Virtual Reality International Conferences 2000,
Laval 18-21 Mai 2000

EXPERIMENTING SERVICE-ORIENTED 3D METAPHORS FOR MANAGING NETWORKS USING VIRTUAL REALITY

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Keywords : Information visualization, Metaphoric virtual worlds, Network management.

Abstract

In this paper, we present experimental network management tools developed within the context of the CyberNet research project. The aim of this project is to study how metaphoric 3D visualization may help the user in the process of monitoring large amounts of dynamic information. Although the project focuses on a specific application domain, network management, it is designed so that it can be applied to other domains. The paper presents how 3D metaphoric worlds are automatically build from real world information dynamically collected on the network. It then focuses on several network administration tools that have been developed for helping network managers to track and understand problems. The paper also presents how 3D navigation and interaction are handled by the system in order to help the user in its task.

1 Introduction

Nowadays, network management is a difficult and attention-demanding task since a network manager has to understand the behavior of very complex networks constituted by thousands of manageable *components*. Traditionally, these components are network devices (such as hubs, switches, and routers). The network information is usually presented to the user using tables and/or graphs. When there is a change in the network status, the interface signals it to the user, usually using some kind of dialog box. The user shall then make a new request and, acting upon it, the system updates the user interface content.

The trend is to manage computers (configuration, system, and activity) as well as software (distributed systems, client/server applications). Network managers cannot think in terms of devices, they have to think in terms of *services*. In our terminology, the term service covers topology, connectivity, routing, DBMS, NFS, mailing, etc. The status of a service can generally be understood by analyzing large amounts of data distributed on the network devices. In order to improve data presentation, we believe that information needs to be logically structured according to services. A service has its own set of involved components and should be presented using the most suited graphical interface.

The objective of the CyberNet project is to study the usability and effectiveness of 3D techniques and virtual reality interfaces for system and network management. We intend to prove that visualization of distributed dynamic data can be made more efficient with 3D technology. There is no reason to use the same representation to visualize the topology of a network and the behavior of a complex client/server application. For this purpose, we are designing a general framework that makes the development of specific visualization tools easy. This framework is designed to dynamically build and update 3D worlds according to the real world data. It also features some specific support for user interaction and navigation. The CyberNet framework is specific in its approach because of the following features.

First, the processed data is dynamic. The visualization is designed in order to cope with this dynamic so that the 3D worlds are permanently updated. New objects are added to the 3D scene, existing objects disappear and the visual appearance of the displayed objects is continuously modified in order to reflect the state of the network data. This dynamic has a lot of impacts on the system design.

Second, the translation between the real world data and their visual counter part is handled automatically by the system. We call this translation process the mapping.

Third, the visualization is based on 3D metaphors. The traditional way to represent network information in 3D is to extend the usual 2D graphical business representations such as 3D bar charts, 3D graphs etc… These representations are well suited to the display of small amount of information but they generally fail when large amount of information is involved and when it is important to show relationships between elements. Although CyberNet can represent information using these simple graphical elements, it is designed to go beyond this kind of representation. In order to represent information CyberNet uses metaphors based on real world well known entities such as towns, solar systems, buildings etc… The idea behind the use of metaphors is to take advantages of the natural hierarchical structure found in most of the metaphors (cities are made of districts, each district is made of buildings and streets, each building has floors, rooms, windows, etc…). CyberNet uses this hierarchical structure in order to classify information realated to a service.

Finally, the use of metaphors has also the advantage of producing worlds that are familiar to the user [1]. Using carefully design user interface, the CyberNet system can benefit from the user knowledge and thus can enhance the user understanding of the world, as well as ease its navigation interaction.

2 Related Work

The interest in 3D interfaces for network management started less than ten years ago. The first experiments in that field were devoted to topology and device administration. One of the first experiments began in 1992 at Columbia University. The COMET group has studied how virtual reality may be used within the context of ATM network management [2]. [3] and [4] presents a network management tool that supports collaborations between users and is accessible from a web browser. In parallel, researchers started to focus on visualizing the network data rather than to limit the visualization to the network structure and connectivity. [5] presents some work done on this topic and introduces studies about services: the mail service is studied in [6] and highlights the interest for the visualization to exploit (cluster, sum up) the hierarchical structure of the data.

