Shared Virtual Reality for Architectural Design

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The paper presents the implementation of a system of Shared Virtual Reality (SVR) in Internet applied to a large-scale project. The applications of SVR to architectural and urban design are presented in the context of a real project, the new railway junction of Porta Susa and the surrounding urban area in the city centre of Turin, Italy.
SVR differs from Virtual Reality in that the experience of virtual spaces is no longer individual, but rather shared across the net with other users simultaneously connected. SVR offers an effective approach to Computer Supported Collaborative Work, because it integrates both the communicative tools to improve collaboration and the distributed environment to elaborate information across the networks.

1. Introduction

Our group, the *Design Network Lab*[1] in the Department of Architectural Design, School of Architecture of the Polytechnic of Turin, in 1996 began to implement an information system to support the design and management of a large-scale project.
The project concerns a central part of Turin, the new intermodal transport system of Porta Susa and the surrounding urban area. The new Porta Susa railway station is becoming the fulcrum of the overall system of exchange between high-speed and local trains, surface transport, both public and private, and the future underground.
The information system is the work environment implemented to support the comprehensive analytical, planning, design, building and managing aspects of the Porta Susa project. The system is conceived to integrate and coordinate the work of individuals and groups: the public administration, the contractors, the firms, the suppliers, the building companies, etc. Besides "professionals", a further main aim of the information system is communication and interaction with public transport users and citizens.

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[1] The scientific heads of the Laboratory are Prof. Anna Maria Zorgno and Prof. Pio Luigi Brusasco.

1.1 PORTA SUSA PROJECT

The Porta Susa project is a major and long-term investment of the Municipality and National Railway Company, and is going not only to change a central urban area (Figure 1), but also to renew the overall system of communications of the city.
The Porta Susa project intends to innovate the Turin communication system towards an integrated system of exchange between different means of transport. The present main railway station, Porta Nuova, is not suitable for high-speed trains because it is a railhead, like most of nineteenth and twentieth century central stations.
The project is increasing the importance of the Porta Susa railway station as the lines will be quadrupled and moved underground. The Porta Susa area is becoming the fulcrum of the integrated system of exchange between trains and aeroplanes by means of a direct train link to the airport, and between the future underground and the private and public surface transport. To provide for these increasing requests and functions, a new railway station will be built at the lowered track level, a few hundreds meters away from the actual one.
Due to the roofing of the lines, the area, no longer occupied by the railway junction, will be available for new purposes and activities. The result will be a spacious boulevard, which will join two, at present separated, parts of the city. On this area the Municipality is planning an international architectural contest, perhaps one of the first contest based on Internet.

