UNIFIED MODEL BASED THREE DIMENSIONAL TOOL FOR MANAGING COMPUTER NETWORKS

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Abstract: Computer network management is a field where several researches have been done and many tools created. The last decades have seen the appearance of a new generation of management tools introducing a new approach based on graphical visualization enabling the users to explore visually a complete system. The main objective of the graphical visualization is to facilitate the different tasks of the administrators. This is particularly important when the system is becoming complex due to the growth of information flow, the heterogeneity of devices and environments or applications that handle this information. In this perspective this research is led with as a goal to study the benefit of the use of 3D graphical representation combined with an object-oriented information model (CIM - Common Information Model - proposed by the industrial consortium DMTF - Distributed Management Task Force). Through this research we have particularly focused on the necessary requirements to offer a high quality of visualization and the ways or languages allowing the modelling of all resources present in a complex computer network.

1 INTRODUCTION

The heterogeneity of devices increases inevitably the complexity of computer systems and particularly networked computer systems. That implies an increase of complexity of system administrator's tasks. Many tools are proposed to the users by industries and research laboratories which main goal is to minimize the effort needed to understand a complex system in order to fully focus on improving the overall performance or solve problems. To fulfil this goal the researches have been directed towards the use of graphical representations that allow easier human understanding of complex systems. As an example field, the techniques used for network visualization may be classified in two groups: those that use a node-link paradigm and the virtual worlds based techniques. The main advantage of using a node-link diagram to represent network structures is that a person can directly see the relationships that are drawn as a set of graphical edges appearing in the diagram. This makes easier for the process of human perception to understand the relational structures of information. 2D and 3D representations are the two well-known techniques using this paradigm. A new technique used to visualize networks is based on virtual worlds. Its main benefit is that it enables to create a visual metaphor and use novel devices to provide a natural and intuitive form of navigation and interaction with the data.

However these tools will never be effective if there are no ways or languages for gathering and modelling all the system resources to be managed. In this work we have chosen to use the CIM object-oriented information model. The main motivation of the industrial consortium DMTF (DMTF, 2005) in providing this model was to solve the problem of the heterogeneity of different devices and environments forming a complex system by facilitating the integration of applications and entire systems developed by different vendors. We think that this object-oriented model can also benefit a lot the understanding of the system complexity if it is associated with a good graphical visualization.

2 RELATED WORK

2.1 Node-Link Representation

The traditional method used in network visualization is the use of a 2D graphical representation combined with a network management protocol (Hewlett-Packard, 2005) (Gus Estrella, 2005) (Bradley

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Huffaker, 2005). The principal shortcoming of these tools resides in their inability to generate an accurate picture of the resource's information specifically when the system is getting too complex. Many techniques have been used to reduce this limitation, for example the use of animation (Deborah Estrin et al., 2005), the optimisation of display space use (Nguyen and Huang, 2005)…

3D visualization eliminates increasingly many of the restrictive issues found in 2D representation techniques such as display clutter and device overlap. The main advantage of the 3D graphical representation is this easiness to provide a tool offering a high quality of visualization according to Schneiderman's precept "The Visual Information Seeking Mantra is: Overview first, zoom and filter, then details-on-demand" (Le Grand and Michel Soto, 1999).

Among the tools using a 3D graphical representation, UNIVIT (UNiversal Interactive VIsualization Tool) (Le Grand and Michel Soto, 1999) is one of the most innovative systems in term of ideas for offering a good visualization. It allows visualising any kind of hierarchical data that can be described with the XML format.

Another popular tool based on 3D visualization is CyberNet (Abel et al., 1999) which main feature is its ability to collect data and visualize large amount of dynamical information. The collected information is structured and mapped on visual parameters (shape, colour, size, location...) of 3D objects in order to build a dynamical metaphoric world where the user may navigate and interact.

Both the above mentioned tools have a common characteristic: they only display information structured hierarchically. In comparison to the two precedent tools, PatrolVisualis (BMC, 2005) offers different sorts of 3D visualization, such as graphs and trees. Its other main feature is the use of natural metaphors for device representation.

