Capture of user requirements and structuring of collaborative VR environments

(Key note speech)

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ABSTRACT

How can we specify user requirements for and structure new Virtual Reality, VR, based collaboration environments with rather limited knowledge about the future? The paper puts the development of VR and collaboration/communication support in perspective. Aspects are put forward on properties and structure of the next generation networked virtual collaboration spaces, underlying digital application models, and semantic web content. The contextual design method applied for user requirements capture and user environment design of collaborative VR environments is exemplified. Comments are finally given on experiences from practical use of VR systems in Denmark.

KEYWORDS

Collaboration tools, Contextual design, Knowledge Management, User requirements, Virtual Reality,

INTRODUCTION

The terms Virtual Reality (VR) and Virtual Environment (VE) was coined in the mid 1980s. Around 1992 VR became the dominantly used expression in the non-research community, (Bryson, 1999). Bryson came up with the definition "Virtual Reality is the use of computer technology to create the effect of an interactive three-dimensional world in which the objects have a sense of spatial presence." He further states after, putting the meanings of the words 'virtual' and 'reality' together, that 'Virtual Reality' means "to have the effect of having concrete existence without actually having concrete existence" and concludes "I think this is an impressively accurate description of what is special about what we are doing in VR".

From Merriam-Webster's Collegiate Dictionary, http://www.m-w.com/

> "Virtual Reality - Date 1989: an artificial environment which is experienced through sensory stimuli (as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment",

Information technology, IT, embraces the technologies to capture, store, manipulate, transfer and deliver information on different system levels involving as users both humans and digital artifacts. The capture and delivery interfaces contain explicit or implicit user models for access of underlying real world application models. The multimedia interface increases the degree of realism as we access the digital application models. VR is a very potent form of multimedia where we very realistically access computer stored digital application models.

We will see a lot of *creative* VR based designs in the future with different degree of mixed reality. They will house completely synthetic worlds inhabited with special kinds of avatars and artifacts offering completely unimaginable tools for collaboration and application model access. Virtual spaces will be designed and built with a great variety of functions, forms and contents.

We will create *new worlds* with up to now unfamiliar properties such as real time space overlays, controlled communication spaces, and intelligent responsiveness. Collaboration *contexts* and *collaboration tools* can easily be changed causing shifts in operation modes with completely new functionality (e.g. move my eyes to another place or person, personal agents, many users handling the same tool in parallel, tools for personal or team views to work space, tools to hand over a complete environment/context). *Virtual products, processes* and *non-existing objects* will be elaborated on in not yet invented ways.

From Computer Graphics World (CGW, 2000) we cite:
"Consulting group CounterEntropy Strategies LLC convened 64 engineering software industry leaders to articulate an agenda for the start of the new millennium. What problems remain to be solved, and what new ones will we face? Some of the answers were predictable; others were surprising." In order of importance they mention - user interface, web implications, interoperability, barriers to implementation, knowledge capture, software distribution, workstation performance, 'Failure of The Grand Unification Theory of CAD', and better tools".

The question arouses how can we structure and specify user requirements for these new environments with rather limited knowledge about the future? One important clue is incremental prototyping in close collaboration with end-users.

In the remainder of the paper I will try to put the development in perspective and give some examples on efforts to enlighten issues on capture of user requirements and structuring of collaborative VR environments.

A PARADIGM SHIFT

Moore's Law (the relation between performance and cost will double every 18 to 24 months) is still valid and will be for another decade. Figure 1 confirms the law through my own experiences.

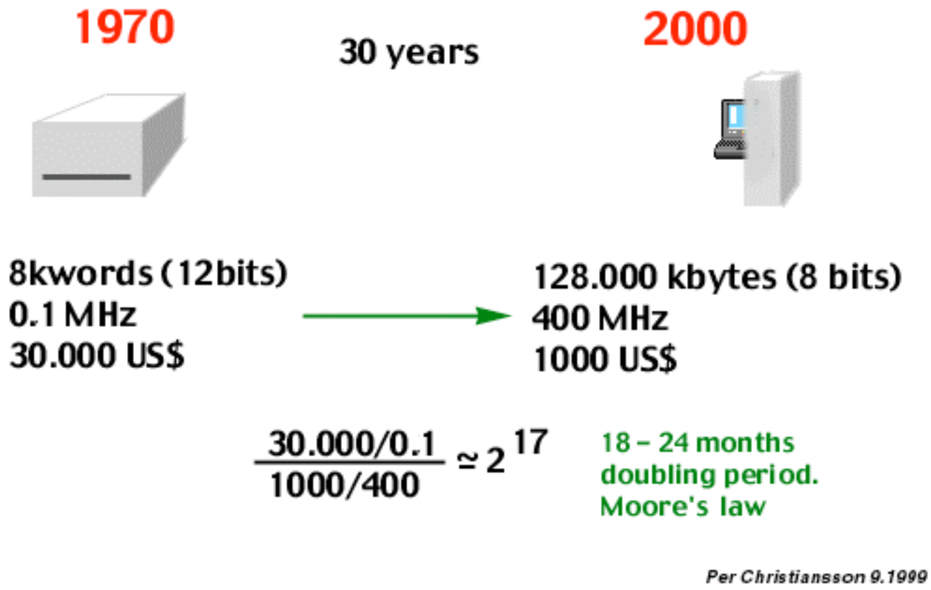

Figure 1 Moore's Law exemplified

From the birth of the computer up till now we have had a rather predictable linear development of computer systems with up-scaling in power, networking, interactivity and generality.

The computer has given us opportunities to expand the limits of the real world.