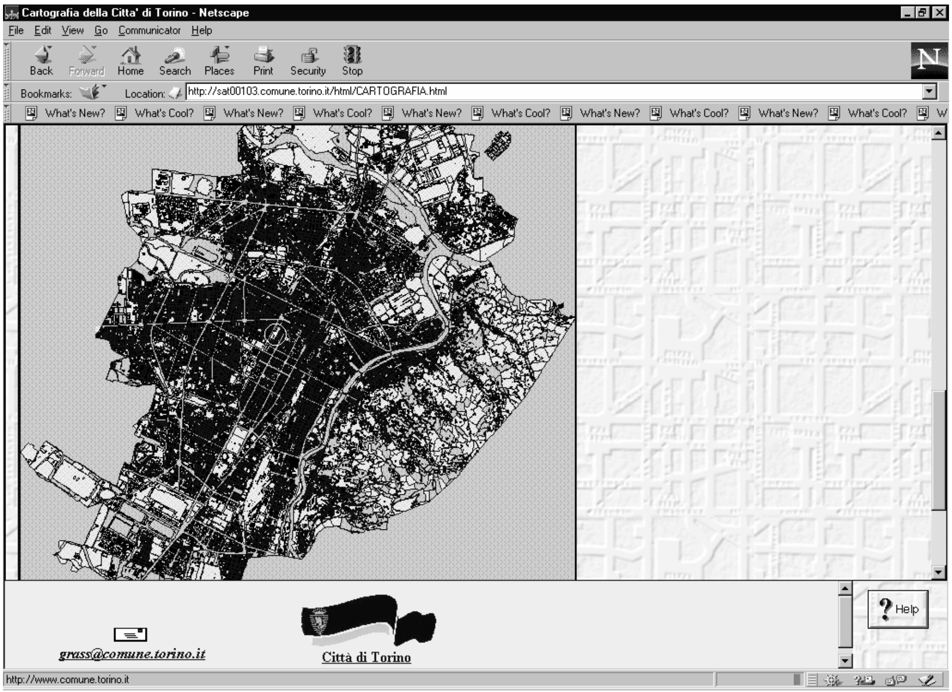

Figure 1. Turin and the Porta Susa area

1.2 COMMITMENTS OF THE INFORMATION SYSTEM

The information in a large-scale project is made up of hundreds or thousands of documents: drawings, drafts, blueprints, pages of reports and technical specifications, letters, manuals, etc. This large body of documents is made and updated continuously by the large number of people from all fields working to the project.

The information system is the environment committed to improving the work of documenting the project and to facilitate the various tasks which as a whole constitute the information-work: storing, retrieving, sharing, adding, modifying and managing documents.

As considered in a previous paper (Caneparo 1997), the main commitments to the information system are distributed access, flexibility, scalability and simplicity of use.

The *distributed access* permits every firm, contractor, supplier and other trading partner to store information on their servers. Meanwhile the users can access the overall information in a transparent way, and are no longer required to know if a document resides locally or remotely. For example, a user can visualise a drawing or a report consisting of parts residing on various servers (Figure 2). Download - upload changes the meaning, the users can browse documents and drawings as if the local disks are a Web site or explore Web sites as if they are local disks. The overall documentation of the project is location-independent and so, thanks to Turin's fiber-optic network, the access of a remote server could be as efficient as a local one.

Flexibility is the capacity to work with the presently used formats of documents, as well

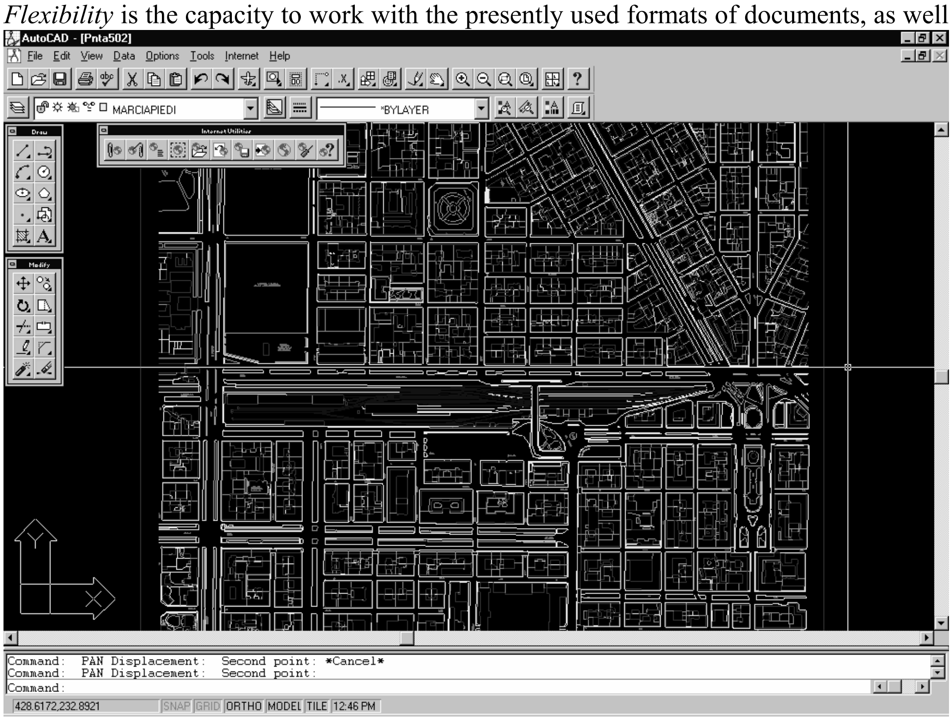

Figure 2. Dawing made of parts residing on different servers.

as with futures ones, not yet foreseen in the current implementation. Flexibility in the processing of different formats of document is obtained by means of the Multipurpose Internet Mail Extension (MIME) of the Web, which allows the processing of various document formats, hence not only HTML documents. This potentiality of the HTTP protocol allows one to associate to each specific type of document the application necessary to visualise, modify, print or save it. Flexibility is understood, as well, as the capacity to dynamically redefine working-groups according to the ongoing task. Flexible definition of work groups requires not only more efficient communication, but also tools to support dynamic changes in the flows of information.

