Hypermedia in the Virtual Project Room - Toward Open 3D Spatial Hypermedia

Preben Mogensen & Kaj Grønbæk

Department of Computer Science
University of Aarhus
DK-8200 Aarhus C, Denmark
Email:{pmogensen, kgronbak}@daimi.au.dk

ABSTRACT

This paper discusses hypermedia aspects of the design of a Virtual Project Room. Based on ethnographic and participatory design studies of landscape architects' and architects' work, prototypes for a notion of virtual project rooms, supporting remote collaboration, is developed. Since (landscape) architects work with 3D objects and environments a natural first step is to design a virtual project room as a 3D virtual environment. The current prototype, *Manufaktur*, utilizes open hypermedia technology to integrate documents with design models in the virtual project room. Manufaktur provides hot-linking of arbitrary MS Windows documents into the virtual project room, it supports spatial arrangement and categorization of (sub) workspaces by means of proximity, and it provides "classical" open hypermedia linking between segments of documentation. Finally, support for two modes of tightly coupled collaboration in the virtual project room is being provided by means of a session management service. Based on the experiences from design of Manufaktur we discuss design issues for the integration of hypermedia and collaborative virtual environments.

KEYWORDS: Open Hypermedia, Spatial Hypermedia, CSCW, 3D Workspace, Collaborative Virtual Environments

INTRODUCTION

The aim of the research described in this paper is to provide a computer-based environment for architects and industrial designers to work collaboratively in distributed project groups via Internet or Intranets. Much of the work has taken place within the Esprit LTR project *Desarte*, which is concerned with computer-supported design of artefacts and spaces within architecture and landscape architecture. The project commenced in the summer 1998 and runs until summer 2001.

We are developing and experimenting with a computer-based work environment, called Manufaktur, which supports and replicates some features of the physical environment – a virtual project room. It is a digital work environment that extends and augments the physical workspace, enabling people to continue to take advantage of the positive features of the physical environment whilst mitigating the difficulties that arise from its constraints. It supports the configuration of spatio-temporal order in the electronic environment by allowing people to construct familiar configurations of documents and objects in a three dimensional virtual workspace. The idea is thus not to replace the physical world artifacts such as paper and material samples, but to augment the physical working environment with a virtual workspace organization.

The work combines experiences and techniques from a number of different fields: Collaborative Virtual Environments (CVE) [10], Open Hypermedia [16, 31], Spatial Hypermedia [23, 24], and CSCW [21, 33]. In the following, we briefly introduce related work that has been sources of inspiration.

Collaborative Virtual Environments (CVE)

A number of collaborative virtual environments have been developed in recent years. DIVE [9, 17] and MASSIVE [13] are among the most well known. Both of these systems provide a combination of 3D worlds, avatars, video, sound and documents. Users are represented as simple avatars and they can communicate by means of various media. For instance, avatars may walk up and share a *Whiteboard* where they can manipulate 2D graphics, watch live video, write and draw simultaneously. They can also import 3D objects, which can be inspected from arbitrary positions. Documents are implemented as portable whiteboards that users can bring with them and be manipulated privately by a single user. Documents can be placed on shared whiteboards or conference tables. A *Conference table* is a service to allow group discussion. A user joins the discussion when his/her avatar gets sufficiently close to the table.

The notion of proximity among avatars and the different communication media is central to the design of CVE [13, 14]. In CVEs, an aura is a specification of a region in which the service or avatar is visible or present to others. Focus is the region that a user pays attention to. Nimbus is the region that a user projects itself to. When an avatar's aura intersects with that of another person they can see each other and start talking. When an avatar's aura intersects with that of a service (e.g. a conference table) the service become available. Depending on the service other users in the proximity of the service become visible (enabling-amplification). This way the Aura concept supports dynamic formation of groups for discussion and casual virtual meetings. Awareness among the users becomes a measure of the quality of service/interaction among objects. The level of awareness is dependent on the degree of overlap between auras, foci and nimbi.

The CVE researchers have experimented with different ways of mediating awareness and formation of groups and meetings in virtual environments. However, the artifacts related to the work of the users have been insufficiently represented in this research, e.g. by not supporting the native document format. The documents that most CVEs support are poor quality writings on the Whiteboard, i.e. manipulation of real office documents and design objects is not supported. This is a serious barrier for bringing CVEs out of entertainment [2] to real world work tasks of e.g. architects. Such integration of documents and objects is a main design issue in the work of this paper.