Designed for network performance visualization, Cichlid (Brown et al., 2000) supports two types of view: 3D bar charts used for displaying numeric quantities, and vertex/edge graphs for representing network topologies in three dimensions. Although it does not use natural metaphors for the devices representations, the main advantage of Cichlid is its capability to offer 3D representations of the performance measures via different types of diagrams such as packet length distribution, traffic volume by address block…

3D graphical representations have proved that they can adequately eliminate the limitations associated with 2D visualization systems, but like most systems they have their own glitches. A possible drawback is the choice of metaphor used to represent the different devices that sometimes does not reflect the real form of an element, or the additional charge for 3D rendering.

2.2 Virtual Worlds

The emergence of multimedia technologies such as video conferencing and streams-based applications has increased the hugeness of information throughout the network. Due to that, the network management tasks exceed the capability of a single administrator and need new tools minimizing the necessary effort to understand a complex system. Virtual worlds offer new solutions to the limitations found in existing network visualization tools. By providing an interactive three dimensional environment in which several users can move around and interact, the virtual world techniques greatly enhance the network manager's understanding.

Based on the CoRgi (Schmidt, 1999) virtual reality toolkit, a study was done using a landscape metaphor as a visual representation for network visualization. The network is totally converted to a natural landscape where mountains and trees represent respectively network switching equipment and computers. An interesting characteristic of this environment is the use of thunder 3D sounds associated with a trouble indicating the source of network errors.

Flatland (Fisk et al., 2003) is an environment designed to monitor traffic at an administrative boundary between the Internet and an internal network. Using the concept of territory, the internal address space of the network is mapped into a circular region while the external address space, the Internet at large, is mapped into a hemispherical region. The two regions are separated by a shield that represents the administrative boundary, the firewall. The colour of rays connecting an originating host to the destination host through the shield indicates the state of intrusions.

In order to provide a way to control high-speed computer networks, VENoM (Virtual Environment for Network Monitoring) (Cubeta et al., 1998) has been developed as a suite of models and applications based upon collaborative virtual worlds. It was designed specifically to visualize large ATM (Asynchronous Transfer Mode) optical fibre, wide area networks. The environment includes physical room layouts, system resource abstractions, real-time, and system-specific information. It also allows multiple network administrators to collaborate in the same virtual world regardless of the person's physical location. The administrators are represented by virtual humans. Similarly all resources are represented by virtual objects which look like them.

In the next section, we talk about the necessary requirement in having a standard model for management system. Indeed, in the management system, all resources should be modelled uniformly in order to make their exploitation easier (CIM, 2000).

3 A STANDARDIZED MODEL REQUIREMENT

3.1 Discussion

As mentioned above, managing complex network is always a great challenge due not only to the growth of information throughout the system but specifically to the variety of technology used in each resource that handles this information. Sometimes each product defines its management data in different ways by creating its own semantics, terminology, data structures and protocols. In an attempt to address those issues DMTF (WBEM, 2005) proposes an object-oriented model, CIM, which goal is to provide a common way to represent the computing and networking elements and the relationships between them.

3.2 CIM Model Advantages

Originally CIM was developed to support the integration of multi-vendor applications into Energy Management System (EMS). By combining the most powerful concepts from relational databases, such as normalization and views, with the most powerful concepts from object-oriented analysis, such as generalization, aggregation, and design patterns, CIM supports the integration of a wide range of utility systems and applications (Podmore et al., 1999). Extensions have been made to handle computer and communication networks.

Through the CIM concept, DMTF proposes a set of grammars carrying:

- Structural concepts derived from the object paradigm: schema, class, property, method, association (seen as a specialisation of the class concept) and reference (seen as a specialisation of the property concept).
- New specific concepts (qualifier, trigger, indication) expressing constraints and/or meta-information on the structural concepts, and the dynamic of modelled elements.

Using those grammars, a modelling approach with three levels of abstraction is proposed: the "Core Model" introducing high level abstract classes allowing organizing the managed elements into physical and logical elements; the "Common Model" that is the extension of the "Core Model" to the following domains: system, application, network, physical equipment and functional equipment; and the "Extension Model": specialises the "Common Model" to the technology domains relating to the implementation of the managed resources. Extension Models are defined by individual companies or organizations, but not by the DMTF. From all elements defined in this meta-model will be modelled the different resources to be managed (CIM, 2000). Figure 1 shows the basic elements of CIM model.

