Using Virtual Reality to Manage Broadband Telecommunication Networks

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Abstract

The management of huge and high-speed networks are going to become far beyond the capabilities of WIMP based user interfaces. Indeed, the nature of the intelligent elements of these networks requires more flexibility and speed than is provided by 2D user interfaces. To remedy this problem, we propose a virtual reality user interfaces for broadband telecommunication network. A qualitative comparison is made to show the advantages of VR system over traditional ones. Then, the implementation of a prototype system built for this purpose is described and observations from its development are discussed.

1. INTRODUCTION

Networks are becoming increasingly more complex and automated [1]. This is due in part to their increased bandwidth, the need for automated protection switching, the deployment of virtual networks based on B-ISDN and ATM technology and the increase in traffic complexity typified by multimedia communications. In turn network management is becoming more complex and more mission critical to a larger number of organisations. In the past, this has led to the development of integrated network management systems using Windows Icons Mouse Pointer (WIMP) based direct manipulation user interfaces.

To reduce the risk of human mistakes, and help the manger find the optimum solution, expert systems for alarm and fault correlation and diagnosis were then integrated with the management systems. These integrated network management systems have attempt to increase the productivity of network operators to keep pace with the increased size and management demands of modern networks.

To further enhance the network management operating environment we have been investigating the use of Virtual Reality (VR) user interface technology for network management applications. This work is important because it will lead to more natural network management system interfaces and hopefully, to further increases in network operator productivity. In this paper, firstly, a brief introduction to network management is presented, then, a qualitative comparison is made between traditional WIMP base and VR based user interfaces. Our prototype VR system is then described and observations from its development will be discussed.

2. NETWORK MANAGEMENT

In order to design, organise, analyse and administer computer and telecommunication networks, a network management system is required. This system employs software and hardware resources to maintain a desired level of service at all times, and to maximise the network efficiency and productivity [3].

Network management systems collect the required data from the underlying network and process it. Depending on the complexity of the system, this task can be done either automatically or manually. It is also possible to use artificial intelligence and database techniques to form a knowledge-base expert system which can help the manager identify, localise and repair network faults.

A complete Network Management System (NMS) must consist of the following parts [2]:

- Network Management Protocols, which gathers the relevant data from underlying network.
- Database, which can be relational or object-oriented. The NMS must provide a repository for data storage and retrieval. Depending on the network size, this database can be centralised or distributed.
- Graphic User Interface(GUI). The GUI must be able to provide a hierarchical view of the network including the logical connection of the nodes. A user friendly GUI provides a more efficient network management system.
- Intelligence, in the sense that it can interpret and analyse data, ignore the trivial alarms, identify the correlated alarms, automatically fix small problems, and report the important ones to the manager.

In general, network management can be categorised into the following functional areas:[3]

1. Fault Management
2. Configuration Management
3. Performance Management
4. Security Management
5. Accounting management

Several protocols, developed by standard organisations, have attempt to provide consistent interface between the functions in multivendor environments. The Simple Network Management Protocol (SNMP) has been widely used in TCP/IP base networks (Internet), and ISO network management protocol has been accepted as an international standard. The Telecommunication Management Network (TMN) architecture, based on the ISO work, has also been expanded by International Telecommunication Union to cover all major telecommunication technologies in public networks [4].

3. TRADITIONAL USER INTERFACES

Today's Network management user interfaces are WIMP based and employ direct manipulation techniques[5] to provide a user-friendly environment for the manager. These systems are a major advance over textual Command Line Interfaces (CLI). In WIMP environment, each Network Element (NE) is represented by an icon within a window. By clicking on the icon, furthur details of the device appears in another window. Messages and actions done by alarm correlation and diagnosis expert systems are represented through text information boxes. Figure 1 show a typical view of such user interfaces.

Despite advances in computer technology, WIMP interfaces appear to be inadequate for visualising and manipulating the huge databases typical of modern network management systems [6]. One of the major drawbacks of WIMP based interfaces is that, even for small networks, the user gets lost among too many open windows, and in too much modelling hierarchy. This means a high conceptual load for the operator and an inefficient use of human short-term memory, when the operator wants to find faulty devices, and/or observe the performance of network elements.