Figure 1: Example from the DIVE system

Spatial hypermedia

The notion of spatial hypermedia was introduced a number of years ago to support information analysis tasks [23, 24]. Spatial hypermedia can be thought of as using a big table or even the floor as a 2D space for sorting information, say books from the library or technical specifications you picked up at an exhibition/conference, or materials relating to ongoing design projects in an architectural office. When you sort the materials in piles on a table, you implicitly create relationships among the pieces of material by placing them in some spatial relationship to each other. Another example could be the task of organizing a scientific paper. The authors might generate small note cards, containing a descriptions or brainstorm thoughts about the content of the paper. During the writing process, the authors might start to organize these cards on a table, perhaps grouping cards into piles, lists, etc. Placement on the table space might be significant. For example, cards might be roughly sorted by priority, with more important cards being placed toward the upper left corner, and less important cards toward the lower right corner. Cards can be easily rearranged as one's understanding of the paper organization evolves. At no time is one required to declare formally an overall structure to the cards on the table. At some point, the structure on the table may have stabilized into something that may become an outline.

Spatial hypermedia systems support this metaphor of organization by allowing items or "cards" to be generated and placed on a "table" (space). Cards may be tailored by changing their size, shape, colour, or other visual characteristics. Cards may contain content or point to external content. Additionally, some systems (e.g., Aquanet [23]) allow cards to be "opened" to reveal another space that also may contain many different cards. Some systems (e.g. CAOS [4, 5]) provide so-called 'spatial parser' that might recognize certain structures (such as piles, lists, etc.) and allow users to manipulate these structures as whole units (e.g., by allowing all the cards in a pile to be moved at the same time). Some systems (e.g. VIKI [24, 26]) allow repeated structures to be "formalized" (i.e., assigned a name, a description of a semantic role, etc.), which might allow the system to provide more functionality regarding such formalized structures (e.g., search for other instances, etc.). Other systems like PAD++ [1] are optimised for quick zooming and navigation of large spaces.

In addition to the features of spatial hypermedia systems such as Aquanet and VIKI, a CB-OHS [29] based spatial service, CAOS [4, 5], has been developed at Aarhus University. CAOS is designed as a distributed and collaborative open service, which also provides an *incremental* parser that recalculates the set of spatial structures upon client modification of realized spaces. Clients communicate with the server via a public protocol. Thus, new clients may be added to the system at any time, and can take advantage of both spatial abstraction persistence and the incremental parser.

Here we explore the possibilities of integrating and extending such an open spatial hypermedia mechanisms in a prototype of our Virtual Project Room component.

Open Hypermedia and Component-Based Open Hypermedia (CB-OHS)

The idea of open hypermedia [16, 31] is to provide structuring mechanisms, which are externalised from the information being structured. When several independent structuring mechanisms such as links, composites and spatial structures are needed an open hypermedia system may be modularised in a number of independent services within a common infrastructure, this kind of OHS is called a component-based open hypermedia system (CB-OHS) by Nürnberg et al. [29, 30]. A CB-OHS is much like a traditional OHS, but with an open middleware (structure service) layer, allowing many different types of hypermedia servers to exist side-by-side. Because these different structure services exist within a common multi-layer framework, there are many possibilities for integrating them. Since we need to integrate many different hypermedia services in our Virtual Project Room development, a component-based open hypermedia architecture shows best promise.

APPLICATION DOMAIN

One of the main components in the Desarte project, which constitute the empirical basis for the current research, is based on comprehensive field studies of (landscape) architectural work practice, to design a virtual project room to support these practices. The project as well as more comprehensive observations and discussions regarding issues pertaining to the practices of (landscape) architecture may be found in [6-8, 27].

In the project so far, we have mainly worked closely together with two companies, an architect company in Austria and two out of eight branches of landscape architects in UK. In both offices work is primarily organised around project work varying in size from one to two people in a few days to around 10 people working together for a period of months.

Any project, except for the very small ones, typically varies quite a lot with respect to intensity, sometimes there is a burst of activity (e.g. when approaching a deadline) and sometimes there is virtually no activity, for example because one is awaiting a decision by local authorities, clients, other contractors, or the like. Therefore, any one person will typically be engaged in a number of projects and will switch between these, often between many a day, as well as revisiting older projects with similar characteristics for assistance.