Towards the three levels of abstraction, CIM provides a common definition of management information for systems, networks, applications and services, and allows for vendor extensions. Within CIM schema all classes modelling managed elements are derived from the ManagedElement class which is an abstract class. It is in the Core Model. One of its subclass is the ManagedSystemElement class. This class is the base class for the system element hierarchy. It represents systems (computers, networks, storage libraries and application systems); the software that runs on them, the functionality provided by them and abstractions of the hardware that composes them.

CIM_Dependency and CIM_Component are two classes abstracting the relationships between managed elements.

This concept is specifically important because it allows to understand well how the different elements are interconnected and how they are hierarchically organised. Another important class is CIM_Indication. It abstracts all events that can change the system's behaviour. Using this class it is possible to associate an action to be carried out when an event is received by an object.

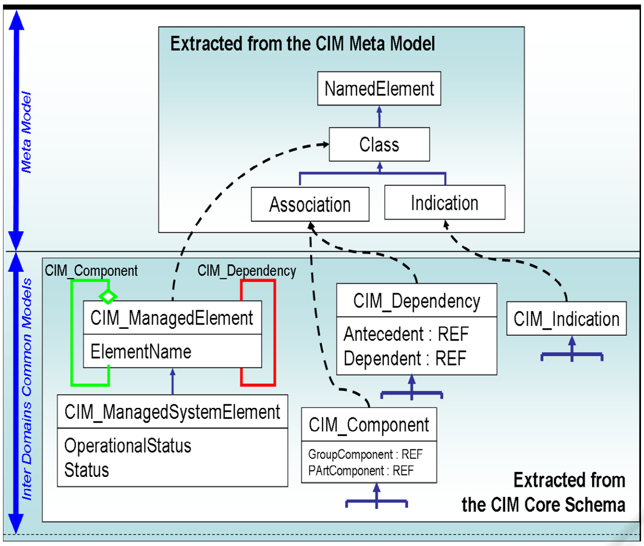

Figure 1: Basic elements of the CIM model.

4 OUR 3D VISUALIZATION APPROACH

From advantages offered by traditional tools and the powerfulness of virtual world techniques we propose through this paper a three dimensional tool to enhance the user's understanding of complex network system. The aim of this study consists in offering complex network administrators an environment allowing them to perform effectively their tasks. To fulfil this goal the future application should provide a high quality of visualization following the Schneiderman's precept. For this, seven high level tasks should be supported (Wiss et al., 1998): **Overview**- Gain an overview of the entire collection of data that is represented; **Zoom**- Zoom in on items of interest; **Filter**- Filter out uninteresting items; **Details-on-demand**- Select an item or group and get details when needed; **Relate**-View relationships among items; **History**- Keep a history of actions to support undo, replay, and progressive refinement; **Extract**- Allow extraction of sub-collections and of query parameters.

Thus, complex network management may be facilitated by the use of 3D visualization techniques if some measures of representation and navigation are satisfied. Le Grand (Le Grand and Michel Soto, 1999) expresses the Schneiderman's precept in term of quality of representation and quality of navigation. The quality of representation implies that a global view should be offered so that the users can identify the main interest in the system before deciding where to begin the navigation. Throughout this process the user should be able to explore some parts of the system and gather information details according to his/her demand. On the other hand, the quality of navigation is expressed by the need to allow users to explore the system and to access the data. The effectiveness of the navigation system may be measured by its capability to allow the user to answer three questions: "Where am I?", "Where have I been?" and "Where can I go?" (Mayer, 1999) The first question refers to orientation that is inseparable to the navigation process because it sets up a prerequisite to decide where to begin the navigation. And the two last questions resume the major problems of users during complex system exploration.

We also underline the importance of metaphorical choice that is not included into the information visualization's Mantra. Indeed (Abel et al., 1999) "the metaphors provide ways of introducing concepts to users with the aid of analogies with familiar real-objects". Thus, using metaphors that the user is already familiar with can enhance legibility of information. Tsygae (Tsegaye, 2003) studied the contribution of metaphor in the network visualization process and concluded that an appropriate form and model set up a first way in system understanding. Nakakoji et al. (Nakakoji, 2001) remark that the 3D representations should not be used abusively in order to avoid people misinterpreting information or obscuring the focus of the information. Indeed, it is important to understand when, and how should complex visualization be used to help people in order to understand and to explore the information easily and accurately. Therefore in our application, all managed resources will be represented with natural 3D shapes.