Generally, current WIMP based user interfaces have three main limitations [7] [8]:

- Monitoring bandwidth: The throughput of management information becomes lower, as a consequence of the complexity of management protocols and low bandwidth of management connections.
- Semantic level of information: 2D graphics is a barrier between the behaviour of the network and what is perceived by the user.
- Level of interaction: As a consequence of the above limitations, the user is typically passive and observes the network rather that actively manipulates its operation.

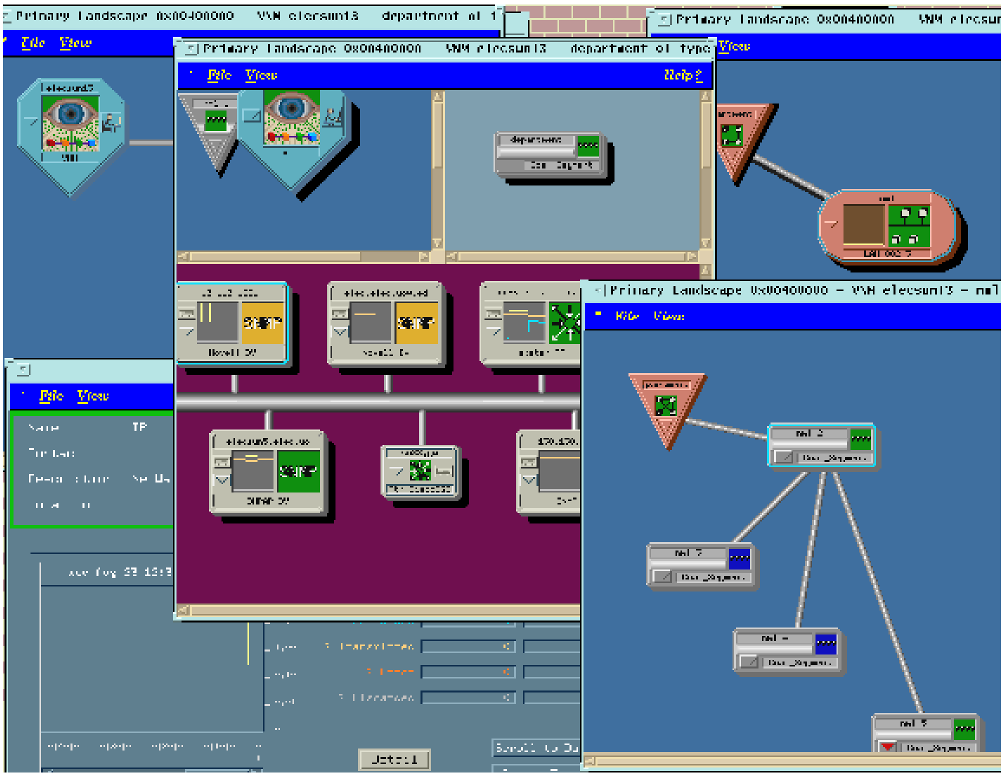

Figure 1. A typical view of WIMP user interfaces

4. VR USER INTERFACES

VR technology can address some of the limitations of traditional user interfaces. VR interfaces consist of realistic 3D real-time animated displays, 3D interaction devices and 3D audio. The main advantage of 3D visual display is its additional spatial dimension. Using a Head Mounted Display (HMD), provides more immersion, which increases the semantic level of display. Three dimensional audio, also adds another dimension to the display system. Research has shown that VR interfaces that don't seem realistic, because of simple graphical icons, or low frame update rate, are more immersive if incorporated with 3D sound [9]. Using a text to speech converter and 3D sound localisation, objects can represent some of their data using speech rather than text. All these together, generate an immersive environment in which the operator can perceive network elements and their behaviour more naturally.

The other element of VR interfaces is three dimensional manipulating devices. They improve the level of interaction, which is another key factor for user immersion. Using a special glove, the user interacts with the virtual world directly by manipulating the objects in the same way they would be manipulated in the real world providing higher levels of immersion and interaction than WIMP interfaces.

With a speech recognition system, sound can also act as an input device. That means, most simple commands, such as changing view point, navigating up and down, and confirming system actions, is done by talking. This, firstly, speeds up these tasks, and secondly, keep the operator's hands free for more important tasks.

As HMDs are usually used in conjunction with head tracker system, the head's rotation and/or movement, acts as another input device. The change of view point according to head movement, simplifies the task of navigation to a very basic natural way.