- Increased calculation and analyses capacity to our brain;
- Expansion of our memory (all information produced is stored - good and 'bad', higher emphasis on meta information creation)
- Embedded intelligence into digital artifacts (from search agents to intelligent buildings);
- Amplification and expansion of human sensory input/output;
- Increased and new creative control of surrounding world;
- Creation of virtual spaces and objects where we have freedom to manipulate geometry, time, appearances, properties and location with spatial presence;
- Expanded human communication and knowledge management abilities.

Some basic concepts for the further discussion are presented in figure 2.

Figure 3 shows an example on knowledge nodes that are beginning to be built now. We will develop specialized 'meeting places' containing more and more digital knowledge and experiences on projects, products, and processes.

The semantic web may be the next step in the evolution of the Dynamic Knowledge Net which also will highly influence the design of distributed workspaces for collaborative work and communication.

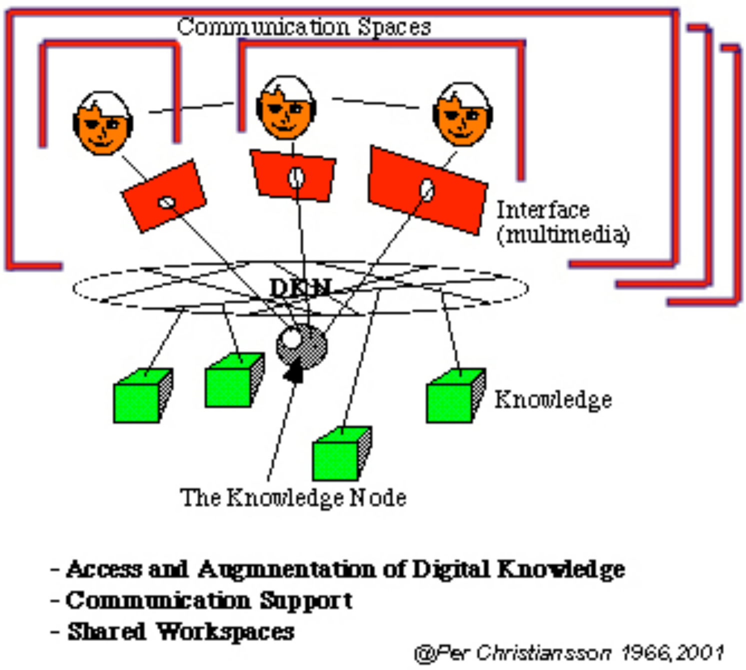

Figure2 Information and communication tools (ICT) support communication between persons in defined spaces and access to underlying information containers. [Dynamic Knowledge Net, DKN, (Christiansson, 1993])

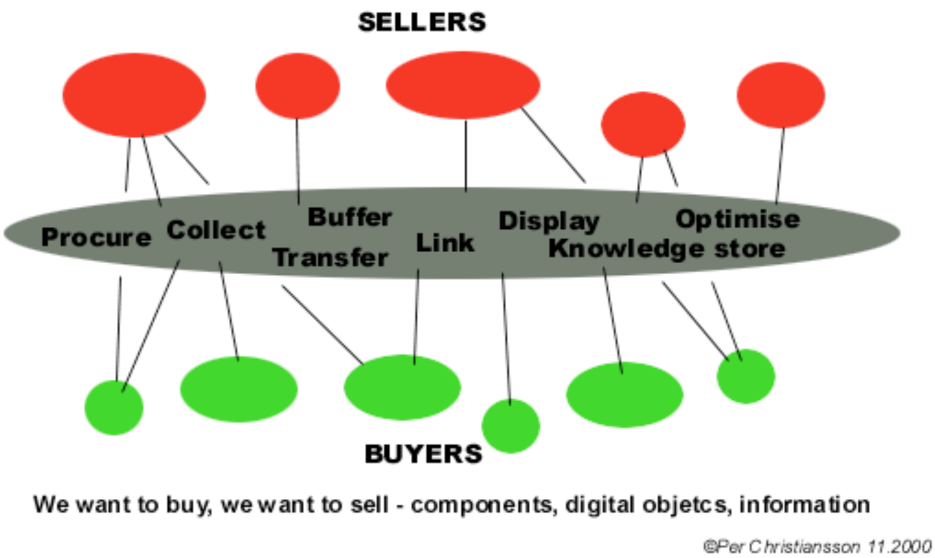

Figure 3 From drawing interchange support to specialized business/project portals.

"The Semantic Web will bring structure to the meaningful content of Web pages, creating an environment where software agents roaming from page to page can readily carry out sophisticated tasks for users." " The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation. "   "The challenge of the Semantic Web, therefore, [comparing to the development of today's WWW indices, my comment] to provide a language that expresses both data and rules for reasoning about the data and that allows rules from any existing knowledge-representation system to be exported onto the Web." (Berners-Lee, et.al., 2001). The semantic web concept will use eXtensible Markup Language (XML), Resource Description Framework (RDF), and Ontologies (with taxonomy and a set of inference rules) as basic building substances. See also (Christiansson, 1998).

DIGITAL MODELS OF OUR REALITY

It is now more meaningful than before to strive for design, construction and usability tests of *virtual buildings*, VB, see figure 4, especially as we cannot make physical prototypes to test as in connection with production of long series of similar items. Ironically it is also easier to handle formalized product models in the latter case as these design and production environments most often are more stationary and organizationally formalized than the building industry.