Figure 2: Arrangements of materials

Both architectural and landscape architectural work is to a large degree characterised by large parts of the work consisting in gathering, assessing, manipulating, and arranging multitudes of materials (e.g., in the case of landscape architects, candidates for paving stones, trees, shrubs, benches, gravel for a path, fences, lights, and many more). Some of the materials are physical samples (e.g. of paving stones), many are paper sketches, faxes, letters, specifications etc., and more and more material are accessed through various electronic representations.

In the process of understanding the problem at hand (e.g. the reconfiguration of a park) as well as potential solutions, the (landscape) architects juggles with all these options in their various representations. The arrangement of these resources 'tells the story' of the process of making decisions, about the options considered, final choices, and discarded alternatives.

This building up of a 'context', the multitude of materials arranged in order to 'tell a coherent story', is something that permeates (landscape) architecture. Sometimes it takes the form of discussions between the various people involved in a project using the multitude of materials as reference points constantly manipulating and shuffling them around to engage in new patterns of relationships. At other times people are working on individual parts of a larger project that eventually must fit together as a whole or working on the same parts but at different times in which case the construction and maintenance of the overall context is what binds the different contributions together. And finally, to a large extent, it is the context represented through the arrangements of sketches, drawings, documents, samples, etc. that are brought together and presented to the client.

Typically, after completing a project with its various constellation of materials, a copy of the package presented to the client is filed away together with some of the resources used in its production in the 'job file(s)'. Other elements of the context are returned to their original locations (e.g. books to the library, brochures to the shelves), some are collected in personal spaces (personal files, boxes, or just in a pile on one's desk), yet others are discarded (e.g. quick 'doodles' or sketches, hand-written notes). However, the relations between different elements of the context established during the course of unfolding work are dissolved. On returning to a project after a potentially very long period of dormancy, there is a lack of information about *how* this particular package is tied into the context of the work as a whole. Even though the package was itself designed to produce and to convey a context, its own working context would be quite difficult for the (landscape) architects to recover.

TOWARD A VIRTUAL PROJECT ROOM

As can be seen from this short introduction to parts of (landscape) architecture, and potentially many more domains [11], a number of design challenges arise, e.g.:

- How to bridge between a 'physical world' of paper, paving stones, models, etc. and a 'digital world' of electronic documents of various kinds?
- Within a 'digital world', how to enable these contexts to be populated with materials and documents from

very diverse sources - the multitude of different software applications in use?

- How to support the building up, rearranging, and maintenance of 'contexts'?
- How to support cooperation on the same project (i.e. same documents) in a distributed work environment?

We have been developing and experimenting with a computer-based work environment, which supports and, in a creative sense, replicates some features of the physical environment – a virtual project room.

The ideas for the virtual project room borrow from many technologies discussed in the introduction. The aim is to utilize the possibilities of a virtual 3D space, although the focus is much more on arranging and working on objects and materials than on representing people, e.g. via avatars. The challenge then becomes to find suitable ways of creating and maintaining structures between the multitudes of documents. Here we have borrowed from the work on navigational as well as spatial hypermedia.

Toward the end of designing a virtual project room, we have developed a first prototype of such a space conceived around the metaphor of '*Manufaktur*' ('craft workshop').

MANUFAKTUR

Manufaktur supports the configuring of multi-media documents, for example pertaining to a project, into specific *workspaces*, including the possibility of 'pre-fabricating' such workspaces for recurrent tasks. Following from the importance of selecting and relating materials briefly explained above, the Manufaktur supports the situated creation and manipulation of context, awareness, and action. The same thing can be the work object for one activity, background material or context for another activity, and would be an irrelevant distraction for a third – all in ways that change on a moment-to-moment basis. It contains or integrates with a series of desktop applications. Specific applications will be developed in support of needs such as creating and displaying narrative, organizing, and component design.

Manufaktur is a workspace in several senses. First, it facilitates the (3D) *spatial arrangement* of objects, similar to the spatial arrangements of models, books, drawings, pictures, etc. in any (landscape) architectural office. In this sense, we envision Manufaktur as a 3D environment, with an abstract and unbounded space, which can be furnished with various objects for particular projects and/or activities. Second, it provides space in the sense of supporting the *context* of the project or task specific assemblage of multi-media documents, their purposeful arrangements, and links between them. From this perspective, Manufaktur is *document-based*. Third, it provides shared space between people.

It is important to note that when we speak of the arrangement of objects etc. we are really speaking of *references* to objects, which physically may be stored anywhere within a local area network (and potentially on a wide area network as well). Somewhat similar to the sharing of physical office space, Manufaktur thus allows, for example, all the members of an office to work in the same unbounded space, in a distributed manner. Figure 3 shows a screen dump from a first prototype of Manufaktur.

