40 USER REQUIREMENTS MODELLING IN DESIGN OF COLLABORATIVE VIRTUAL REALITY DESIGN SYSTEMS

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Abstract

Advanced Information Technology today gives us the opportunity to implement sophisticated distributed systems for collaborative design. Persons with different interests and competencies in the building process such as architects, installation engineers, structural engineers, clients, and builders can all at least theoretically be brought together in a distributed design space where a virtual building is drafted, designed, built, and functionally evaluated. A design space built in a virtual reality environment will enable us to realistically and efficiently simulate the form, function, construction, and use of the building under consideration. The paper presents experiences from the early phases of user requirements formulations and design of such collaborative design spaces. The findings are mainly based on collaborative university and consultant engineering company work done in the EU IST-project 'Distributed Virtual Workspace for enhancing Communication within the Construction Industry - DIVERCITY' as well as experiences from student collaboration in distributed learning environments and earlier research within the area. The early conceptual design of the virtual workspace follows the so called Contextual Design methodology which gives input to the subsequent data modelling work and implementation in an object oriented web distributed environment. The method used is described and examples on resulting Work Models (work flow, sequence and artefact models) are presented and commented on.

Keywords: *design, virtual reality, collaborative work, ICT tools, knowledge management.*

BACKGROUND

Today we experience a great focus and interest in advanced multimedia (MM)/virtual reality (VR), computer interfaces and knowledge management (KM), issues. Why is that?

Due to introduction of very efficient and fairly low cost Information and Communication Technology (ICT) tools, the previous local project and working contexts become more global in nature. 'All' information (digital) will be there under our fingertips, competencies and digital knowledge can be efficiently configured to different needs, and hopefully efficiency gains can be transferred for quality improvements in work and products.

With regard to ICT solutions we have gone from personal computers to local area networks and now world-wide Internet based computer networks. The micro scale solutions get scaled up to macro solutions emphasising certain problem domains:

- Need for *meta classifications* to facilitate communication between computer stored building process models and person to person communication with MM/VR support;
- Implementation of secure and adapted *virtual communication and collaboration spaces;*
- Design (with user participation) *of new ICT tools* with completely new characteristics including achievement of better co-ordination between user requirements capture, user interface design and system implementation.

The new paradigm regarding KM and collaboration can be characterised by:

- *All information* will be stored ('good' and 'bad', all old versions maintained with history);
- Digital information *ownership* and *maintenance* will get higher focus;
- Dynamically networked information in *logical information containers* (the composition recipes and meta information are important and can build on XML tagged communication standards);
- *Peer-to-peer societies*/interest-groups/villages and widespread personal and project servers;
- *High accessibility* (wireless access points, portable communication units and multi-modal MM interfaces to information and communication channels in both personal, project, and global aspects);
- *Virtual spaces* for communication and learning;
- Improved and new *ICT based services* (global identification and personal positioning units, in physical objects embedded intelligence with Internet connectivity, personal and project libraries, and global market places);
- Ongoing *change process* where it is important to build shared visions and values, concretise what changes could/can mean, and supply tools to support the change process (models and parameters, knowledge transfer, scenarios, requirements capture, experimenting, best practice critique).

THE VIRTUAL WORKSPACE, VW

Which activities are supposed to be carried through in the virtual workspace (VW)? We should be able to handle the building artefact from idea to usage, maintenance, demolition and recycling and thus include all the traditional activities like client briefing, design, and construction simulation in the VW activities.

What models and tools should the VW contain, describe and/or refer to?

- Building *organisations and management processes* including links to the project external processes like those provided by information and component suppliers;
- The building (*virtual building*, VB) and its components (see also figure 1);
- Production systems and *construction* activities;
- *Usage and maintenance* of the building artefact;
- *User models* that will highly influence computer interfaces and collaboration styles;
- *ICT tools* especially those that are new and unfamiliar to the process participants;
- New types of *services* and linked building applications;
- VW *administration* processes.