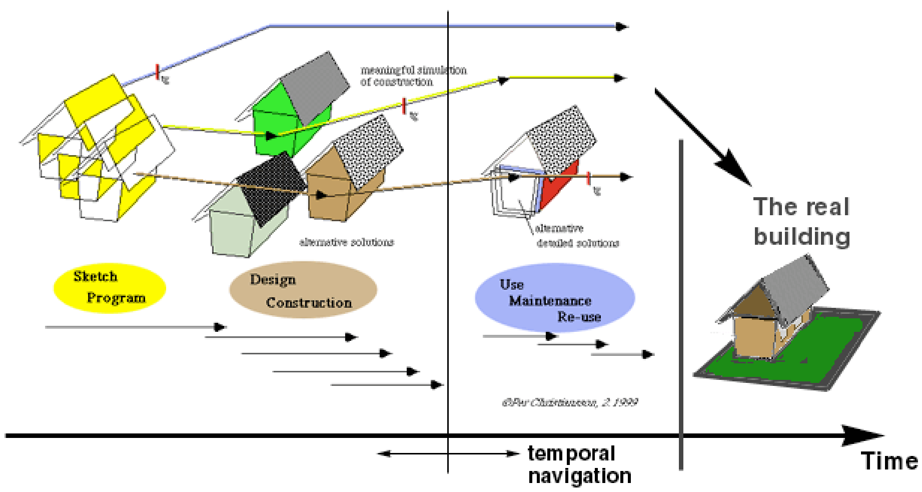

Figure 4 Alternative designs of the Virtual Building, VB, can be built and tested before the construction starts (Christiansson, 1999).

We will continue to build redundant building product and process models using a wide variety of digital knowledge representations. The VR access to these models will increase in importance for interactive virtual building design throughout its lifecycle, and for collaboration and communication support. The building material and component manufacturers will be early suppliers of digital building parts in standardized formats. Parts that easily can be accessed in VR environments and handled in e-business portals, see also figure 3. At the same the need for meta models increases to provide structure in the exploding amount of digital information stored in the networks.

It is also worth mentioning here the increasing use of interactive 3D models distributed over the WWW and accessed in web browsers for detailed and functional product demonstration and documentation. These models could also be embedded in the products themselves. See e.g. Cult3D at http://www.cult3d.com/.

IT TOOLS TO SUPPORT COLLABORATION AND COMMUNICATION

Due to introduction of ICT we must define some basic parameters to describe the collaboration in existing and not yet defined environments. These parameters are participants, collaboration subject, form of interaction, communication content, meeting spaces, time (real time during collaboration and time points in the life cycle of a design artifact), collaboration artifacts (communication channels, control and access mechanisms, and user applications and information containers). (Christiansson, 2001).

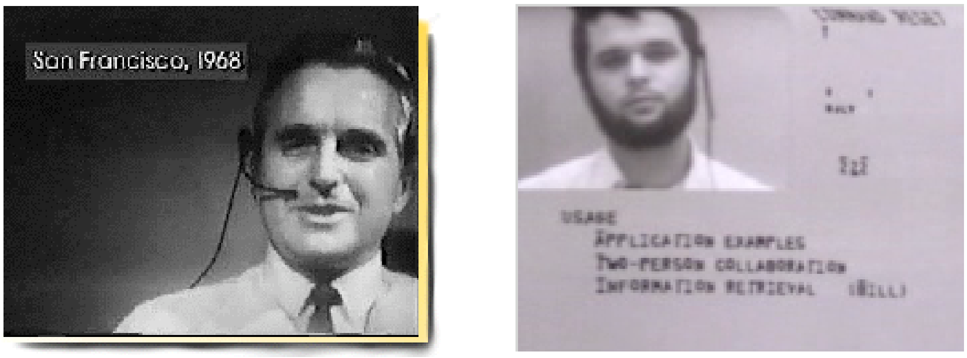

Figure 5 Doug Engelbart 1968 demonstrates distant collaboration over the net with document sharing and video communication. From http://vodreal.stanford.edu/engel/17engel200.ram. Vigraphical Sketch. Douglas C. Engelbart. Bootstrap Institute

Already in December 1968 Douglas Engelbart demonstrated the first networked remote collaboration with video communication and remote control. See figure 5.

A review of the development and our experiences from use of different Internet supported collaboration tools (from CuSeMee 1990 to the peer-to-peer based Groove, http://www.groove.net/) are reported in (Christiansson, 2001). See also (Modin, 1995).

The interest for creating Virtual Reality (VR) environments increased after the introduction of the CAVE (a recursive acronym for CAVE Automatic Virtual Environment) virtual reality system in 1992 at the University of Illinois at Chicago (see also http://www.evl.uic.edu/anstey/THING/aw_article.html). In order to provide a low cost VR environment a peer-to peer PC windows based system was developed at KBS-media Lab at Lund University (Lindemann, 1996). See figure 6. The system enabled synchronous or asynchronous manipulation of and navigation in 3D building models. The participants were represented by Avatars in the model view, guided tours could be stored and objects manipulated and annotated (yellow stickers on objects) for information to visitors. The system showed that low cost high quality 3D collaboration system could be implemented and useful. (With additional 3D low cost glasses such as CrystalEyes, http://www.stereographics.com/, the notation of presence could be increased).