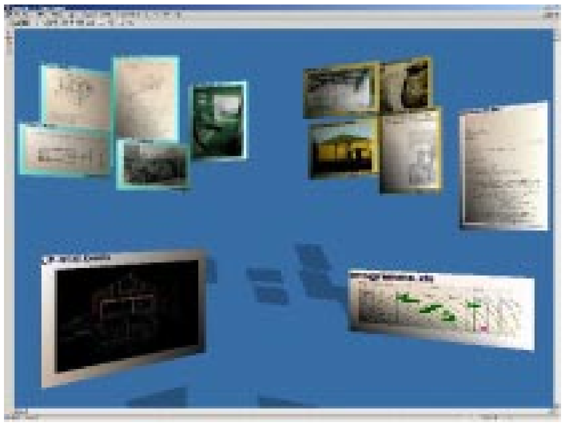

Figure 3: Interface of Manufaktur

Double clicking any of the document objects will launch the proper application with that document, and changes to it will be updated within 3D *Manufaktur* in near real time. The objects can be moved, rotated, etc; light effects may be applied; documents can be made (semi) transparent; organized into groups, and much more.

Objects in Manufaktur

Objects in Manufaktur can be moved around in various ways. They can be pulled to the front, where they are most clearly visible, or pushed further back. They can be turned so that one can see their spine (which can be given a semantic, e.g. with the thickness of an object indicating the number or size of documents in them, and the spine colour indicating an affiliation), or their back (which may be used e.g. for displaying a table of contents or relationships to other documents). Placing objects at an angle adds a perspectival dimension.

Several different types of objects can populate the space:

Document-objects - 'Live' documents of various kinds (documents with an ActiveX document server, e.g. MS Excel spreadsheets, MS Word documents, AutoCAD drawings, bitmaps, Micrographx Designer structured drawings, etc.) residing in 3D rendered OLE/ActiveX containers. An example of such a 3D rendered OLE container could be a spreadsheet rendered on to one of the sides of a 3D box. The document is 'live' in the sense that what is rendered onto the 3D object is the current display from the document's host applications, and updates are received as the document changes (OLE linking) – double clicking an object opens it within its host applications.

(3D) models of parks, buildings, towns, etc. The (3D) models may, for example, be artefacts used in a project such as models of a building, urban area, landscape site, or entire counties. The models can be scaled, moved, turned, flipped, animated, etc. as any other object. They therefore lend themselves to several uses: as a reference point 'up in the corner' that one might take down and explore if appropriate, as models to 'walk into' or change, or as one big and 'fixed' object that is used for defining the topography of the space (e.g. a wire-line of a site gradually filled with document-objects as the project progresses).

'Implantations' – objects or devices that support the customising of a space to changing uses, for example, to create spatial partitions or for imprinting specifically expressive codes [22]. An example may be the use of walls for providing a sense of size, location, or direction, or semi-transparent objects such as boxes, cylinders, spheres, etc. to define specific areas. Another example is applying lights of specific colours to a certain area within the 3D space, to indicate some particular status of the documents placed in that area. A third example is shown in the screen dump (Figure 3) – lightings that make the objects cast a shadow on the 'ground' to provide a sense of distance (otherwise it may be difficult to see whether it is a big object far away or a small one close by). Thus topographical features may (but do not have to) be added to decorate or aid the 'intelligibility' of the space – the system treats them just like any other object.

Groupings – representations of sets of objects (including groups) that may be manipulated as a whole. Besides the implicit grouping made by placing objects within spatial proximity, groups can explicitly be defined and manipulated. Currently, two kinds of explicit groupings are supported. The basic grouping mechanism might be compared to an ordinary named folder where objects can be inserted/removed and one can manipulate the individual objects or all objects within the group. The more specialised grouping mechanism may be compared to a pin-board, which snaps objects to a given plane (the pin-board). As objects get within a certain, user defined, proximity to the "pin-board" it snaps to it (and the group), when they are dragged away they are removed from the group, and the group can be manipulated by manipulating the "pin-board".

Endpoints – representation of link anchors on document-objects within Manufaktur. The representation is a small, coloured, semi transparent box residing on the surface of the document-object being linked. The endpoint may be moved and resized within the limits of the document-object surface. This enables a linking capability to parts of document-objects residing within Manufaktur. The linking aspects of Manufaktur will be elaborated below.

