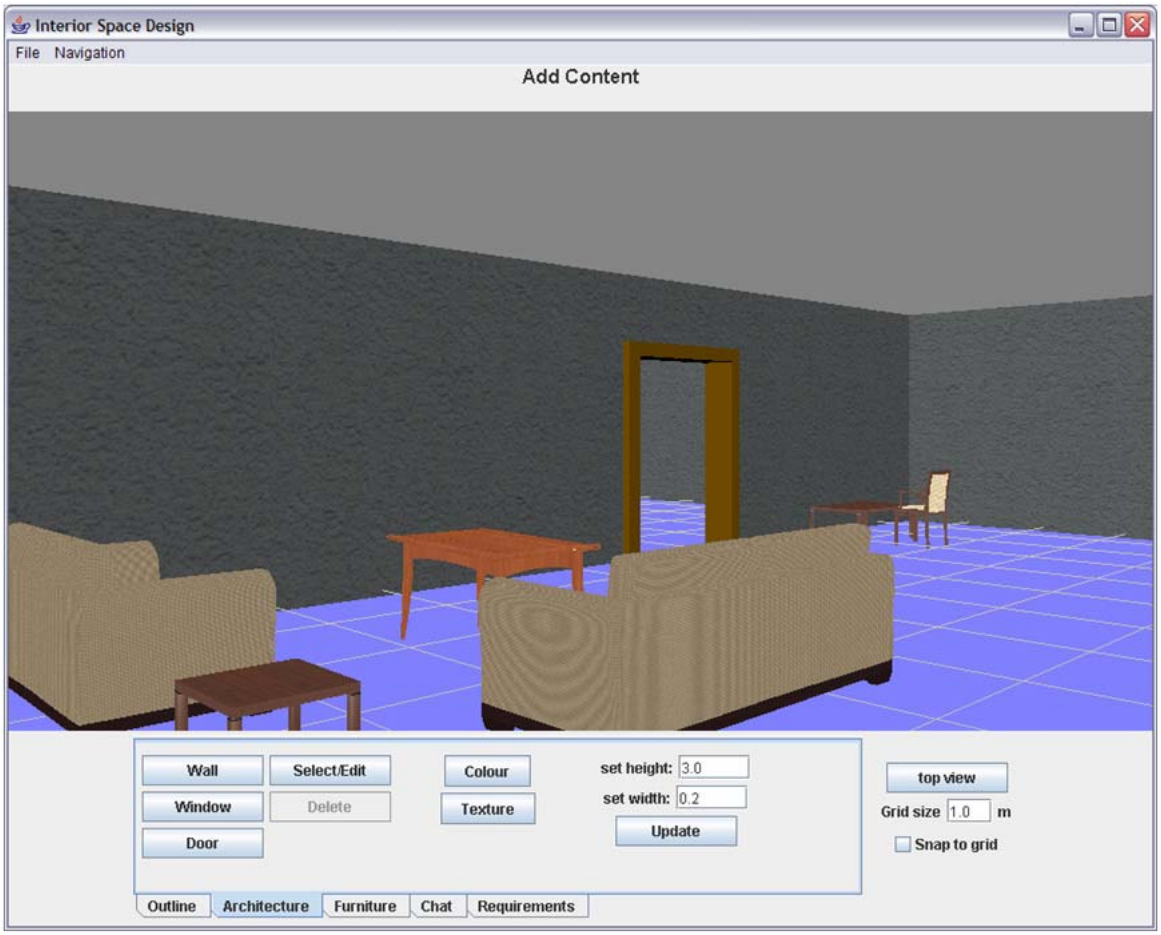

Figure 4. Evaluating a concept

To summarise, the interior space CVE enables designers and clients (and any other potential users) to interact about the object of interior space design, synchronously and asynchronously, situated in a 3D virtual environment that simulates their real interior space, while they are located at different geographic places.

6. Conclusions and future work

The paper presented an approach for the methodical design and development of VECD that incorporates the social aspects of collaborative design. The approach taken uses the perspective of the theory of social action to gain a better understanding concerning user activities during collaborative design and proposes useful levels of abstraction for thinking about VECD as well as guidelines for design and development. The proposed approach aims to aid designers of VECD concerning the tools and techniques they could include in their system, and also to guide the design of new components and metaphors for collaboration in 3D environments, especially in application areas that have not yet been fully explored. Finally, to demonstrate the applicability of the proposed approach, we presented the design and implementation of a prototype VECD for interior design and explained the use of our guidelines as the source of our basic design decisions.

The paper claims that designers of virtual environments and VECDs in particular, also need to be informed by principled frameworks in order to achieve a general understanding of the typical activities that these environments should support. Currently, most approaches for the design and development of VECD remain at the level of supporting instrumental and communicative actions. The theory of social action gives a general principled framework about social reality, which has been employed for the identification of collaborative design activities and related guidelines for design at other levels of

abstraction. For example, thinking about collaborative design as discursive action has helped us recognise additional requirements for VECD, such as the need to design tools and functions for expressing user requirements in the interior space case study; certainly other ideas may arise for other applications.

The proposed approach should not be thought of as a top-down process only. Despite that it has been described as such - to yield understanding -, the emphasis should be placed at the content of the design activity and not at the process. In other words, we identify requirements and guidelines, which are significant (if not essential) content elements of any collaborative systems design process, regardless of the particular methods that may be organised as top-down or bottom-up, linear or cyclical, etc. However, we acknowledge that methodical approaches can be complemented, refined and contextualised by in-situ research methods that can identify specific requirements for particular applications.

We are currently conducting user studies to collect empirical data about the types of social actions designers are engaged to and to evaluate the available tools and techniques in terms of their level of support to the respective action types in various design domains. Furthermore, we are planning to use our approach for the implementation of collaborative environments in other application fields, as well as to extend the proposed guidelines into a design and evaluation methodology.

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