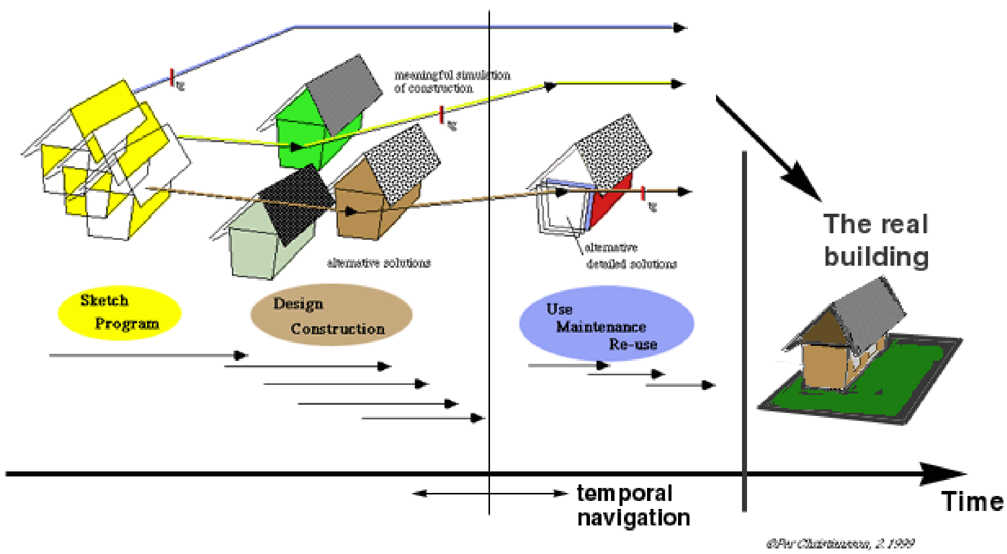

Figure 1 Alternative designs of the Virtual Building, VB, can be built and tested before the construction starts (Christiansson, 1999).

In connection with the DIVERCITY project we made the following definition of a Virtual Workspace.

'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 thus:

- 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.

SYSTEMS FOR COLLABORATIVE DESIGN

In research connections we started to use groupware for ICT supported collaboration in the end of the 1980s in local area networks and later on the Internet. Among the earlier systems we should mention Timbuktu from Farallon (screen sharing, file transfer), CuSeeMe from Cornell University (video, sound, text chat), Aspects from Group Technologies (shared document writing), MacEuclid from University of Colorado (reasoned arguments), First Class from Softarc (structured email discussions), and more recently Netmeeting from Microsoft. Today we find a range of server and peer-to-peer based groupware, see also figure 2. Groupware shall though be regarded as a *complement* to personal meetings in physical rooms.

Today we have access to Internet based ICT tools to support e.g. application sharing, remote computer control, chat, shared whiteboards, videoconferencing, calendars, discussions, file sharing, 3D model manipulation and trading.

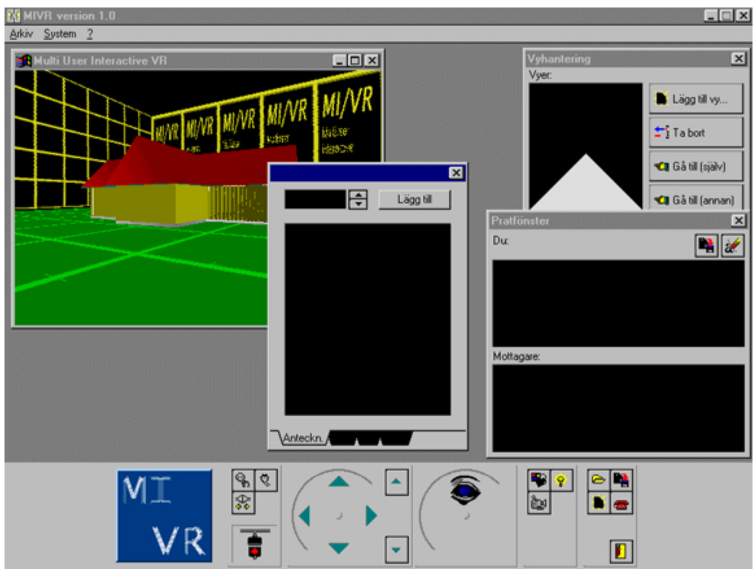

Figure 2 Low cost virtual reality environment for synchronous and asynchronous work on building models. From (Lindemann 1996).