The *scalability* is the possibility of integrating further individuals or groups into the project, dealing with their computer systems and networks. This should be made possible, either for the entire time of the project or, instead, for a limited time, e.g. to gather specific know-how.

Effective *simplicity of use* comes from the machine understanding what the user wants to do. Most of present available programs do not take into consideration real human functions, but instead offer tools to automatize information work. What we have tried to do with the Porta Susa information system is to integrate the tools the users are actually familiar with, in a networking-distributed environment. Present simplicity of use derives from the integration of the different applications (CAD, word processor, spread sheet, etc.) with the Web browser. This is particularly true with the most recent applications developed to be integrated in an Internet - intranet environment. The Web browser can automatically load the plug-in or the program associated to the format of the specific document. Today’s graphic and multitasking OSes allow one to create an integrated and coherent system around the Web browser, in which the user is no longer required to know about the compatibility of formats and of the corresponding programs.

A further key to simplicity of use derives from the intelligible organisation of the thousands of documents produced by the project. In early implementations of the system, the intelligible organisation was based on global coherence among the documents (Caneparo 1995), achieved by means of the definition of uniform and common criteria for the creation and storage of the documents. Up-to-date implementation experiments with another approach, focused on three-dimensional representation.

1.3 VIRTUAL REALITY

Virtual reality (VR) is more than just a further three-dimensional representation. Because of the computer interactivity it permits us to enter and explore complex data through a spatial representation. VR differs from animation in that the user is actively involved: s/he can move -walk in or fly through- the virtual model, the movement is unconstrained, i.e. no predefined path exists.

VR could deliver a paradigm shift in data representation and information access (Table 1), from 2D graphics to 3D representation, from window based interaction to space exploration.

	Time-sharing	Desktop	Networks
User	Specialist	Single	Group
Interface	Text	2D / 3D	VR / Multimedia
Decade	1970 -‘79	1980 -‘89	1990 -
Interaction	Read and type	Paint and click	Navigate and communicate

Table 1. Paradigm shift in data representation and information access.

In the Porta Susa project not only designs and prototypes, but the whole documentation is accessible by means of VR. Through Internet the numerous and various protagonists of the project have the immediate opportunity to inspect the work in progress.

CAD 3D models are converted to Virtual Reality Modelling Language (VRML) and then uploaded to the server. Several programs and plug-ins for WWW browsers are available to explore VRML models. Since the conversion from CAD to VRML models is automatic, the representations accessible through the Internet are easily kept in sync with the design at its current stage.

Spatial representation is crucial for exploring architecture and buildings, but VR should not be limited to this task. VR enhances the understanding of interferences between flows of different transport systems, i.e. passengers of the high-speed trains, local trains and underground. VR improves the storage of a single document among the several thousands of the overall project and then its easy retrieval by “walking in” a 3D representation of the project with the relevant documents associated to the objects and buildings.

2. Shared Virtual Reality

The exploration and critique of a VR model across the net is essentially an individual process, because each person, independently from others, downloads the model and examines it. Shared Virtual Reality (SVR) differs from VR in that the experience of 3D spaces and objects is no longer individual, but rather is shared among several users across the Internet. SVR opens *virtual places* in Internet, *cyberspaces*[2], where people can enter, meet and communicate with others connected simultaneously.

SVR produces a further paradigm shift merging the capacity of network communication with three-dimensional representation. As avatars[3] people can meet in virtual spaces representing any physical or symbolic places whatever (Figure 3a, 3b).

SVR is a new medium, a different way to achieve real-time 3D interaction, different from the Web wheel of authoring - publishing - browsing pages.

For architects and planners SVR means a new way to communicate their ideas, to *broadcast* a design, to meet clients and contractors directly in the 3D model. As soon as

[2] According to the definition of William Gibson (1984), cyberspace is the total digital network, a place of meeting and communication.