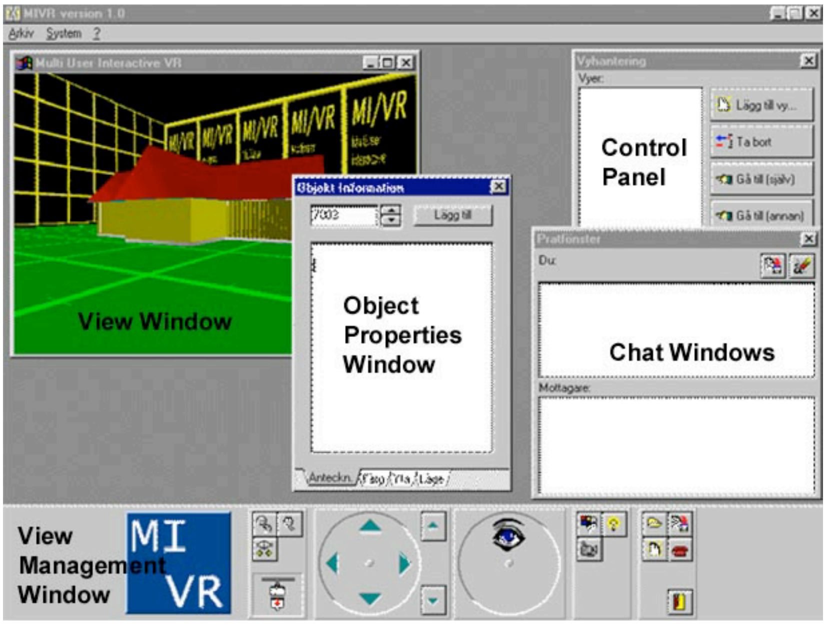

Figure 6 Low cost virtual reality environment for synchronous and asynchronous work on building models. From (Lindemann ,1996).

Screen element	Description
View Window	Shows the current view of the model loaded.
Object properties	If a user clicks on an object in the model the object properties window is shown and it is possible to change attributes and to annotate it.
Chat window	Enables two users to exchange text messages with each other.
View management	Enables user to save views and to move between views.
Controlpanel	The heart of the system. From this the user can connect to another LCD-VR system. Move around in the model. Change view angle and many more functions.

Table 1 Screen element descriptions to the low cost VR environemnt in figure 6. From (Lindemann ,1996)

Concerning *augmented environments*. From 'Occlusion in Collaborative Augmented Environments' http://www.cg.tuwien.ac.at/research/vr/occlusion/ (Virtual Environment Group, Graz University of Technology, Austria. Project started 1996). See also figure 7. And from the same source:
"One of the main advantages of using an augmented environment for collaboration as opposed to an immersive setup is the direct interaction of participants in reality. While the collaborators in an immersive setup always have to rely on more or less satisfying representations of each other, ranging from disembodied hands or heads to complete bodies visualized in plausible poses, users of an augmented scenario always are able to directly see each other and the interface devices they are using. This combination of reality and virtuality leads to the problem of correct occlusion between real and virtual objects, which of course does not exist in an immersive environment."

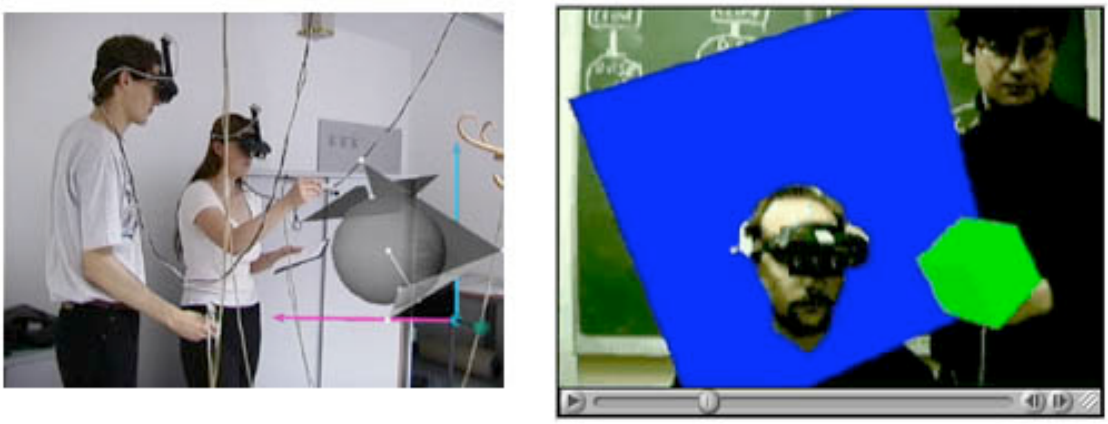

Figure 7 Augmented reality examples. Left; "A tutor and student are working together in Construct3D. Both are constructively solving an example from vector analysis." from http://www.cg.tuwien.ac.at/research/vr/studierstube/construct3d/. Right; 'Virtual object intersecting real head' from http://www.cg.tuwien.ac.at/research/vr/occlusion/headmove.mov

VIRTUAL COLLABORATION SPACES

The DIVERCITY project example

The ongoing DIVERCITY EU IST project, http://www.e-divercity.com/, aims to improve the process of building design and construction by enabling user groups to operate both more efficiently and with better interaction in virtual reality environments. The project addresses the three key building construction phases:

- *Client-Briefing*, requiring detailed interaction with the client;
- *Design Review*, requiring detailed input from multidisciplinary teams of architects, engineers, and designers;
- *Construction*, for fabrication and/or refurbishment of the building/s.

The objective of the project is to produce a prototype virtual workspace that will enable the three key phases to be visualized and manipulated, and to *produce a set of VR tools that aid the construction design and planning process*.

The R&D team in the EU DIVERCITY project (IST project No: IST-1999-13365, is composed of building industry representatives from Denmark (COWI), Finland (Equator), and France (SPIE), system developers from England (University of Salford), Italy (CRS4), Finland (VTT), and France (CSTB, CS SI), and researchers from Denmark (Aalborg University), England (University of Salford), Finland (VTT), and France (CSTB, CS SI, CRS4).