The main functionalities (partly overlapping) of groupware or Computer Supported Collaborative Work (CSCW) software are:

- *Share and manipulate* applications and digital memories;
- *Design support* (analyses, synthesis, simulations, decisions, model annotations, reviews, planning, co-ordination, evaluation);
- *Communication* (discussions, sketching, brainstorm, presentations, learning, purchase).

Experiences from Using Collaboration Tools

We have during 10 years collected experiences on Computer Supported Collaborative Work (CSCW) in joint industry research and distributed learning. Some of the findings are summarised below, see also (Modin, 1995) and (Christiansson, 2000):

- Important to plan the *collaborative work on documents* with regard to choice of *atomic level* at different work stages to avoid re-examining whole documents/chapters;
- Establish *versioning routines* for documents and program source codes;
- Establish routines for long term back-up and *document maintenance* (both physical and logical);
- If you base your work on using digital information *containers they must be easily accessible* both physically (near to Internet/intranet access points via wireless connection or fixed points) and logically (network domain access);
- Permanent *wall display* units in meeting and lecture rooms are of great advantage;
- Be aware that most people are *not familiar* with paperless way of working;
- Provide easy *instructions for use of communication tools* (remote and local control of cameras in video conferencing, setting up of desk-top groupware);
- Distant *video/sound connection* over Internet, e.g. over a CuSeeMe reflector is only adequate using very low image update;
- Very good *social connections* may be achieved through remote connections though wishes for better eye and body language contact is reported;
- *Shared applications* work very well both for collaborative production work and creative sketching.
- Possibilities to continuously *document the decision/collaboration process* should be better.

THE DIVERCITY PROJECT

The ongoing DIVERCITY project aims to improve the process of building design and construction by enabling the user groups to operate both more efficiently and with better interaction. 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 visualised and manipulated, and to *produce a set of VR tools that aid the construction design and planning process*.

Organisational changes of collaboration forms take place globally and in Europe with focus on dismantling discipline borders between the building process parties. DIVERCITY is a long desired tool to support collaboration both across and along the building process time axis. Cultural barriers within the building process will hopefully be less important as we get efficient communication tools like DIVERCITY with high degree of realism and distributed presence through multimedia/VR and 3D interfaces. Except efficiency gains we may also develop a common understanding of building process and product quality issues including constructability studies related to safety concerns.

The DIVERICTY System

We believe that when developing systems as DIVERCITY which support collaborative work in virtual environments it is important to:

- Define the virtual workspace and its key properties;
- Apply a creative design process;
- Develop new and better user interfaces and collaboration support;
- Involve end-user participation during development;
- Employ incremental prototyping and continuous evaluations during the process;
- Investigate how use of such a system can enforce establishment of shared values among building process participants.

The DIVERCITY system will support new efficient and pleasing ways of collaboration but will also support existing work processes. It will be capable to integrate existing systems and contain project specific process support. It will also as far as possible meet expected advanced ICT tools and network solutions such as secure peer-to-peer communication, and long-term project library support. See also figure 3.

In the DIVERCITY system we take into account models of the:

- *Virtual Workspace* (VW) form, function, usage context
  and especially;
- *Actors* (user models);
- *Products* (design artefact models), and access to product models and supplier information;
- *Processes* (contexts, building design process and cultural models, and access to external applications including information resources and individual information)
- *external applications.*
- *ICT tools* (DIVERCITY specific artefact models).