[3] In Hinduism an avatar is the Terrestrial incarnation of a god or goddess. In SVR an avatar is the user “incarnation” in cyberspace.

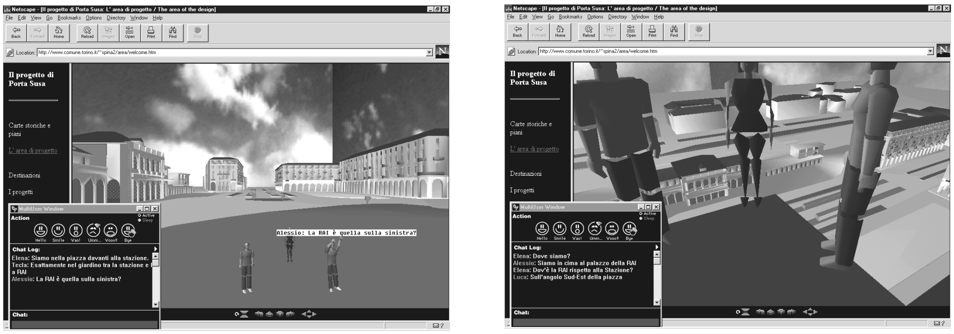

Figure 3a, 3b. Avatars meeting in cyberspace.

early stages of the design are modelled, they can be explored and discussed making everyone feel at home, even if they are sited in front of a computer at the office. Virtual tours and meetings about the project can be arranged to consider ongoing problems and decisions among small or large groups. Virtual meetings can be scheduled in advance or, instead, arranged ad-hoc among people collaborating on the same task.

2.1 SHARED VIRTUAL REALITY PLUG-IN

The tool to gain access through the Internet to SVR is a plug-in for the main WWW browsers. The plug-in allows us to explore three-dimensional scenes by means of the Virtual Reality Modelling Language (VRML)[4].

The plug-in is automatically loaded when the HTTP protocol defines the corresponding 3D format. To the WWW browser the plug-in adds the tools for exploring 3D space, for visualising other users who are simultaneously connected and for communicating with them.

At present the plug-in runs with Windows 95 and NT on Intel CPUs, while porting to other platforms is expected.

2.2 EXPLORING SPACES

Moving a virtual observer controls exploration of virtual spaces and designs. The users define the virtual observer's movements and this is an important aspect of VR interaction. The method of interaction depends on the available hardware. With two-dimensional devices (e.g. mouse, trackball) the user defines a plane on which, by means of the pointing device, s/he traces and modifies on the screen a vector defining the path of the observer in the environment. With three-dimensional devices (e.g. spaceball) the user gains continuous control of the movements in 3D.

The SVR plug-in simulates the physical properties of objects, for example, it does not permit one to pass through objects, and the movements of the observer are restricted according to physical laws such as acceleration and gravity. The simulation of these properties slows down the interaction with the world considerably, in that a powerful

[4] For VRML specification, see http://vag.vrml.org/ .

CPU and a 3D graphics accelerator card considerably improves smooth movements and interaction feedback.

2.3 DATA FORMAT OF SVR

The SVR plug-in adopts the Virtual Reality Modelling Language (VRML), Version 2. The VRML is a file format for describing three-dimensional interactive worlds and objects, conceived to be used in conjunction with the WWW. Since May 1997 the VRML is recognised as an ISO standard, and defines a worldwide accepted language.

In essence, the VRML is a plain ASCII language to describe 3D worlds. As HTML is a language to format documents for the Web, VRML is a language to create spaces and objects. Interpreters (browsers) for VRML are widely available from several companies and institutions for many different platforms.

VRML defines the syntax to describe a scene, consisting of lights, geometries and their properties. The properties attributed to geometries are colour, texture, animation and hyper-links to HTTP documents in Internet. Version 2 adds the possibility of animating objects, and improving VR worlds with sounds and the visibility option, that is fog.

The SVR plug-in implements the VRML 2's multi-user capacities and makes use of Java programming.

Java adds further action to VRML worlds. Java applets can be associated to polygons and objects to perform specific actions based on events, time or user's interaction. For example, it' s possible to use a wall of a building as a blackboard or sketch book, or define an interactive environment to assemble objects from primitive solids.