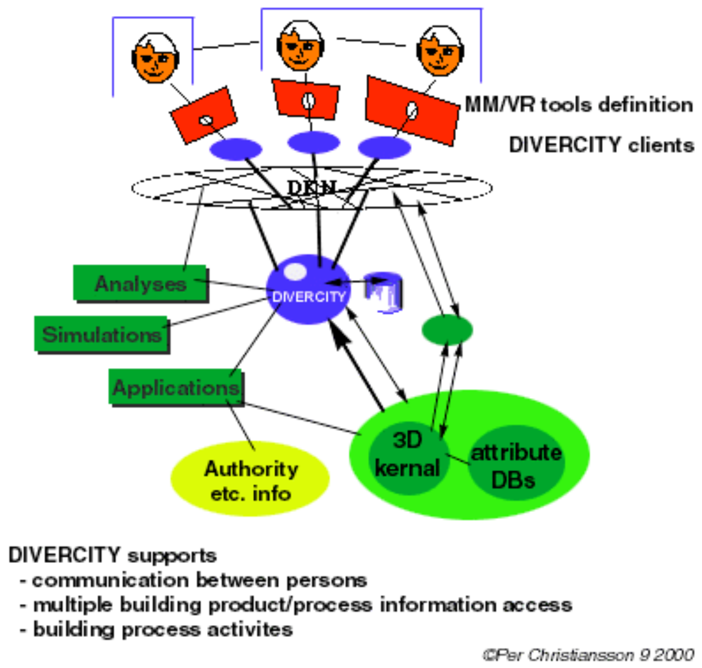

Figure 8 DIVERCITY in context. The overall function, form, content and behavior must be well defined.

How can we structure a distributed application model efficiently? Today's commonly used computers can only directly manipulate small 3D solid models. A tessellation process must be carried out to minimize the graphic calculation load on the computer. In addition to that the distributed containers of digital models which are augmented in a scattered virtual workspace environment have to be structurally optimized. It is important to study on which domains and on which levels systems like DIVERCITY will contain knowledge about the building product under design, application programs and external information sources. How much of the building model and semantics does DIVERCITY contain? See also figure 8.

In connection with the DIVERCITY project we made the following *definition* of a Virtual Workspace. (Christiansson et.al., 20001)

> 'The Virtual Workspace, VW, is the new design room designed to fit new and existing design routines. VW may well be a mixed reality environment. The VW will host all design partners from project start with different access and visibility (for persons and groups) in space and time to the project, and will promote building up shared values in projects. The VW thus acts as a communication space with project information support in adapted appearances. VW gives access to general and specific IT-tools '

A collaborative VR design system should

- Provide effective *collaborative* VB access;
- Be able to *reference* complete (also redundant) models of VBs and building processes;
- *Integrate* existing applications to the VW in a uniform and user adapted manner.

The Virtual Workspace, VW, will house a number of *actors* and *artifacts* such as, design team members, guests (e.g. suppliers), the process manager artifact (PMA), communication artifacts, container artifacts, the design artifact (the virtual building), and sub-spaces. S*ubspaces* used in different building process contexts may be, negotiation spaces, collaboration spaces, co-ordination spaces (to allocate resources such as external applications, information sharing, project constraints handling, collaboration rules, design goals, defined and active spaces and sub-spaces), and external access spaces (window to market, vendors, other project webs).

The Process Manager Artifact (PMA) supports the project manager in co-ordination activities such as

- *Resource* management (links to and description of applications for modeling, analyses, and simulation, documentation tools, data warehouses, etc.);
- *Communication* management (access and viewing right to models and documentation in the Virtual Workspace, time browsing support, information ownership administration);
- *Process and project descriptions/documentation* (meta description of processes, contract/agreements, pre-studies, meta data repository, thesaurus, dictionaries).

The communication layer in DIVERCITY uses the XML/HTTP based Simple Object Access Protocol (SOAP). See also http://www.develop.com/soap, http://www.w3.org/TR/SOAP/, and http://www.oasis-open.org/cover/soap.html.

The common geometric representations of the product models in DIVERCITY use the Industry Foundation Classes (IFC) developed by the International Alliance for Interoperability (http://iaiweb.lbl.gov/), as well as the ISO Part 42 of STEP (Standard for The Exchange of Product data), (Coudret et.al., 2001).

Learning spaces

Virtual collaboration spaces will have a great impact in the learning domain. Companies will to a higher extent than before be forced to provide facilities for (distributed) learning and often in collaboration with other knowledge transfer and knowledge provider organizations. In fact learning is highly linked with all knowledge management activities within organizations.

Figure 9 shows how physical spaces for learning and regular office spaces are linked to form virtual learning spaces in what we could call a distributed learning environment. My own definition from 1999;

> ”*Distributed learning* takes place in a virtual learning space that expands the conventional study chamber and classroom in time and room with regard to learning style and interaction modes as well as learning material and learning methods”.

The underlying logical configuration of knowledge nodes (for a whole education, courses, and persons) raises some fundamental questions on control of information flow between teachers, students and course administration as well as physical storage of learning material. To this we shall add dynamic net configuration, user adapted interfaces in more or less advanced multimedia environments, and virtual rooms that can change states (function and form) quickly (adapted for groups, individuals, presentations, discussion, etc.). See also (Christiansson, 2000).