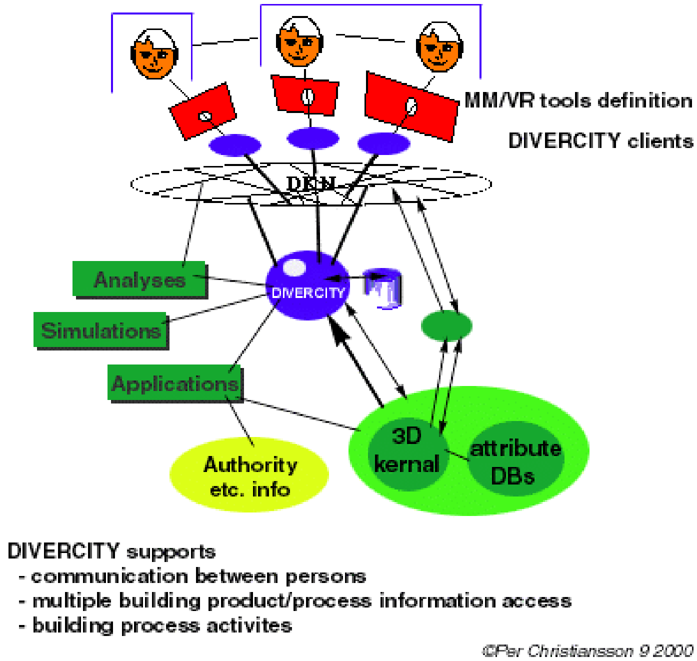

Figure 3 DIVERCITY in context.

> *DIVERCITY function, form, content and behaviour must be well defined. On which domains and on which level will DIVERCITY contain knowledge about the building product under design, application programs and external information sources? How much of the building model and level of semantics does DIVERCITY contain?.*

DIVERCITY will provide a Process Manager Artefact, PMA, as an important artefact and design team 'participant', which will support the activities in the Virtual Workspace. See also figure 6.

THE CONTEXTUAL DESIGN METHOD

Design context

In all system development activities it is of great importance to define a balance between resource input, ambition level and available time, see also figure 4. Bear in mind that a research project cannot compete with industrial development but rather provide unbiased input, new ideas and methods, constructive critique and fruitful collaboration.

It is extremely important to bridge the gap between the user requirements specifications and the actual interface design and implementation of the underlying operational models of the distributed virtual workspace system, see also figure 5. This is certainly true as we actually design a new type of design artefact that will highly influence the traditional working methods and integration of design resources. Often work starts with UML (Unified Modelling Language) based object modelling of the system with efficient tools like e.g. Rational Rose from Rational Software Corporation (http://www.rational.com/) taking too little account to early conceptual analyses of user requirements and user interface functionality. The risk is near at hand that important properties of the final product with regard to end use are overlooked. In DIVERCITY we use Rational Rose to support the actual system design.

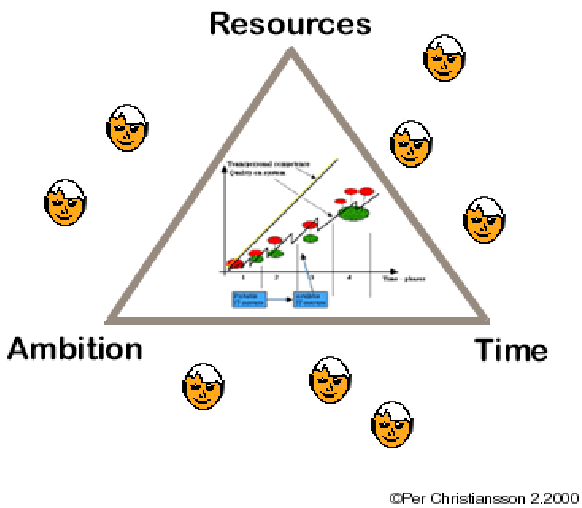

Figure 4 The relations between available resources, time and degree of ambition must be clear at the beginning of the project.