More recently, [7] reports AT&T laboratories experiments concerning the management of large dynamic telecommunication data sets (~250 million events per day). The results of the studies seem promising since the presented tool improves network management and marketing of network services. [8] presents a performance analysis tool called Virtue. The Virtue tool adapts itself to the dynamic behavior of the studied application. It gathers information from multiple sources involved in the monitoring of complex distributed parallel applications. Related to our field, SGI has developed a 3D computer-monitoring tool called Performance-Copilot [9]. The tool can be used for monitoring computer arrays and clusters or in the context of Web server and Oracle DBMS management. The major benefit of this tool is to help the users to quickly isolate, drill down and understand performance behavior, resource utilization, activity levels and performance bottlenecks. [10] presents a set of network visualization tools that gives 3D graphic representations of the Internet from a geographical point of view.

This research domain is part of the Information Visualization field [11] [12]. 3D Information Visualization has lots of aspects and applications. In a special report [13] shows how it may help in the context of the “Global Information Infrastructure” to retrieve information, interact with databases, manage networks or browse the web. [14] reports an experiment done by Xerox in order to go beyond the usual desktop metaphor. An active research area is Business data 3D visualization [15]. The main idea is to provide 3D graphical representations of rows and columns of numbers in order to improve perception and support decision-making. [16] presents a data mining visualization software developed by SGI called MineSet. The strength of this tool is the integration of several 3D visualizations that can be used simultaneously by the user. Extensive work has been done towards web based information visualization [17].

3 Managing Networks using the CyberNet Platform

In network management, information is spread over a large number of network components. This information is collected and structured in order to be presented as a metaphoric 3D world. A large part of the system is devoted to this collecting and structuring purpose. It has been described in previous papers [18].

The result of the collect is a hierarchical structure of objects that represent a network service. The leaves of this structure are called entities. Entities encapsulate raw data collected from the network devices. They can represent physical devices (e.g., hubs, routers, computers, etc.) or conceptual items (e.g., connections, processes, etc.). The same entity may appear several times in the hierarchy (being a leaf of several intermediate nodes). Intermediate nodes are used to structure information. There are several types of intermediate nodes (called relations and service nodes) but this is out of the scope of this paper. The design of the service hierarchy is under the responsibility of a domain expert and should closely match the conceptual service structure.

Basically, this hierarchical structure evolves with time, and new branches are automatically created or deleted, and the real world values stored at the leaves level are permanently updated. The purpose of the visualization process is to automatically translate this hierarchy into a 3D scene hierarchy, and to update the 3D world according to the real world modifications.

The CyberNet platform is written in JAVA and the CORBA distributed object technology is used to support communications between the distributed parts of the system. The user interface is accessible from any VRML-enabled WWW browser. In the current implementation, the visualization uses VRML through the EAI (External Authoring Interface). Because of technical limitations of the EAI, we are porting the user interface onto JAVA3D.

4 Visualizing Information using the CyberNet Platform

4.1 Metaphoric worlds

As it has already been reported in the previous section, our visual structure is based upon the concept of 3D metaphors. Metaphors are used because the user already knows their underlying structures. We have designed real world metaphors such as buildings, cities or solar systems. But it is sometime useful to design more abstract metaphors such as cone-trees or landscapes. A metaphor is not designed for a specified service. In this context, a service can be visualized using any metaphor provided if it offers sufficient capabilities for viewing the service information. This allows the user to select the metaphor best suited to his needs. Because of the dynamic nature of the system, each change in a service is reflected in the metaphoric 3D world. In this section, we present the components of a metaphor that allow visualizing information, and how the mapping between a service and a metaphor is achieved. Finally, we present the interaction mechanisms provided by the virtual world.

4.2 Metaphoric components

In the CyberNet system, the visual structure of a metaphor is composed of *graphical components* (GCs) which are basic building blocks from which metaphoric virtual worlds can be built. Each graphical component has visual parameters that can be modified in order to visualize information. There are two kind of graphical components: 3D glyphs and layout managers.