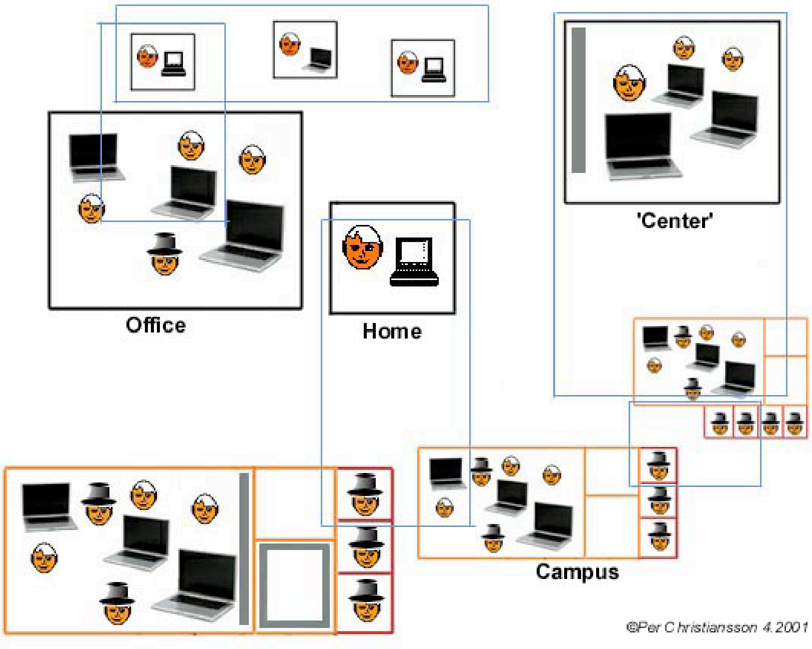

Figure 9 Relations between physical and virtual collaboration spaces in a distributed learning environment(the persons with hats are tutors)

CONTEXTUAL DESIGN AND USER REQUIREMENTS CAPTURE

It is extremely important to bridge the gap between the user requirements specifications, the actual interface design, and implementation of the underlying system of the distributed virtual workspace. This is certainly true when we design a new type of design support artifact (DIVERCITY) which will highly influence the traditional working methods and integration of design resources.

It is hard to find well formalized methods to support the entire design of a products like the above mentioned DIVERCITY. We chose due to its well worked out user centered approach the Contextual Design method (Beyer and Holtzblatt, 1998) to try to early take into account end user work practice and interface requirements. We use incremental prototyping techniques where the whole design team including end users participate from the very start of the design process. Our design approach is of more creative and innovative nature than routine.

The design team should have a broad competence from the start of the project. The two main groups are the *user environment (U)* and *systems design (S)* groups. It is important to maintain close collaboration between the U and S groups. From functional requirements the form of the system (user interface and environment, information structures, and control and management services) are gradually formulated.

The U group has a big role in the initial system specification. Who are the system users and how can the system support communication, what models and design tools will they use, and what storage requirements do they anticipate. The S groups starts to investigate possible knowledge representations to be used in the system under design, possible interconnection of application programs and product models, and required system management functions. Both groups document and communicate their conceptual modeling work internally and between the groups. In the DIVERCITY project the S group partly used the *contextual design* (Beyer and Holtzblatt, 1998) methodology and the U group UML, *Unified Modeling Language,* (http://www.rational.com/uml/resources/whitepapers/index.jsp).

There are five different types of *Work Models* in the Contextual Design method (these models are used to make detailed storyboards describing the user environments). The Work Models, listed below, were developed in close collaboration between COWI and Aalborg University. See also (Christiansson et.al, 2001).

- *Flow*, representing communication and co-ordination necessary to do the work (roles, responsibilities, actions/communication topics, and spaces which in DIVERCITY are regarded as project internal or project external memories and virtual/physical spaces);
- *Sequence*, showing the detailed work steps necessary to achieve intent. Sequence models can reveal alternate strategies to achieve the same intent. The sequence models are complemented by the artifacts models to show how the design artefact is manipulated and with what tools. They also help to reveal the design intent and how the team, groups and persons think about their work.
- *Artefact*, showing objects created to support the work. Artifacts are identified and grouped in relation to *intended* and/or real use and their properties described (e.g. personal/shared, DIVERCITY-specific/general, synchronous/asynchronous usage, access rights, access levels, artifact memory, alternative artifacts for the same activity, alternative VW activities with use of same artifact, artifact hierarchies, identification icon and name);
- *Culture,* representing constraints on the work caused by policy, culture or values, formal and informal policy of the organization, business climate, self-image, feelings and fears of the people in the organization, possibility for privacy;
- *Physical,* showing the physical structure of the work environment.

The flow and sequence models, graphic examples in (Christiansson et.al., 2001), are combined with the artifact models and synthesized to storyboards, figure 10 and figure 11.

Using *storyboards*, the team develops the vision into a definition of how people will work in the new system and ensuring that all aspects of work captured in the work models are accounted for. It is now time for a detailed *user environment design, UED*, with no prescribed order of work as in the storyboards, valid for many story told, and with detailed user interfaces proposal. Objects and other knowledge representations are further specified to meet user-induced requirements. Figure 12 shows the progression from design to development.