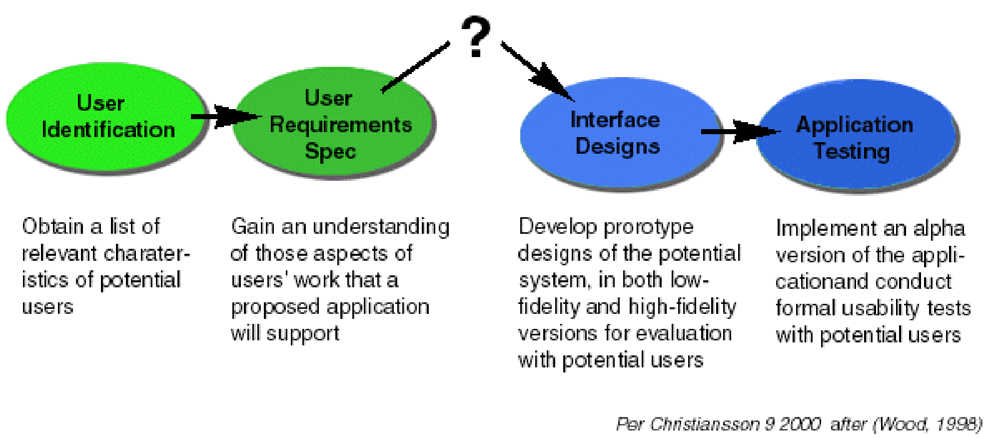

Figure 5 Very little 'specific descriptions information' is available on how a designer transforms the information gathered about users and their work into an effective user interface design', from (Wood, 1998).

The design of the DIVERCITY can be characterised as participatory design with end user participation (Mumford E., Henshall D., 1979) from the very start of the system design process. Mumford says about participation, "It is not a new concept although it has been given other names such as democracy, involvement, sharing, co-operation".

Contextual Design

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

The method is only partially implemented because the design team is spread over Europe (we should really need the DIVERCITY system itself in the design process). This implied obstructing a complete contextual inquiry process (talk to the customer while they work) and the incremental progress refining and consolidating system form and functions (structure and time dependent models). It is important to design and implement efficient collaboration and documentation tools early in the project and set aside administrative resources for that.

There are five different types of *Work Models* in Contextual design (these models will later in the project be used to make detailed storyboards describing the user environments):

- *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;
- *Artefact*, showing objects created to support the work;
- *Culture,* representing constraints on the work caused by policy, culture or values, formal and informal policy of the organisation, business climate, self-image, feelings and fears of the people in the organisation, possibility for privacy;
- *Physical,* showing the physical structure of the work environment as it affects the work.

Conceptual Work Models

The following Work Models are presented as examples of the type of presentations that was developed in close collaboration between COWI and Aalborg University:

- Top level Work Flow model for lighting design, see figure 6;
- Top level Sequential Model for lighting design, see figure 7;
- Example of Artefact Model for lighting design, see figure 8.

Sequence models show design intent and the workflow models show how these intents are achieved (strategies for organising work) (Beyer and Holtzblatt, 1998).

The *sequence models are complemented by the artefacts 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. We use real data and cases during artefact model construction and also use similar cases to compare artefacts use. The artefacts shall support communication as well as possible.

This paper does not go into detail on artefact models. It should though be mentioned that artefacts are grouped and described according to parameters such as:

- Artefact *group* in relation to *intended* and/or real use (supplier information, requirements from authorities, other public information, communication tools, firewalls, analysis and simulation programs, product and process models, process manager);
- Artefacts *properties* and *characteristics* (personal/shared, DIVERCITY-specific/general, synchronous/asynchronous usage, access rights, access levels, artefact memory, alternative artefacts for the same activity, alternative VW activities with use of same artefact, identification icon and name).