A 3D environment like this not only makes it possible to have many windows open at the same time, but it also, by spatial proximity, allows to indicate the (changing) relevance of a document for work-in-progress. This means that there are in effect different 'levels of openness' of a document, which can still be identified from far away. We see this as a possibility for supporting the kind of fluent relationships between fuzziness and precision, to zoom into a detail and out to see the whole, and to simultaneously hold present a large number of parameters and their relationships. The current integration architecture of Manufaktur is depicted in Figure 4.

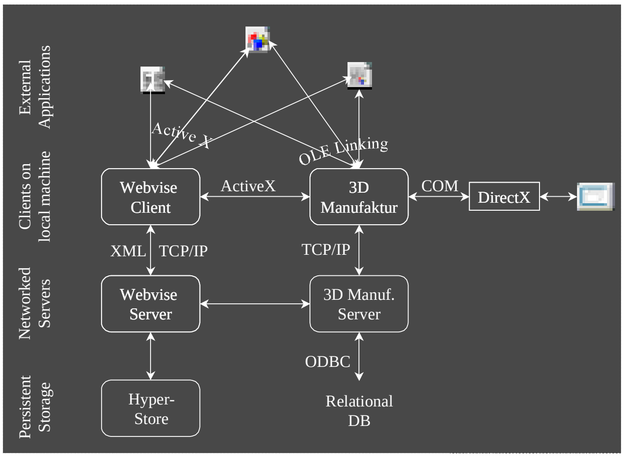

Figure 4: Integration architecture of Manufaktur

The status of the various parts of Manufaktur is that a fully functional prototype of the Manufaktur client has been installed in pilot installations on two sites, triggering a host of design issues. In what follows, we focus on the hypermedia aspects of Manufaktur, leaving for later discussions and other papers issues as bridging between the physical and the digital, combination of 2½D and 3D versions of Manufaktur, and some of the collaboration issues.

HYPERMEDIA SUPPORT IN MANUFAKTUR

All the above are means to support the establishment and use of context when working on projects. They do so by providing means of arranging objects. But having them co-present is not the only form of supporting context and expressing relationships between parts of documents. Consider, for example, the work involved in producing a CAD drawing of a building. Here there are relationships between, say, the drawing and several initial sketches of the concept guiding it, between corridors and specifications for the widths, between doors and fire regulations, between a room and various suggestions for furnishing it, between a wall and potential materials for it, etc. All these relationships are hard to express by means of spatial proximity alone, and if attempted would often produce unwanted clutter. Therefore we also operate with open hypermedia links [16] in Manufaktur.

Integration with Webvise

As depicted in figure 4, Manufaktur is closely integrated with Webvise [15]. The basic integration uses the same strategy as Webvise uses for integrating with other external applications [16], e.g. MS Word, MS Excel, Bentley's Microstation. Anchors in Manufaktur can be any object (currently with the exception of imported 3D mesh files) or workspace. When a link is established to or from an object, a representation is created on the object as described in the section ‘Objects in Manufaktur’ above. When a link is followed to an object in a Manufaktur workspace, the workspace is opened and the given object and the representation of the anchor are highlighted within that workspace. This enables linking to objects, e.g. document-objects, within their proper context and it facilitates the possibility of marking parts of the document-object via moving and resizing of the coloured, semi-transparent box residing on the surface.

The integration with Webvise provides basic linking facilities. The pilot installations of the prototype integrated with Webvise have showed the potential strengths in combining traditional linking facilities with the possibility of using spatial means for providing structuring mechanisms between large amounts of related documents. However, it has also pointed to a range of potential improvements, such as a more generic mechanism for integration with external applications, link types for providing overview, behaviours on links in order to provide more flexible means for traversing link structures, and possibilities of supporting the establishing of spatial structures.

Hypermedia extensions in Manufaktur

Since we wish Manufaktur to integrate arbitrary materials from the users’ computer environment, we have made a first attempt at going beyond the classical open hypermedia location specification approach [16]. In classical open hypermedia, an application is augmented with a menu or toolbar of operations that establish communication with the open hypermedia service, in this case Webvise [15]. With this strategy a special tailoring is needed for every application that needs to be integrated. This has been recognized as one of the problems of open hypermedia, and in the Microcosm project [12] the Universal viewer has been proposed as a solution to this problem. However, the Universal viewer approach is very fragile and works only for text based generic links. Due to the need to manipulate multitudes of different document formats in their native applications, Manufaktur is aimed at seamless and advanced integration of arbitrary applications on the MS Windows platform. Thus we have chosen another strategy for providing integration with external applications - ActiveX components.