Multi-user capacity is inherent to the nature of VRML. The SVR plug-in implements several options to make VRML worlds effective cyberspace communities of people across the Internet. To gain access to a SVR world the user has simply to follow the appropriate link from her/his WWW browser. After a while (depending on the size of the model) s/he will be projected into the shared virtual reality world.

After the user has selected from her/his WWW browser the link to an SVR world, the WWW server defines the MIME type that the Web browser associates to the SVR plug-in. The Web browser loads the plug-in and transfers to it the address of the VRML model to be downloaded. The plug-in downloads and interprets the VRML language in a virtual 3D world. If the world contains the definition of a SVR server, the plug-in loads the multi-user module. The multi-user module is the client, which requests, over the net, the defined SVR server. The reply from the SVR server specifies the number and position of the other users connected. If there are other users in a defined *aura*[5] of interaction, the plug-in downloads from the WWW server the geometry and description of the appropriate avatar. After the download is completed, the avatar is displayed in the proper position, while the plug-in regularly transmits the position of the user and in the meanwhile receives the positions of the other users.

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[5] The aura is the predefinible radius of visibility and interaction among avatars.

2.4 COMMUNICATION IN SVR WORLD

The multi-user module integrates a chat program. The chat allows people in SVR worlds to exchange brief written messages. The plug-in forwards the message to the SVR server, which redistributes it to every user, connected (Figure 4). The ongoing experiment focuses on vocal messages, so, as a result, the communication becomes more friendly. A main drawback of vocal messages is that the communication is not duplex, a certain time lapse between the submission and the reception exists, and single packets can arrive delayed or out of sequence. Individuals in wide spread groups can receive the message at different moments, making effective interaction difficult.
The integration of the SVR plug-in with the main WWW browsers permits one to use other tools of communication. To gain audio capacity, RealAudio™ or a conference program can run concurrently with the SVR plug-in.

3. Design Applications of Shared Virtual Reality

3.1 SHARED VIRTUAL PROTOTYPES

One of the primary aims of VRML is the sharing of three-dimensional models across the net. For architects and engineers VRML makes it possible to share models on the basis of a platform independent standard. No matter what the CAD and modeller

Figure 4. Chat active among users simultaneously connected.

program are used, the model can be exported to the VRML format and shared across Internet.

Buildings, structures, infrastructures can be closely examined before they are built. The different participants in the project can explore design and technological solutions in depth and in detail by walking in and flying through. The ability to explore the model is important in order to examine the interrelations between the parts. The use of colours can produce either realistic representation, for example to evaluate the environmental impact, or a symbolic representation, for example to highlight the integration and the interference among parts and objects. Because the virtual spaces are shared, persons from different places can meet in the virtual prototype to examine a design, to discuss problems and to take decisions. Decisions made in early design phases cost less than those made later since changes requested during the building process, if they are not impossible, will result in increased costs.

Design stages, as soon as they are computer modelled, are made available across the net. It could be possible to have no intrinsic gap between conception, simulation, examination and decision. Moreover, due to SVR the decision making process can involve every participant, no matter what time-schedule-appointment. Everyone, in front of her/his workstation, laptop or notebook, can examine the shared virtual prototype and join the meeting (Figure 5a, 5b).

Porta Susa is a large-scale project involving several teams working on different aspects, sometimes distinct, but more often interrelated. Sharing 3D data among the teams is necessary but not sufficient, because it is essential to make and keep these data coherent. The coherence is based on both modularity and extensibility. VRML 2 standard has been conceived with modularity and extensibility in mind. VRML is based on blocks, which can be loaded separately and then easily combined. Each block can be upgraded or substituted and new blocks can be added. In the Porta Susa project a taxonomy of VRML blocks has been defined, of which the most primitive elements are the building parts. These parts are available on the server, and shared among the various participants. The blocks from CAD or VRML can be easily combined into more complex objects, as far as whole buildings.