- *3D Glyphs* (3DG) are 3D objects whose appearance may be controlled in real time through visual parameters. 3DGs represents data through visual parameters (e.g., color and size…). The level of complexity of a 3DG is related to the number of visual parameters it offers for modification.
- *Layout managers* (LM) are responsible for one of the most important visual choice: the use of space [19]. They are used as containers and may contain 3DGs or other LMs. They organize their children in space (position and orientation) according to built-in policy and may also animate these positions along paths. For instance, a LM may organize elements in orbit around its center, it can stack its children along an axis, arranges its children on a plane in rows/columns, or uses a cone tree model. Layout managers can also add some visual elements like semitransparent bounding boxes around their children to enhance the visualization.

Using these two kinds of graphical components, one can build a 3D-scene hierarchy using LM as intermediate nodes and 3DG as leaves. Each internal node of this hierarchy is a LM and each leaf is a 3DG. Specific graphical components must be defined for each metaphor. For instance, in a city metaphor, the minimal requirement is 3DGs of houses, buildings or roads and a LM that positions these elements in different districts. A solar system metaphor could be composed of a star and planet glyphs, and an orbital layout manager. The more GCs are used in a metaphor, the more numerous the ways to visualize the data. Some metaphors cannot be used to visualize a service because of a lack of graphical components to show information.

Designing graphical components is not enough. The metaphor should also provide support for user interaction (user interaction features navigation in the world as well as selection and manipulation mechanisms of 3D objects). We experimented that the interaction tools proposed to the user should also be metaphor dependent. Our idea is that the user does not navigate in a city in the same way he is navigating in a building or in a cone tree. We define *metaphoric components* (MC) as graphical components that provide some level of built-in metaphoric support to handle user interaction. In a first time, we will see how to use them to construct a 3D visualization from a service.

4.3 Model Mapping : mapping the Service Model onto the Metaphor

Mapping is the process that automatically constructs a 3D metaphoric world from the information contained in a service. In our current implementation, each metaphor is defined by a hierarchy of MCs (i.e. a town metaphor is based on MC called Town, Districts, Streets, Buildings, Floors etc). We call *model mapping* the process of defining which service element (leaf or intermediate node) will be visualized using which MC. The basic idea behind mapping is to define a set of association rules for each service. These association rules are based on the type of each service element and its position in the service tree. In particular, since an entity may be a leaf of several intermediate nodes, it may have several visual counterparts in the presentation domain.

4.4 Visual Parameter Mapping : mapping Information onto Visual Parameters

The basic information stored in each entity should be translated into some visual information. This is the purpose of *visual parameter mapping*. Each MC has visual parameters that may be dynamically modified in order to display information (position, orientation, size, color etc…). A trivial example is the mapping of a process entity on a box glyph: the CPU used could be mapped on the color of the box and the memory used on the size of the box. When designing a mapping, care should be given to preserve metaphor coherency and identification purposes. For example, if one rule uses the color for identification purposes, other rules must not use this visual parameter to represent a value. Generally, a relation is associated with a LM and an entity is associated with a 3D glyph. Thus, the graphical hierarchy follows the structure of the service. However, it appears necessary to be able to add special visual intermediate nodes in the graphical hierarchy in order to achieve visual mechanisms at a graphical level.

5 Experimenting Virtual Reality : Network Management Applications

Designing a service model requires an expert knowledge of the service. The raw data should be carefully chosen and stored in well-defined entities. The relations and the service hierarchy should match the expert understanding of how the service works. On the other side, designing the metaphor requires skills in 3D graphics and user interface. Once service models and metaphors have been developed, testing several metaphors for a given service model is only a matter of defining mappings.

We present below some examples that highlight the use of 3D worlds to visualize network information. All these 3D worlds have been generated automatically from information collected on real networks. Any metaphor may be applied to any data set as long as a mapping between the real world data and the visual parameters of the graphical components of the metaphor has been defined. At present time, the mapping is hard coded but we are working toward an automatic mapping scheme.