Besides all these facilities, the idea of VR interfaces is also driven by the increasing levels of integration and complexity in emerging networks. In these networks, the operator needs to see the repercussions of each management decision on the overall performance of the network, before the decision is implemented. With estimated revenue losses of $US75000 per minute for a failed OC-24 trunk [10], the need to validate network management decisions is obvious. For emerging networks, the level of complexity of the virtual services networks, and the underlying physical network, is much higher. The ITU-T B-ISDN and ATM Forum standards define similar extensive procedures for virtual circuit and virtual path fault and performance management and the use of the ITU-T TMN architecture to manage the overall network [11].

A VR interface allows the network structure, its performance levels and the management information flows to be visualised together, potentially in real-time. This provides more extensive interaction than currently envisaged by the TMN g interface [12].

Coupling the network management system, the VR interface and network models to network simulation facilitates what-if analysis. It then becomes practical to predict the impact of network management decisions on the underlying network. The results are immediately visualisable through the VR interface reducing the chance of operator error.

5. IMPLEMENTATION

In order to validate our VR interface hypothesis, a prototype system is being constructed. This system has the basic VR elements such as 3D image rendering and 3D navigation tools. It is coupled to an existing SNMP based data network management system (Cabletron SPECTRUM), as shown in Figure 2. Tree kinds of information are retrieved from the network management system: network configuration, topology, and performance/fault data. While the former are nearly static and rarely need updating, the performance and fault data are quite dynamic, requiring a continuos update

The network configuration and connectivity information is extracted, as network topology changes, from the NMS using its Command Line Interface (CLI), and automatically, a virtual network world database is constructed. This database is used by the VR system to build the virtual environment.

To provide a real-time user interface, performance/fault data must be collected directly from the NMS. We plan to achieve this by establishing a direct link between NMS and VR systems, in which the VR part sends its inquiries to the NMS using CLI commands to retrieve the required data. The VR part also convert the operator's manipulation of the network to appropriate CLI commands and sends them to the NMS. The physical interface between the systems is provided by the underlying network.

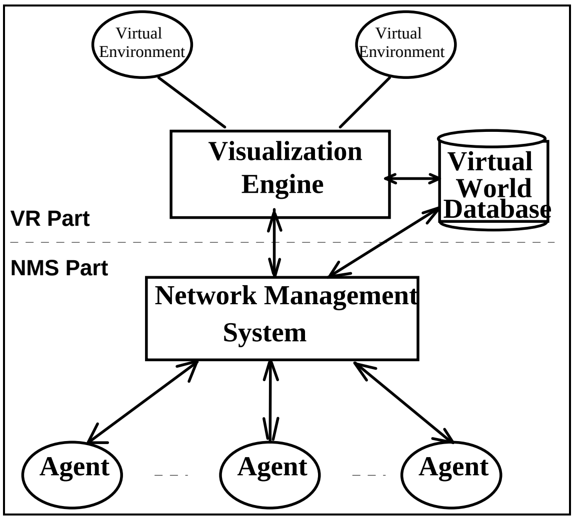

Figure 2. The architecture of the system

After the construction of a virtual network world, the user can navigate it, by walking or flying around the network. The state of the icons in the world represent current network performance levels. For instance, the thickness of a link determines the amount of load being carried out by the connection, its color represents its operational ststus, and a disconnected link is represented by a broken line. Correlated alarm information is presented using speech synthesis with clues to the location of the alarm provided by spatially locating the sounds in 3D. This is in contrast to topological maps and colour based roll-up procedures used in existing WIMP based systems.

Objects in the virtual world are active so more information about their status can be obtained by walking into them for a detailed internal view. If the object is a link, walking into it will show the virtual paths within the link. If the object is a network element, walking in will show the interfaces contained in the element. If the object is a sub-network, walking in will show the layout and status of the sub-network elements. The walk in metaphor captures the hierarchically structure of the network and constrains the information presented on the screen to a comfortable level for network operators.