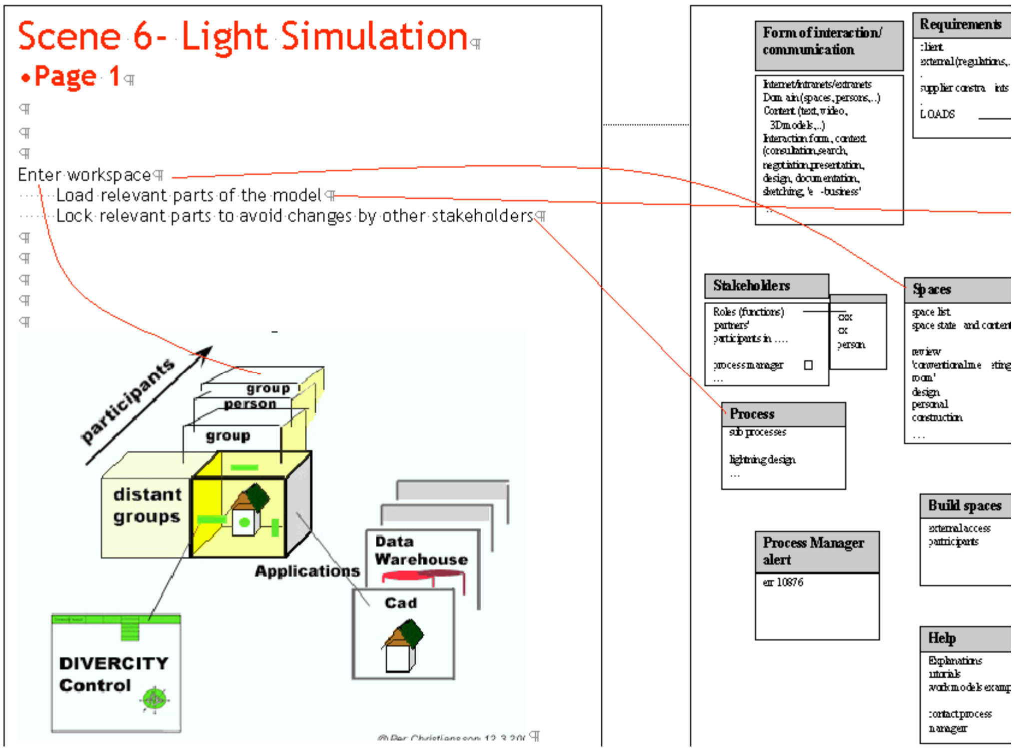

Figure 10 High level story board for light simulation during design. The 'story' (text under header) is linked to artifacts here denoted as graphic entities.

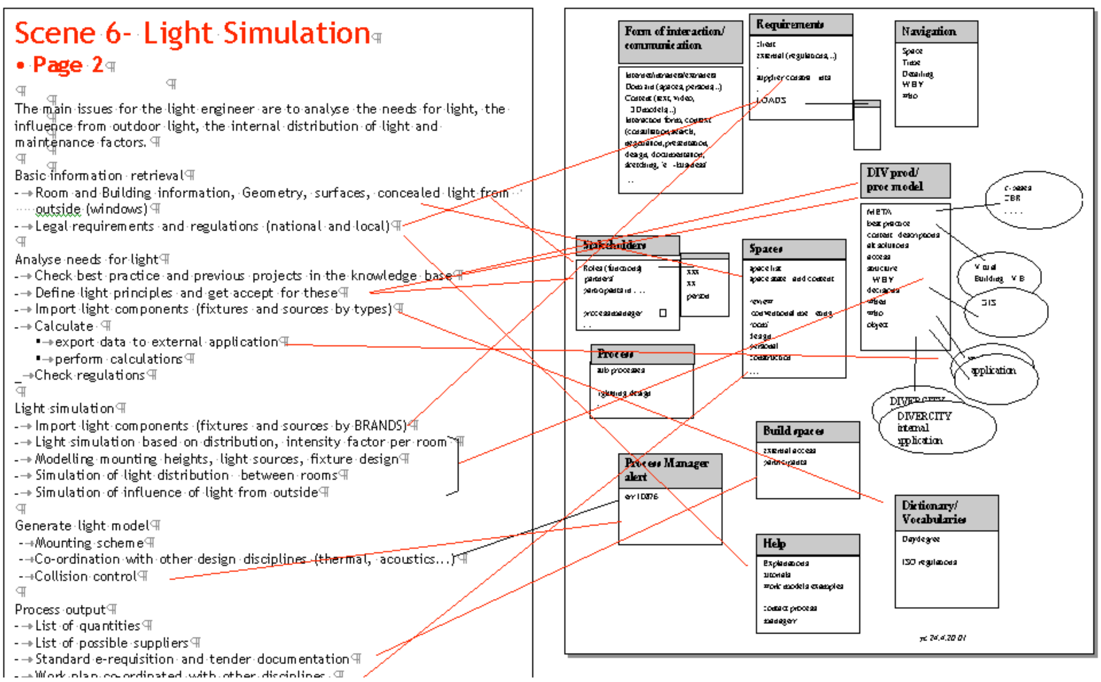

Figure 11 Storyboard in figure 10 further detailed. [Christiansson P, Svidt K, Aalborg University and Skjærbæk J O, Aaholm R, COWI Aalborg]