5.1 Geographic Administration tool

Geographic administration tools are useful for tele-maintenance as well as for physical link problem detection. In that later case, the network manager may notice that some physically grouped devices have a transmission error ratio abnormally high. The geographic visualization depends upon the application, examples exist for WANs and are based upon earth or country maps. We develop an example of a LAN geographic administration tool based on the building metaphor. The idea that lead to develop such a metaphor was to exploit the structured nature of a building: a building is made of floors related to each other by stairs, floors have corridors that give access to rooms, inside rooms you may find furniture, people etc. Our major goal in designing this metaphor was to study user navigation and interaction schemes in some virtual representation of our day to day world. The user can navigate in the building using predefined paths (see the metaphoric navigation section bellow). He can interact with elements for selecting all offices/users/workstations of a specific department, he may define walls and floors level of transparency, etc. The building metaphor is very much oriented toward network administration needs. The building is schematic and is viewed as a container for classifying network devices. The precise size and aspect of the building is not rendered but the relative locations of objects are. Each network device (e.g.: computer, hub, switch and routers) is placed at its real world location. Using this tool, network managers can view their network according to the real world location of devices and identify problems related to geographic proximity.

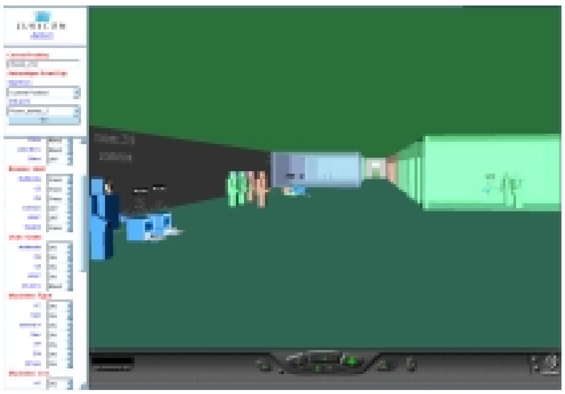

Figure 1: Geographic administration tool based on the building metaphor.

The building metaphor may be used for other purposes than just representing a real world building. The first experiment we made was called the “virtual company building”. The idea was to build a virtual building in which a virtual office still represents a real world office but where offices are arranged according to other criteria than their real world spatial relationship. For example, each floor of the virtual building groups all the offices that belong to a specific department (it does not matter if the real world rooms are in Japan, France or USA). Used in conjunction with other views, this kind of model is very important for the network manager to be able to understand and monitor network traffics generated between the resource of a dispersed department.

5.2 Topology Administration tool

Topology administration tools are useful for detecting network element failures or problems concerning load balancing. We develop an example of LAN topology administration tool based on the cone-tree metaphor. The cone-tree is well adapted to visualize hierarchical data structure and most LANs (or at least parts of the LAN) may be conceptually modeled as tree with leaf nodes being computers and intermediate nodes being routers, hubs and switches. Computers that have several network links appear several times in the hierarchy. In this example, hubs are represented by a box 3Dglyph (which identify the hub itself) and a cone that represents the collision domain of that hub. All the devices that are connected onto that hub are connected to that cone. Switches are represented by a box 3Dglyph and a set of edges that connect the box to the 3Dglyph of the devices. The bandwidth usage and error ratio measured on each device affect in real-time the color and size of these cones and edges. Using such a representation, the user may rapidly identify the overall traffic and notice congestion problems. Of course, other mappings could be defined in order to monitor other network values.

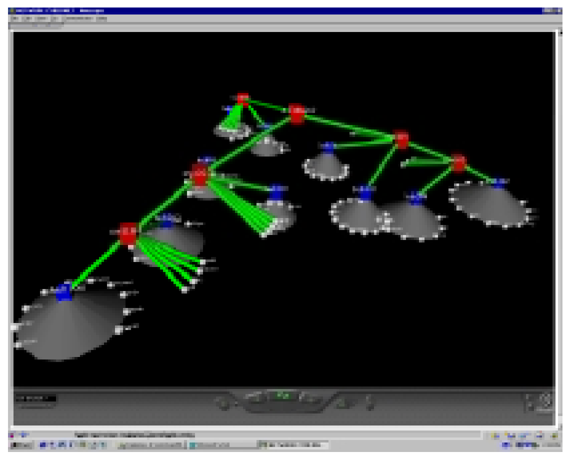

Figure 2 : Topology administration tool based on the cone-tree metaphor.