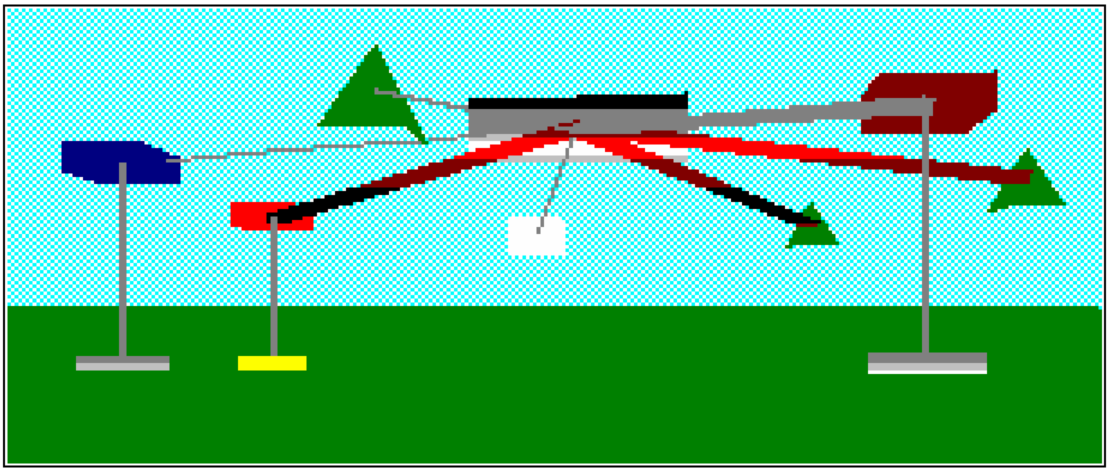

Figure 3. A typical view of the prototype system. Triangles represent SNMP manageable devices, boxes represent sub-networks, lines represent network links. All icons are colour coded by utilisation.

Navigation in the world is via using mouse, Joystick, Logitech Cyberman 3D mouse or Data Gloves. Currently, we are examining how the operator can interact with the interface in a more natural way. For example, to grab a network element, for moving, disconnecting, etc..., the most natural way is to grab it with a virtual hand, using VR gloves.

The other important issue, is the representation of network element in the virtual world. Using special rendering techniques, such as texture mapping and gouraude shading, the scene should be designed in such a way that it can immerse the operator, so that they can forget about the interface, and act as though they are in the real world.

6. OBSERVATIONS

The prototype system is still in its infancy and is yet to incorporate texture mapping for a realistic, potentially architectural, display. The usage of 3D speech, speech recognition, and Head Mounted Displays, are still under development. But, using this prototype system, the user can observe the hierarchy of the network and its spatial relationships. The network can freely and quickly be navigated to observe the primitive information for network elements such as faulty devices and overloaded links. We achieve this without becoming lost in a screen full of windows, the typical problem with existing WIMP based systems. A typical view of the prototype system is shown in Figure 3.

One of the major advantages of VR user interfaces for network management is their short learning time. As user's interaction with the system is designed to be as natural as possible, there isn't much need to teach operators how to use the system. That is, if operators learn the basic principals of the interface, they can easily and quickly decide, when facing with more complicated situations, how to do the task. For instance, there is no need to teach operators how to move an object, because everybody know how to move objects with his hands. This is in contrast to WIMP user interface, in which all actions should be taught to the operator.

This advantage, also useful for users, has a drawback, as well. As people’s attitudes are different, one’s representation may be someone else’s misrepresentation [13]. This makes the design of VR user interfaces much harder than traditional ones.

The other important factor is the user’s cognitive load during operation. As in WIMP user interfaces, the interaction between user and computer is not natural, the user has to not only think about ‘what to do’, but also ‘how to do’ it. For instance, if the alarms associated with an object are needed, the object has to first be selected, by clicking the mouse button on it. Then, from a menu the appropriate action must be selected. This simple task seems quite easy and straight forward. However, working with many objects in a window and with several other windows in this manner, causes confusion, because of limitations of human short term memory. While in an immersive virtual reality user interface, these kinds of tasks can be done by using a speech based interface with speech and visual acknowledgment, reducing the operator’s cognitive load.

7. CONCLUSION AND FUTURE WORK

We have constructed a prototype VR interface for network management. It shares some navigational features with traditional WIMP based system. However, it does not suffer from those systems problems in visualising network hierarchy and performance levels.

Future work will investigate fully utilisation of the facilities offered by VR interfaces. The future systems must support:

- Real-time on-line operation.
- Higher levels of immersion.
- Full user interaction and manipulation of the network operation.
- Integration with network simulators for what-if analysis.
- Multiple administrative domains and multi-user computer supported collaborative work to facilitate distributed network management.

To satisfy these demands, some of the issues to be addressed include:

- Database management system for storing virtual world information.
- Semantically useful renderings of networks and network management information into virtual worlds.
- Reporting events and alarms using non-textural techniques.

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