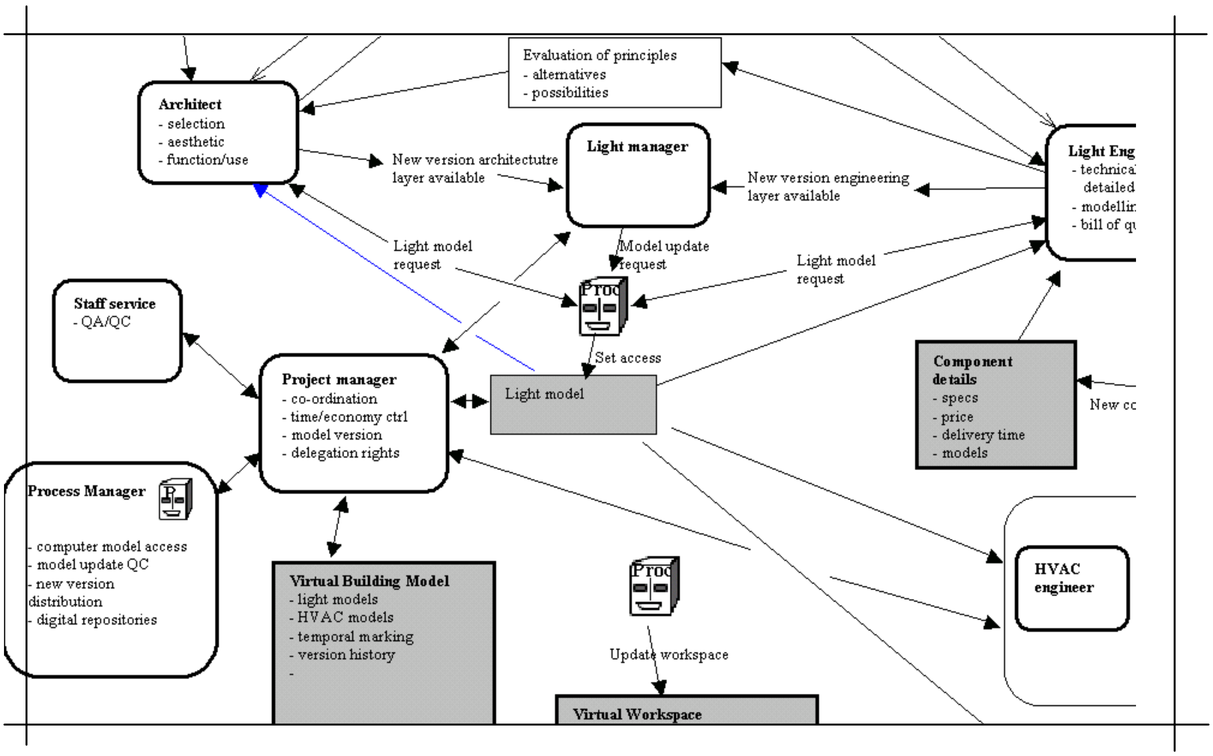

Figure 6 Part of Top level work flow lighting model from many simultaneous individual perspectives. (From the DIVERCITY project).