5.3 Distributed Services Administration tool

The previous examples are quite traditional in the way they represent network data. We want to address more complex problems related to the management of a complete service involving lots of network components. Client/Server applications (like mail, DBMS etc) are typical services for which we believe 3D metaphoric worlds can help. An example of such a service is the NFS (Network File System) client/server application. NFS is used by Unix computer to export their file systems to other computers. Using NFS a remote disk is viewed in the same way than a local disk. But on the network administrator and system manager’s point of view, each access to a remote disk generates network traffic. A typical NFS site configuration involves lots of networked computer on a typical Unix/NT workstation network. We choose NFS as an example of the administration of a complex networked client/server service. Our design principle was to avoid the use of graphical links to represent relations between a client and a server. This kind of representation easily leads to an unreadable graph. We choose to represent both the server and the client as separated objects, and to identify the existence of a client near the server representation as well as the existence of a server near the representation of the client. We developed the city metaphor to show either the configuration or the runtime characteristics of such a client/server applications. Each town is a sub network, each district of the town is a computer, and each building is a disk resource. There are several types of buildings, mainly buildings that represent local disks, and buildings that represent remote disks. On the server side, local disks may be exported, in that case each client (computer that import that disk) is represented on the server as an additional floor on the local exported disk building. At each floor, the number of windows shows the number of filehandles opened on the disk. Some other information is also accessible such as the traffic generated by the NFS server or the error ratio. In the user perspective, the world has the advantage of presenting both synthetic and detailed views of the service. It is synthetic viewed from far away since it allows to easily identify servers and to understand their activity (tall buildings). It is detailed since the user can have access to the details when he gets close enough to a specific object. The major advantage is that all the data that is required to understand the behavior of the system is available in one view.

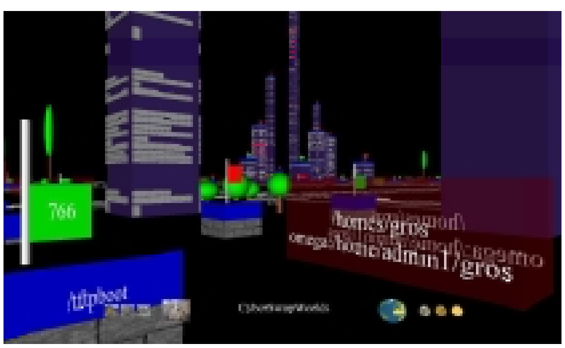

figure 3 : Distributed service administration tool based on the City metaphor

5.4 Computer Administration tool

Computer administration tools are useful to track computers and users activities over a network of workstation in order to prevent problems and easily administrate networked systems. Monitoring a network of workstation requires lots of information to be accessible at the same time (user, processes, memory and processor usage). Our idea was to study how to display in one world the dynamic result of the "top" unix command ran simultaneously on all the computer of the domain. For this purpose we developed an example of a computer-monitoring tool based on the solar system metaphor. Computers are stars, users are planets in orbit around stars and processes are satellites floating in-between the star and the planet. The visual parameters (orbit radius, size, color) can be used to represent cpu usage and virtual memory consumption. The system administrator can notice the load of computers, and identify when they are reaching some limits. In the context of networked workstation the tool can be used to monitor the same set of data using different model mapping. An example of such an interesting networking administration is to monitor user's activity: users being stars, computers being planets with process floating in between. In that case the system administrator easily identify the computers a user is logged on and the activity of the user on each computer. Another example is the process centered view for which processes are stars, computers are planets and users are satellites. In that case the user may easily identify extensively used applications and detect potential problems concerning a specific instance of an application. The solar system metaphor was the subject of some additional work concerning clustering of information. The idea of clustering is to have access to several levels of representation. It is different form the simple LOD mechanism that is already in used for graphical performance reasons in most of our metaphoric component. Using clustering the user may control the level of details represented in the world. When the users asks for more details, the service model itself can be modified in order to collect more data on the network. When the user asks for less details, the service model is modified in order to reduce the number (and potentially the frequency) of the collected information.