We have extended Webvise with a small ActiveX component, called ActiveEndpoint, which the user can insert into any OLE container (like, say, a spreadsheet running inside a MS Word document, just much simpler), i.e. the ‘anchor’ becomes a small active application. Via standard interfaces (e.g. IOleClientSite) the ActiveEndpoint retrieves the container’s internal reference for it (i.e. the container’s ‘Moniker’ for the inserted control) and hands this reference over to Webvise. When Webvise wants to access the control, for example in order to show it, it recreates a connection to the control via the moniker and asks it, for example, to show itself. This way we can provide open hypermedia linking without tailoring of the applications being integrated.

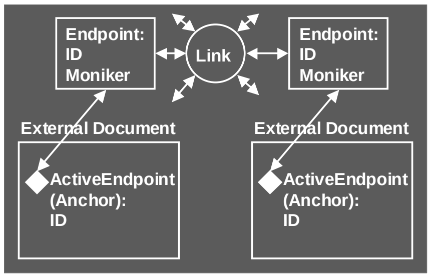

Figure 5: ActiveEndpoints

This approach has both pros and cons:

The *pros* of this approach are: It allows integration with all applications acting properly as OLE containers. Code for the ActiveEndpoint has only to be maintained in one place regardless of application. Endpoints may contain a state, for example a unique identifier and information to allow customisation of size, colour, shape, behaviour, etc. Endpoints may display a set of functionalities to the user via defined verbs (e.g. local maps, various kinds of displays within the container, meta information) available directly, e.g. from a right mouse click. And last, endpoints may be moved by the user within the current document, between documents, and between applications (whenever the ActiveEndpoint is activated, it tells the server who it is (the unique identifier) and where it is located now.

The *cons* of the approach are: Unlike location specifier based linking it requires write access to the containing document. Inserting an endpoint into a document will in most cases change the layout of the document, which may not always be ideal. Finally, not all OLE containers behave according to the standard specification.

Despite the disadvantages, we find the approach promising as a platform dependent (Microsoft Windows) solution to open hypermedia linking in a Virtual Project Room setting, where many of the documents are owned and being dynamically changed by project participants. The ActiveX based approach may also be combined with the traditional location specification based approach supporting linking and annotation of materials without write access.

Document-objects as hotlinks

In contrast to both spatial hypermedia systems and CVEs mentioned in the introduction, Manufaktur is designed to give the user a visual cue of what is the content of the documents and materials available in the environment. This is done by means of OLE linking. This ensures that the workspace is always up to date whether it is one self or another user that has changed documents within it. The link that is created between the 3D workspace and the document is a "live" link that supports a scaled preview of the document content representing the document in the workspace. With this feature, work in e.g. an Excel spreadsheet is visualized directly in the 3D workspace as a "live" texture on the surface representing the spreadsheet in Manufaktur.

Link types and actions

The Manufaktur system uses hypermedia linking in a variety of ways, and it has shown useful to let the users distinguish themselves among which kind of semantics/behaviour they wish to associate with a given link. See the use example presented later. We also anticipate the need to support future browsing and filtering of the structures. Thus the underlying open hypermedia system, Webvise, has been extended to support semantic types for links by Hansen et al. [19] as part of the Manufaktur development.

The typing mechanism was inspired by the TEXTNET [36] system's use of types in reviewing of scientific papers. This means that the OHSWG standard [31] communication protocol used by Webvise has been slightly extended to cater for link types. This extension to the client and server were simple to add on top of the OHSWG protocol. The integrated applications need to be able to visualize on link types. As an example, the OLE communication from Webvise to Microsoft Internet Explorer was changed to pass on the name of the type for the link being presented. Currently, the name of the type is simply inserted as a "title" on links [28]. This creates a tool-tip with the name of the link type when the mouse is placed over the link. In this way (part of) the knowledge incorporated in the link type is passed on to the user immediately.

A vital part of link semantics is action. An attempt at providing link actions in Webvise [19] has been implemented by incorporating scripts written in TCL/TK [32] into links. Link attributes with the name 'Script' are interpreted as TCL/TK scripts, scripts are edited in the client in the same way that attributes are edited. Actions on links (and in future, other hypermedia objects) are used in Manufaktur for specifying behaviour of links. For instance, the link follow behaviour may occur in terms of either an animated move of icons into centre action or alternatively launching the document in its editor. Multi-headed links [18] may also be associated different behaviours depending on the link type, e.g. following the link may present each endpoint one at a time or it may be scripted to compile the extent of the destination link anchors into a single document or window to present the destination information together in one compact view.