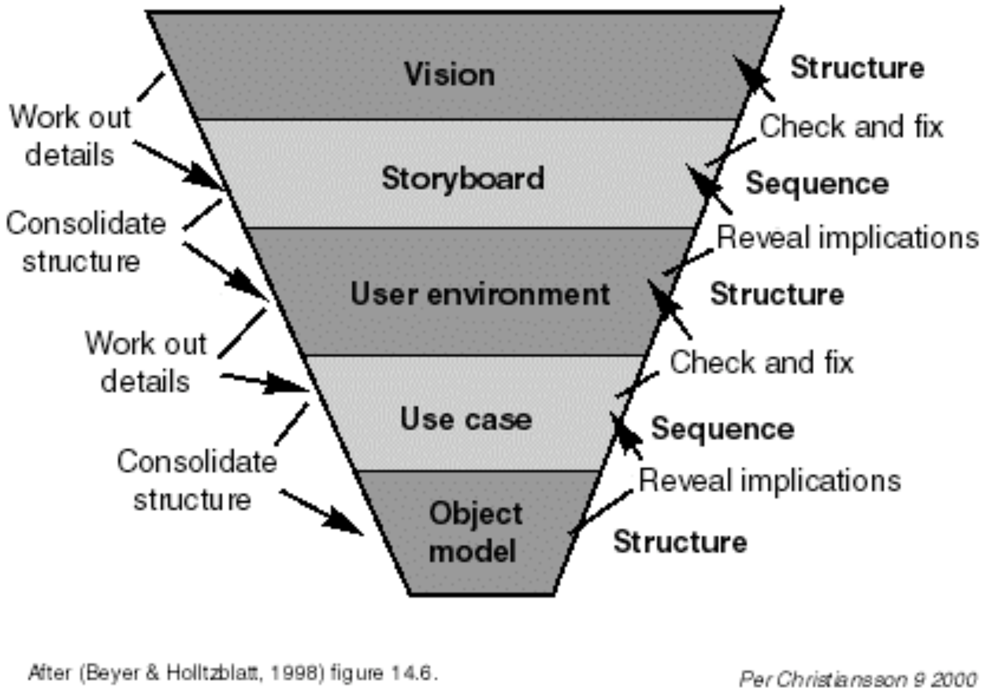

Figure 12 *The progression from design to development. The stories show a particular instance of using the system; the structure shows how the system can support multiple stories and drive lower-level stories specifying more detail. After (Beyer and Holtzblatt, 1998).*

VIRTUAL REALITY IN DENMARK

There are three main VR Centers in Denmark. The Aalborg Center the first established and most heavily equipped even after European standards.

- 'VR Media Lab' is one of Europe's largest virtual reality (VR) installations and supports research and education at Aalborg University as well as carries out industry collaboration and knowledge transfer in general. The center manages a six sided CAVE, Panorama and a passive 3D wall projection auditorium. See also http://www.vrml.auc.dk/.

- Virtual Reality Centre, 'VR•C', http://www.vr-c.dk/ established by UNI•C (The Danish IT Centre for Education and Research) and The Technical University of Denmark, DTU,

- Centre of Advanced Visualisation and Interaction, 'CAVI'. A newly established center in Aarhus in collaboration between the Alexandra Institute, National Center for IT Research (CIT) and Aarhus University.

Our experience from industry is that interactive 3D visualization must be presented to clients at least in the early phases of projects and also be used in connection with procurement for construction. The ANS project, figure 13 Left, proved to be very helpful for realization and planning of a new villa district in Kjellerup commune with respect to constructability, views from different living domiciles and for planning of communication areas. A panorama set-up was used. Figure 13 Right, shows a snap-shot from a 4D model under development that will be used for risk assessments and flow cost optimization during construction of a dwelling area at the sea front in Aalborg.

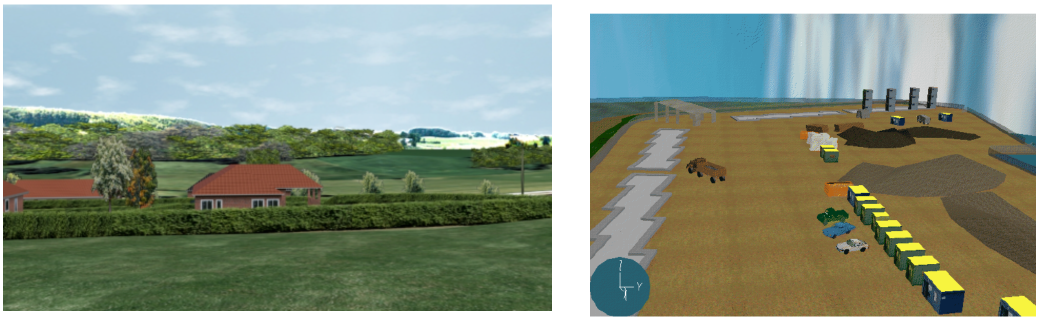

Figure 13 Left: the ANS project at Kjellerup commune by COWI Consulting Engineers and Planners Aalborg, and Aalborg VR Media Lab (Bjergaard et.al, 2001). Right: The CASANOVA Project in Aalborg commune by COWI Consulting Engineers and Planners Aalborg, Salford University, and Aalborg VR Media Lab.

Figure 14 shows a dynamic interactive 3D visualization of airflow in a livestock building. The CFD (Computational Fluid Dynamics) simulation model was converted to a VU model (Pic, Ozell, 2000) which was interactively handled in a panorama and CAVE (six sided) environment at VR Media Lab Aalborg. (The VU system was launched in 1993 and adapted for VR environments 1998.)

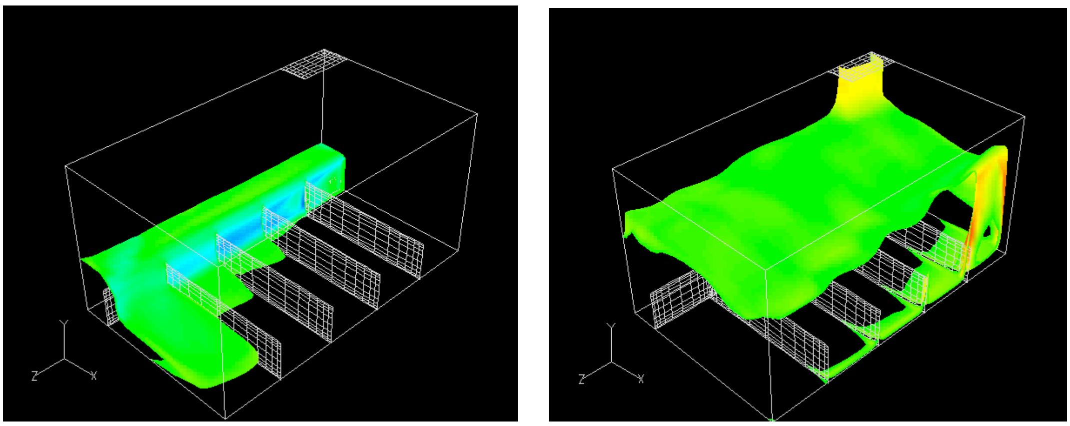

Figure 14 Displacement ventilation in a livestock building (Svidt et.al., 2001)

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