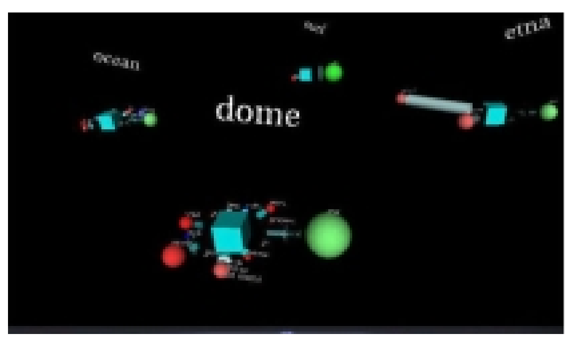

Figure 4 : Computer administration tool based on the solar system metaphor.

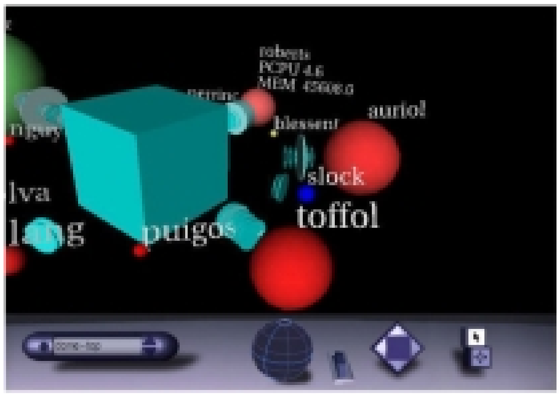

Figure 5 : Computer administration tool based on the solar system metaphor with more details.

5.5 Network Traffic characterization

Network traffic characterization tools are important in the context of network planning. The idea is to be able to analyze a real traffic in order to identify potential architecture problems. Unlike the previous four examples, this tool processes static data. This is because it is not yet possible to collect and process the network traffic data in real time. The network traffic is captured at a specific point of the network using a network sniffer. The result is a very large set of network packets. The packets are analyzed in order to extract some typical values such as round trip time (rtt) or congestion window size (cws). Finding interesting information in such a flow of data is very difficult. Here again, 3D can help. The network traffic characterization tool can help the user in rapidly identifying data of interest. For that purpose, the raw data and the derived values (rtt, cws) are displayed in 3D. Information is classified in term source/destination addresses and ports. We developed a tool based on the 3D-landscape representation. The tool is used in different situations. First it is used to identify and select connections of interest: the landscape x and z are the source and destination addresses and the height and color represents some computed values like the bandwidth or the variance of the cws. Second, it is used to analyze a specific connection according to time: the landscape x axis is the time and the z-axis represents ports, the height and color still represents a network value. The network traffic characterization tool is a great help to the user for quickly identifying the time and connections of interest (source, destination and protocol) according to predefined characteristics based on rtt, cws, etc. Once detected, the connections of interests will be further studied using standards mathematical network traffic analysis methodology.

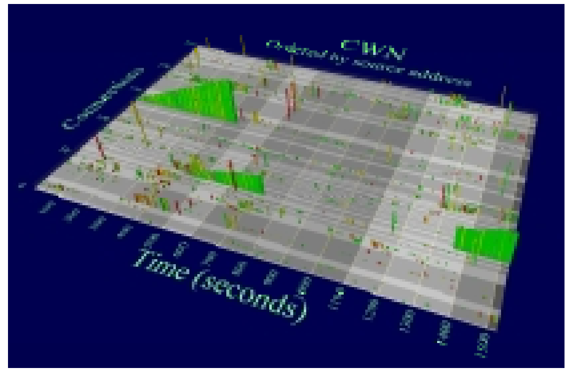

figure 6 : Network traffic characterization tool based on the landscape metaphor

6 Putting it all together using Interaction and Navigation

We believe that one of the strength of 3D metaphoric representation will come from the combined used of all the tools that have been presented so far. After some experiments, it appears more effective to provide the user with several tools that interact between each other than to attempt to introduce additional information in one world.