3D Spatial Hypermedia

Manufaktur is used as a 3D graphical browser for open hypermedia structures. As described in the previous section on objects in Manufaktur, the document-objects can be grouped into composite structures (groups and pin-boards) through manual addition. But this kind of clustering/grouping should of course be supported by graphical parsing similar to VIKI [26] and CAOS [4, 5]. However, spatial parsing in 3D is slightly more difficult since objects can be close to each others in two dimensions but very far apart in the third dimension, e.g. will we consider a composite a stack if the distance from the top element to the next element is hundreds of measurement units? To solve this problem we are implementing spatial parsing with inspiration from the concepts of aura and nimbus [14] which originally were used to only render a representation of the parts of the hypermedia structure, which are sufficiently close to the user's "camera". This way Manufaktur is extending the notion of spatial hypermedia [24, 25] into 3D, since it supports implicit (as well as explicit) grouping of objects into composites by means of measuring their proximity in the 3D environment. We are currently experimenting with various ways of supporting implicit spatial structures inspired by the CVE aura [14] concept, where objects in the workspace may be interpreted as members of the same composite if they have certain level of overlap between their auras. By using the notion of aura to determine spatial proximity as a semantic grouping, objects can be assigned individual auras and groupings do not have be dependent on the absolute distance but can be grouped based on the, user definable, size of the aura.

DISTRIBUTION AND COLLABORATION

As we saw in the example from the landscape architects, design work is collaborative and often distributed. In case of the landscape architects, they have eight relatively small branches distributed across UK, and they often need to cooperate on common projects across the various sites. Furthermore, they envisage a use of the Manufaktur as a tool for presenting the 'project package' to their clients. This raises issues pertaining to distribution, various platforms (ranging from a fully equipped (virtual) project room, over clients running on workstations, to a 'viewer' running inside a WWW browser), and access rights (among people from same branch, same company, other company, etc.). Figure 5 depicts the implemented distribution architecture.

Manufaktur is developed in a distributed architecture where object databases, client applications, open hypermedia services, and session management services may be distributed over multiple servers on Internet and Intranets. The open hypermedia services include navigational, annotational, compositional, and spatial services. This architecture is conforming to a Component-Based Open Hypermedia model similar to the proposal by [29]. Entering a collaborative mode is done by starting or joining a session on the Session Management Services. The SMS will update the clients with the state of the session being joined, and then event notifications received from one client will be distributed to the other clients in the same session. Currently we support individual (uncoupled) mode and a tightly coupled collaboration mode [20, 34], where the virtual project rooms are synchronized and all users are aware of ongoing activities in the viewable area of the room. In this setting we see a natural distinction between two types of tight coupling. The first one is a mode where all object manipulations are reflected in all clients in the same session, and each user's actions are visible and distinguishable, but the users may place themselves (their camera) as they wish. The second tightly coupled mode is WISIWYS where all users share the same camera in the workspace, which they are all allowed to move. The first of the two tight coupling modes is primarily intended for "awareness" purposes, whereas the second primarily is intended for synchronous collaboration. Therefore, e.g. link following to an external application by one client will result in the document being launched on all clients in the second mode, but not in the first mode.

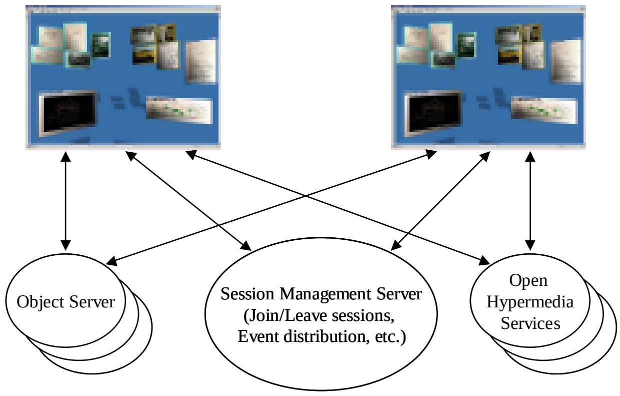

Figure 5: Manufaktur - distribution

The object server is currently implemented by an 'of-the-shelf' SQL database (MySQL), and it holds the objects in a platform independent format necessary to render the workspace in a suitable 3D environment (e.g. OpenGL or DirectX). The session management service is an implementation of a CB-OHS session service with protocol operations to invoke updates of the 3D workspaces. The Open Hypermedia Services is an extended version of the Webvise system [15, 19], which supports several linking and composition abstractions as described in previous sections and papers.