3.2 THREE-DIMENSIONAL DATA BROWSING

It has been previously mentioned that we expect the VR to be a paradigm shift. VR on the Internet, i.e. VRML, consists of a new way of interacting not only with objects and

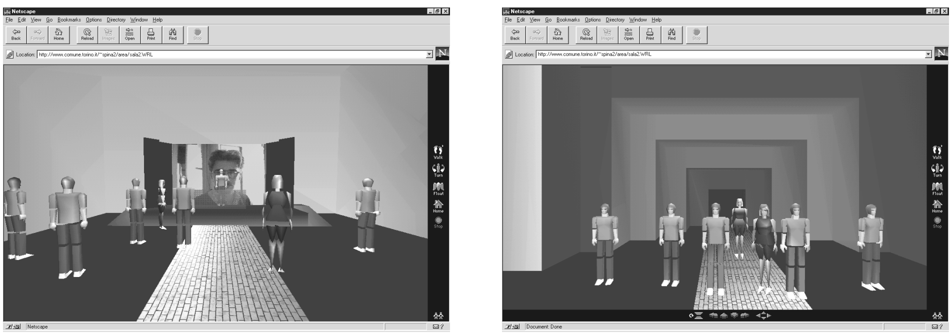

Figure 5a, 5b. Meeting in the virtual auditorium.

buildings, but with information in general.
VRML worlds can be modelled to represent not only designs, but also the interrelation between the objects in the design and the overall information of the project.
The Porta Susa project consists of thousands of drawings, drafts, blueprints, pages of reports and technical specifications, data, historical changes, etc. A primary aim of an information system on the project is storing and retrieving such a vast amount of heterogeneous documents, which varies and modifies during the life of the project itself. SVR offers the information system two paradigms: the model of buildings and the model of relations among documents. The two models are presented separately, but in fact they are closely interrelated, because, by means of VR, it is possible to move from one model to the other and back again.

3.2.1 Model of Buildings
The model of buildings is a simplified three-dimensional representation of the overall Porta Susa area. To store a document (whatever its medium), the user walks into the model up to the object/building which that document relates to. Then s/he just links the document to the related object or group of objects. To retrieve a document, the users explore the VR model up to the object to which the document relates and then with the cursor s/he explores the surroundings by selecting HTTP hyper-links to documents. The VRML and HTTP permit the building of a "web" of interrelated links among documents on the Internet, allowing users to view different and remote servers as ubiquitous data sources. Moreover different media are managed transparently by the MIME protocol, freeing the user from most concerns about data formats and their compatibility. VR has proved a powerful tool to manage building information, which is intrinsically related to a spatial paradigm.

3.2.2 Model of Relations among Documents
Instead of representing the physical relations between objects, the model of relations among documents presents the links connecting documents, directories and servers. The single documents are the nodes and the hyper- links are the arrows connecting them. Further objects represented are the directories, grouping document-nodes, and the servers, storing the directories.
The logical structure of hyper-links is more easily understood as a graph. The graphical representation, whether two or three-dimensional (Figure 6a, 6b), highlights the organisational structure of the project, and makes evident the relations between the documents accessible through the net. The user can explore the overall documentation of the project "flying through" the model of the relations between the documents, and can browse the interrelated documents by clicking on (Figure 6b).

3.3 COLLABORATIVE ENVIRONMENT

The Porta Susa information system is the operative tool conceived and created to support and improve the collaboration between the protagonists of the Porta Susa project. As noted in previous studies (Benford 1991) (Garlegher, Kraut and Egidio 1990) (Greenbaum and Kyng 1991) (Schuler and Namioka 1993), Computer Supported

Collaborative Work (CSCW) is not based on a single factor, but rather on the integration of three primary aspects: memory, process and collaboration.

Memory is the knowledge of the project and design from its early stages, to the present state. Active memory provides both the long-term storage of information and the representations necessary to deal with the huge amount of heterogeneous documents. The memory consists of drafts, drawings, reports, letters, technical specs created, exchanged and updated during the project. In a previous paper (Caneparo 1997), I have considered the forms of representations used to deal with memory (primarily precedents and indexing schemes) and how they relate to the ISO 9000 standards (Caneparo 1994).

Process is the capacity to work with the information of the project. This capacity consists of the user’s ability to access, update, modify both single, and bodies of, documents. Often the process spans the project both horizontally, between users with similar tasks, and vertically, between persons with different roles. A single task, e.g. modifying a drawing, could involve several draftsmen, architects, contractors, public administrators, etc. Work progresses by means of both concurrent and independent processes. The information system should be closely coupled to the data processed and flexible enough to support a dynamic environment, gradually evolving according to the tasks faced.