Our idea is that when a problem occurs, the first task of the network manager is to identify the nature of the problem. The problem can be caused by lots of factors: is there a physical link or power supply problem somewhere? Does some network component overloaded or out of order? Is there a software crash problem? Etc. Let’s present a typical ideal scenario: a network manager detects a problem on a specific service (i.e. the mail) using a service administration tool, he notices that the problem seems to come from a server that is not running properly. He switches to the computer administration tool but he can’t get information on that computer. So he activates the topology administration tool and notice that all the computers connected to the same switch than the computer are also running into problems. He concludes that the switch seems to be the source of the problem.

In order for the user to easily interact with all the tools, several topics have to be studied. First, all the tools should be accessible from the general framework. They should be able to share information (mainly entities) and the user should be able to interact (select and manipulate objects) and navigate easily within the 3D worlds. The selection mechanism should work directly on the entities at the structured data level and not to be limited within the scope of the current metaphoric world.

6.1 Navigation

Anyone that had ever experienced 3D interfaces will agree that navigating in a 3D world is not a trivial task. The user interface of traditional 3D browsers provides navigation mechanisms that allow the user to modify the virtual camera parameters. Using these tools, it is common that after some movements, the user get lost in space and tries to restart from the beginning. It is obvious that when the user navigates from office to office in a virtual building he does not use the same navigation mechanisms than when he is exploring a landscape of data or studying the topological structure of a cone tree. In the CyberNet visualization framework, all these metaphoric worlds are constructed using standard well defined graphical components: Layout managers are used to arrange 3Dglyphs in space. For example the same "stack" layout manager is used to align offices along a corridor as well as to stack floors one on top of the others in order to construct a building. But how to navigate along a corridor is obviously not the same as how to navigate from one floor to the other. Our guess is that navigation mechanisms should be associated to graphical components. This association will lead to the design of what we call *metaphoric components*. The goal is that the user navigates into the world with the mechanism the most suited to the metaphor itself. We call this principle "*metaphor-aware navigation*".

In order to be able assist the user in its navigation task, the CyberNet system maintains a *user's current location* in the 3D world, a *current node of interest* (the node that is supposed to have its current attention) and *a new node of interest.* When the user is simply moving around into the world, the user's current node of interest and its current location are identical. But some navigation tasks require the user to be located in a place and to have its node of interest on another object (an example is the "look at" navigation mode).

As a first level CyberNet proposes to support two scheme for the user to identify its node of interest: *Absolute navigation* requires the user to select a new node of interest using a selection mechanism similar to the one supported by most VRML browsers for viewpoint selection. This selection can be done, either by using a 3D embedded interface (by clicking on an object for example), or using an external menu. Of course this menu could be hierarchical and context sensitive. *Relative navigation* requires the user to select a new node of interest relatively to the underlying metaphor hierarchy using traditional browsing operators such as up/down (in the hierarchy), or next/previous (element at that level). For example, when the user is in an office, choosing "next" will automatically bring the user to the next office in the corridor,

The system has to determine the set of movements that should be done within the context of the current metaphor in order to go from the user's current node of interest to that new node of interest. These movements are dependent upon several user navigation modes. Basically the idea is to be able to specify what the user wants to do according to that new node of interest and how this should be done. This is done by the combined use of a *user mode ("go to and "look at")* and a *movement mode ("point to point", "Interpolated" and "path")*. The movement possibilities obtained by logically combining these two modes are explain in [table 1].

Movement mode **User mode**	**Point to point**	**Interpolated**	**Path**
Go to	The user jumps to the new node of interest and gets attached to it. (VRML)	The user flies in a straight line from its current location to the new node of interest and its orientation is modified. (VRML)	The user travels from its current location to the new node of interest according to a metaphor-based path.
Look at	The user stays at its current position and looks toward the direction of the new node of interest. If the object is moving then it is tracked.	The user stays at its current position, its direction of view is animated from its current value to the direction of the new node of interest.	The user stays at its current location, but its direction of view follows a metaphor-based path from the current node of interest to the new node of interest.

[table 1] : movement obtained by combining navigation modes. (movements marked VRML are supported by most VRML browsers).

The notion of path based navigation is central to our navigation. The first interest of path based navigation is to give the user a knowledge of the relative locations of objects in space. We already reported that it is of prime importance for the paths to be metaphor-aware. Navigating in a building is a good example of such a metaphor-aware navigation mechanism.