STATUS OF DEVELOPMENT AND USE

We are still in the early stages of the Manufaktur development and it is still too early for firm statements regarding the use of the Manufaktur. The first MS Windows version has been developed in continuous dialogue with representatives from the (landscape) architects, it has been presented at various stages in two landscape architect offices and one architect office, and recently (October '99) it has been installed on a pilot installation in one of the landscape architect offices, and it is planned to install in another landscape architect office in November.

Around eight of the landscape architects and two of the architects have used the prototype, mainly on finished or almost finished projects, to see whether the idea as such would bear through. A group of landscape architects have decided to apply the Manufaktur prototype on their next smaller project to try it in real work environment. Furthermore, they are planning to see whether it could be used for presentation purposes in relation to clients.

Naturally, with respect to ease of use, the Manufaktur prototype is still not complete. Likewise, there is still a good deal of conceptual work to be sorted out before the prototype may be said to constitute a coherent, efficient and effective tool. There is no doubt, though, that the experiences so far strongly indicates that the overall idea is a powerful one, and that the Manufaktur may become a useful and much needed part of the general suite of tools that are available for (landscape) architects, and potentially others as well.

Recently an SGI IRIX version of Manufaktur has been developed on top of Performer, which allow stereo projection of workspaces, e.g. on a HoloBench. The distribution infrastructure of the Manufaktur system allows multi-platform access to shared workspaces with different display bandwidths. Document-object hotlinks work across platforms as well as invocation of applications on a MS Windows based client is possible from the HoloBench.

DESIGN ISSUES AND FUTURE WORK

Manufaktur is a first attempt on creating Virtual Project Room support by means of distributed collaborative 3D workspaces and hypermedia. However, there are still a number of open issues that future research in the area needs to focus on. The Manufaktur concept is not meant to replace physical project rooms, it is rather meant to supplement distributed project groups in their collaboration. This implies that Manufaktur should become a natural element in the real workspace of architects. This could be accomplished by having Manufaktur become a room-ware component [35], which constitute touch sensitive walls in the project room, where the designers may go and pick materials from the virtual space of Manufaktur similarly to how they pick materials from the physical bookshelf, tables or the floor.

To develop this kind of virtual project room support we need to develop a better understanding of how users may perceive virtual extensions/augmentations of their project rooms. A number of design issues and questions arise:

Wall sized projections. Is a touch sensitive Smartboard sufficient? Will stereo projections like CAVE and HoloBench technologies be efficient? What kind of physical interaction should be supported in the room? Two-handed I/O? Keyboard? Gesture recognition?

Understanding the workspace. Which metaphors apply to this new notion of workspaces? How do architects understand the space? Should workspaces be furnished like a physical room? How do a user perceive borders between sub-spaces, e.g. parts of the virtual project room belonging to different physical locations?

Representing hypermedia structures in 3D. How can traditional link-based hypermedia structures be visualized and mapped to the virtual project room space? How do they correspond to spatial structures? And how do these structures fit together with a workspace metaphor?

Supporting collaboration. What does tightly or loosely coupled collaboration mean in a virtual project room? Does it imply a shared orientation, i.e. worlds are mirror to maintain left and right references? Do the users always have a shared camera angle or can rooms look different to different users?

Future experiments involving users working with prototypes in line with Manufaktur will be undertaken in the Desarte project to address these questions. The distribution and collaboration mechanisms as well as augmented room experiments will be further developed in the Distributed Multimedia project (DMM) under the Danish Centre for Multimedia.

CONCLUSION

This paper has explored the notion of virtual project rooms for architects working in distributed project groups. Based on the needs identified in participatory design studies, technologies coming from several different research areas have been brought together in a prototype called Manufaktur. The main interface of Manufaktur is a collaborative and distributed 3D workspace, which utilizes open hypermedia, spatial hypermedia and collaborative hypermedia techniques in combination with collaborative virtual environment (CVE) concepts. The results of the research so far are a novel interface for collaborative handling of architect materials, a novel open hypermedia integration method and an extension of spatial hypermedia from 2D to 3D. New experiments will bring the prototype software into various physical room settings with wall and table projections in both mono and stereo.

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