Collaboration, the users do not make explicit distinction between working cooperatively or individually. Several persons are required to deal with various tasks in the large-scale project. This can be done by traditional hierarchy, by subdividing responsibilities and tasks, or in a more flexible way, by setting up dynamic, ad-hoc, groups to deal with a specific job. Dynamic definition of groups requires more efficient communication in order to effectively exploit the pool of human resources and to share the knowledge and skills of the single members.

SVR offers a unitary approach to the different aspects of CSCW. The approach adopted is the *virtual yard*, where people involved in the project from his/her computer can connect to and “walk in” to retrieve information, to meet someone, to discuss a topic and to take a decision regarding an aspect of the project.

The virtual yard is not the model of a real, physical, place, but instead a symbolic representation of the project. The participating contractors, subcontractors, firms, suppliers and other trading partners manage their own virtual stands in the area of the

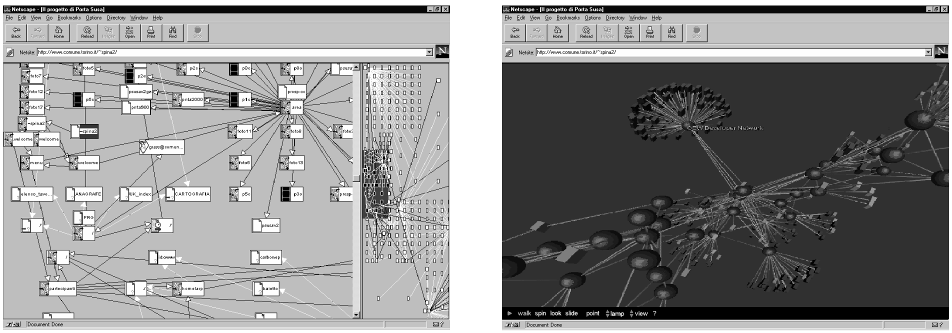

Figure 6a, 6b. 2D and 3D navigable maps of the hyper-links between documents in the Porta Susa project.

project on which they are working. These stands represent the distribution of know-how, duties, responsibilities and jobs and provide hyper-links to relevant information and to the people who are working on it. The cluster of these stands constitutes the nucleus of the virtual yard. Around this nucleus there is an auditorium, where participants in the project can meet each other and discuss by means of the SVR tools (cf. 2.4). There is also a library into which one can enter to gain access to the 3D models of the logical structure of hyper- links between documents (cf. 3.2.2).

Acknowledgements

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References

Further information on the project is available on-line at:

http://www.comune.torino.it/~spina2

http://sat00103.comune.torino.it/

Benford, S. (1991) “Requirements of activity management”, in Bowers, J. and Benford, S. (eds.) *Studies in Computer Supported Cooperative Work: Theory, Practice and Design*, Elsevier Science, Amsterdam, pp. 285-298.

Caneparo, L. (1994) “Groupware and Design Education in Architecture”, in Harfmann A. and Fraser M. (eds.), *Proceedings, ACADIA ‘94 Conference*, The Association of Computer Aided Design in Architecture, St. Louis, pp. 153-160.

Caneparo, L. (1995) “Coordinative Virtual Space for Architectural Design”, in Tan M. and Teh R. (eds.). *Proceedings of CAAD Futures ‘95*. Centre for Advanced Studies in Architecture, Singapore, pp. 739-748.

Caneparo, L. (1997) “Shared Information System for Urban and Architectural Design”, in Coyne, R. Ramscar, M. Lee, J. and Zreik, K. *Design and the net. Proceedings of the Sixth International EuropIA Conference*, Europia Productions, Paris, pp. 39-52.

Garlegher, J. Kraut, R. and Egidio, C. (eds.) (1990) *Intellectual teamwork: social and technological foundations of cooperative work*, Lawrence Erlbaum Ass., Hillsdale.

Gibson, W. (1984) *Neuromancer*, Ace Books, New York.

Greenbaum, G. and Kyng, M. (eds) (1991) *Design at Work*, Lawrence Erlbaum Ass., Hillsdale.

Schuler, D. and Namioka, A. (eds.) (1993) *Participatory design: principles and practices*, Lawrence Erlbaum Ass., Hillsdale.