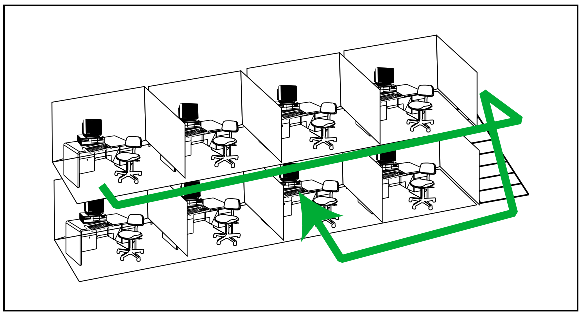

figure 7 : The metaphor-aware navigation path from one office to another.

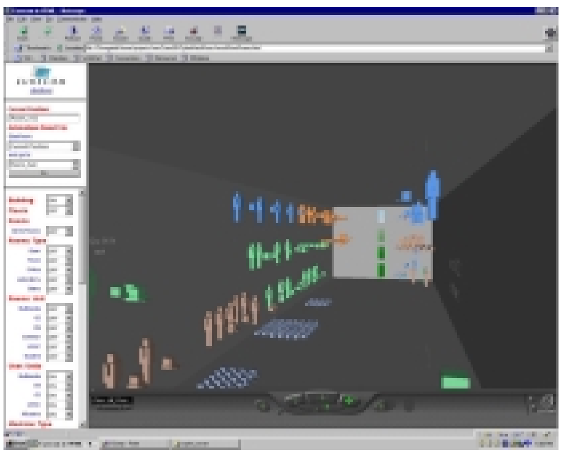

Figure 8: Geographic administration tool based on the building metaphor with transparent walls and floors.

6.2 Visual parameter modifications

We found important to be able to interact with the world in order to be able to modify its appearance. An example of such a study as been done within the context of the building metaphor. Our idea was that having a model of the building and being able to navigate and interact with objects according to the metaphor is important but sometimes frustrating. Virtual worlds should bring more possibilities than just mimic the real world. With this idea in mind, we develop mechanisms that allow the user to have control over the world appearance itself. In the building metaphor, walls and grounds transparency may be modified by the user. The user may make all the ground and office walls transparent in order to directly see the content of the whole building, he may make some offices partially transparent according to criteria such as the department they belong to etc. In the network traffic characterization tool, the user may select some data to be transparent and thus not visible, this is much used to remove aberrant values that are disturbing the user.

7 Conclusion and Perspectives

We have presented a tool for network management that takes advantage of virtual worlds interaction capabilities and the possibility of displaying large volumes of multidimensional information. We have designed a system that is able to automatically build virtual worlds for information display and is capable of handling highly dynamic data. The system is able to update in real time data modifications and does so without requiring user intervention.

Preliminary feedback from users showed that 3D metaphoric visualization seems promising. It eases problem detection and understanding. However, we are still looking for new visualizations that make the most of the opportunities of virtual environments. We are developing new metaphors and associated 3D glyphs and layout managers with special focus on their adaptive representation and navigation capabilities. New interaction mechanisms also need to be studied further.

Although this work has been done within the context of network management, every application that involves the user to interact with huge amounts of dynamically structured information may be targeted (such as stock exchange, bank trading or web administration).

Several topics are currently under study. Data characterization is one of them. Until now, data values mappings onto visual parameters are hard-coded. We are developing a visual parameters taxonomy and a data characterization. These classifications will allow us to implement generic adaptors, and thus automatically map real world data values onto visual parameters, according to the current metaphor. A lot of work still has to be done in the field of user interaction and combined use of different tools. We also have to study how to add persistency to the system in order to be able to playback and analyze some crucial sequence of events offline. We also want to provide ways to interact with the real world (e.g. kill a process on a workstation).

Another topic of interest is the experimentation of our 3D based administration tools using virtual reality devices such as a head mounted display, gloves or a large barco screen although we feel skeptical about users acceptance.

The CyberNet project is supported by France Telecom and the Eurecom Institute. You may experiment static demonstrations of most of the interfaces presented in this paper as either VRML files or Real-Video Streams at our web site: http://www.eurecom.fr/~abel/cybernet.

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