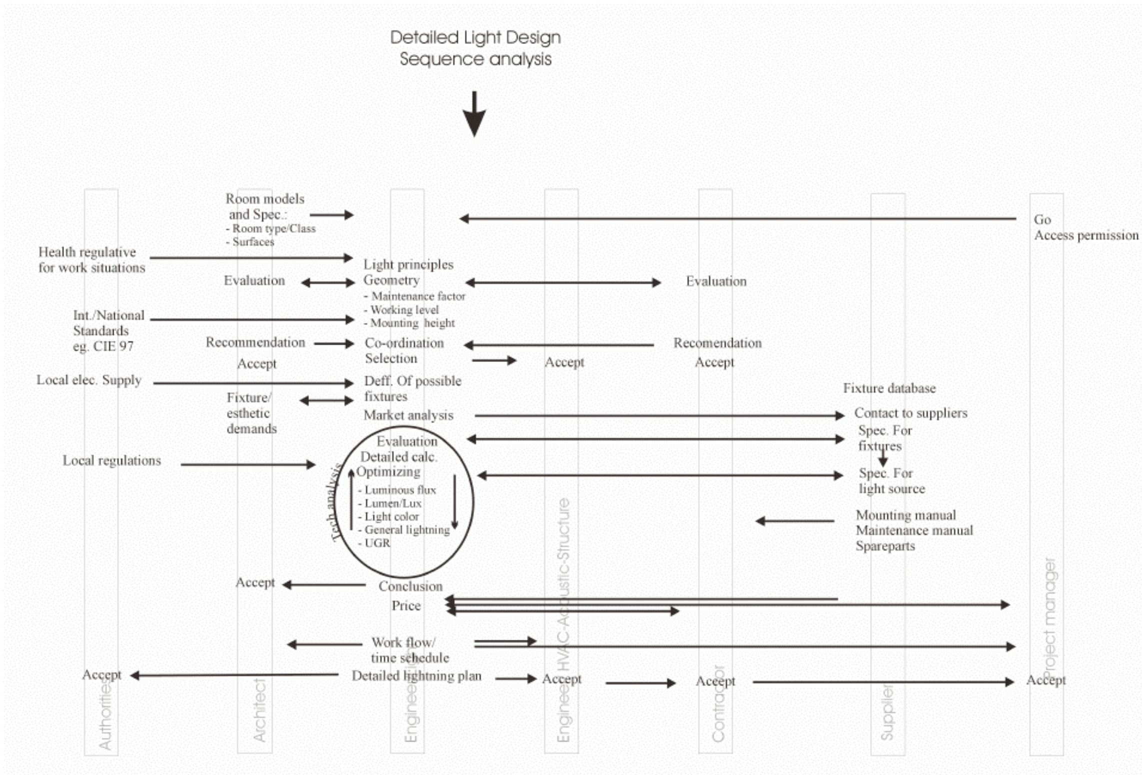

Figure 7 Detailed light design sequence model. (From the DIVERCITY project).

Action	**Artefacts (today)**
Access permission/demand	Contract/agreement
Get geometry details - Room type/Class - Surfaces	Drawings (electronic, hardcopy) Text documents (electronic, hardcopy) Telephone, email-program
Idea generation	Best practice, previous experience (intranet DB, hardcopy), supplier information, new developments
Define light principles	Best practice, previous experience (intranet DB, hardcopy), supplier information (catalogues, telephone, email, internet)
Set up requirements from external constraints	Health regulatives/standards
Light geometry - Maintenance factor - Working level - Mounting height - ..	Standards/Codes (electronic, hardcopy) or built-in third party tools as e.g. FABA-light Drawings/docs from architect (electronic, hardcopy) Telephone, email-program

Figure 8 Extract from artefacts descriptions for detailed light design. Action taken and corresponding artefacts used today. (From the DIVERCITY project).

THE VIRTUAL WORKPLACE

The Virtual Workspace, VW, will house a number of *actors* and *artefacts* such as, design team members, guests (e.g. suppliers), the process manager artefact (PMA), communication artefacts, container artefacts, design artefact (the virtual building), and sub-spaces. See also figure 9. The subspaces that will be used in different building process contexts may be:

- *Negotiation* spaces;
- *Collaboration* spaces;
- *Co-ordination* spaces (to allocate resources such as external applications, sharing information, project constraints, collaboration rules, design goals, defined and active spaces and sub-spaces). The PMA will typically be supportive in this space;
- *External access* spaces (window to market, vendors, other project webs).

The main navigation dimensions in the VW are:

- VW space/subspaces geometrical co-ordinates including locations;
- Real time in VW space and subspaces (also providing for delayed synchronous collaboration);
- Virtual building process time;
- Virtual building geometrical coordinates;
- Virtual building economy;
- Level of details in VW space and subspaces.

The Process Manager Artefact (PMA), see also figure 6, will support in co-ordination activities:

- *Resource* management (links to and description of applications for modelling, 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).

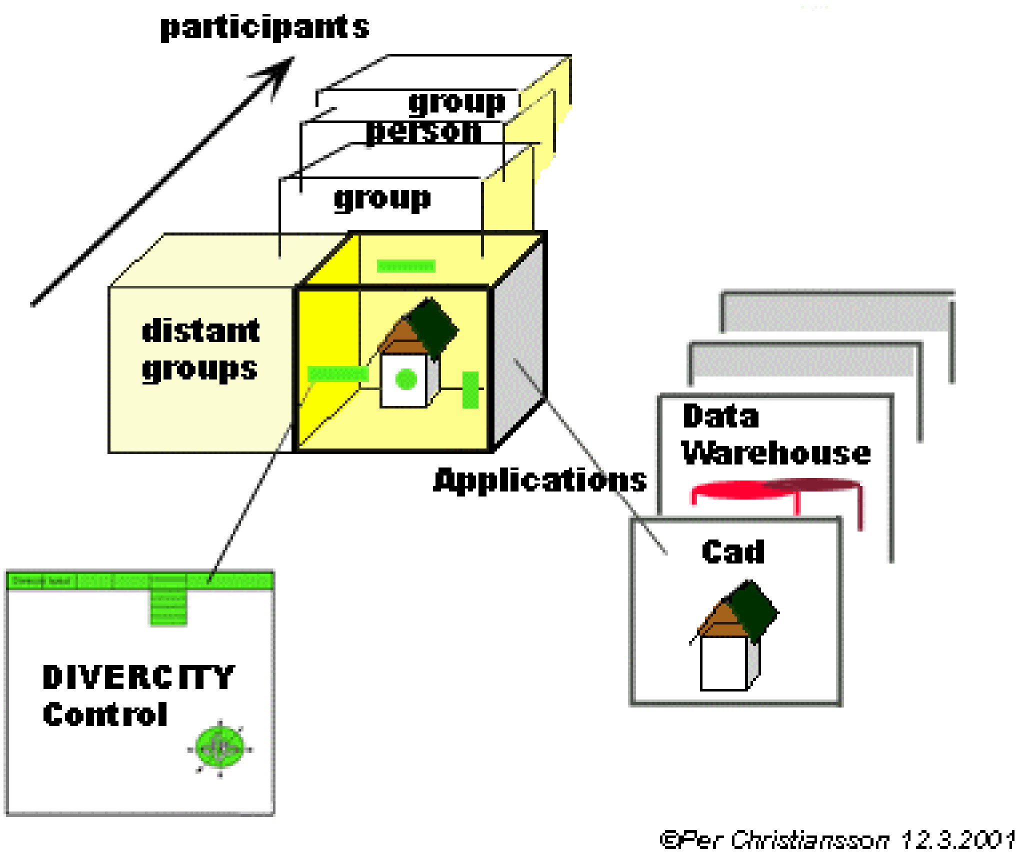

Figure 9 Principal VW layout with space 'dimensions' and application 'artefacts'. (From the DIVERCITY project)

CONCLUSIONS

Positive experiences are reported from using the Contextual Design method in connection with design of a system that is intended to support collaborative design in virtual environments. The R&D team in the EU DIVERCITY project (IST project No: IST-1999-13365, http://www.e-divercity.com/) 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). Valuable experiences are used from earlier research in the field, student collaboration in distributed learning environments as well as practical engineering and architectural experiences.

The collaboration between industry participants and researchers has proven to be very valuable and necessary to form a creative design and development environment where new ICT tools are introduced, tools that will have an immense influence on future work procedures, knowledge transfer, and building process organisation. The proposed DIVERCITY system should indeed have been of great help in the distributed collaborative design work itself.

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