4.1 Visualization System and Metaphors

As complex systems may not be only structured hierarchically, a graph representation will be effective to represent how different devices are interconnected. This type of visual representation is particularly important to visualize for example an overview of a server farm. The tree representation is used to show how a domain or equipment is composed of individual elements. Even though the tool we are building will allow visualizing any type of complex system, the first prototype is simpler. We currently offer a 3D standard object forms used to represent computer network (computers, switches, printers…). Then another tool will soon be added allowing the user to choose the colour and the geometry of each object to be displayed according to the system to be managed. The example in figure 2(a) shows association relationships are represented by interconnections between 3D objects. Each link is an instance of the CIM_Dependency class. They are modelled by a cylinder which width and colour may be changed to indicate the data flow between two elements or simply the status of the connexion.

The button labelled "GlobalBehavior" allows the user to move the scene entirely. After clicking this button, one can translate, rotate or zoom the scene to find interesting views. While the "SimpleBehavior" button is used to move independently the objects. This allows the user a full control of the display. In fact, one of our goals consists in offering the user an environment where he/she can adapt the presentation following his/her needs.

The hierarchical composition of equipment or a domain is displayed as shown in the figure 2(b). This is very important because it enables the user to understand how a large domain is set up or of what specific equipment it is composed. The links used in this figure are instances of the CIM_Component class.

4.2 Navigation and Interaction

Using the Java3D API, we have taken advantage of several of the features it offers to create a good navigation. Zooming is used to allow users to explore the detail or the context of the system. The left mouse button allows rotating an object or an entire scene. To avoid a possible clutter of the display and to provide the user a full control of the scene the right mouse button is used to move an object and thus rearrange the disposition in order to have a better presentation. By clicking an object with the middle mouse button, a "popup menu" appears. This menu allows the users to have details about the clicked object such as: its description, the objects with which it is associated and its substructure (i.e. what it is composed of). For example, from the submenu description one can have a window describing the object. This is a textual description of the object (for instance its location in a WAN, LAN, or the devices that it is composed of, or other parameters).

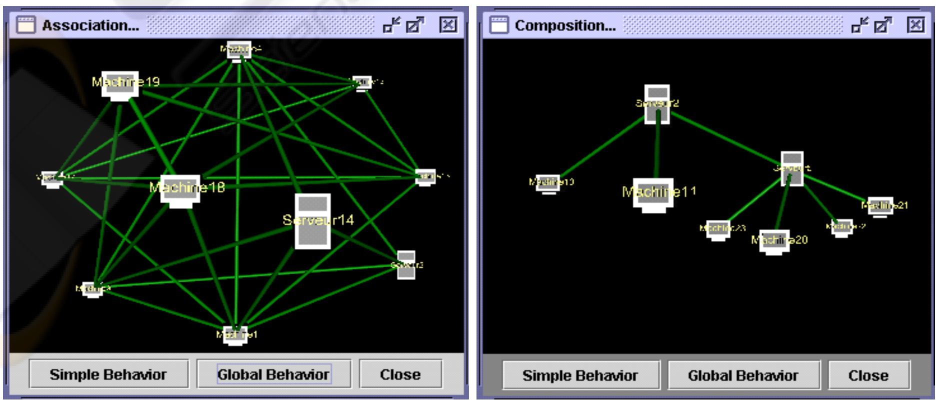

Figure 2: 3D display relationships (a) and composition relationships (b).

5 SOFTWARE ARCHITECTURE

Figure 3 shows an overview of our system. The 3D visualization application communicates with a complex system which deals with all the management information.

The collection and the organisation of information are not the main interest of our study; however we think that it is always good to give a brief explanation of the management system. In fact it is based on WBEM (Web-Based Enterprise Management) architecture proposed by DMTF. This architecture consists of the Object Manager (OM) and Object Provider (OP) notions.

An Object Manager is an application responsible of one or more management domains that may be functional (ex: security) or structural (ex: computer or satellite component). In the WBEM architecture, an Object Manager is implemented by a management database called a MIB (Management Information Base). All information of resources to be managed is stored in the MIB described using CIM model.

An Object Provider is a manager entity responsible of the integration with a specific environment. This environment may be an environment to be managed (ex: UNIX, Windows), a management environment (ex: SNMP) or any type of environment. For each type of environment an Object Provider will be necessary. The Object Provider assumes an important role by providing a homogenous view of heterogeneous environments to be managed. The Object Providers act as gateways between the management system representing OMs and the real managed world (WBEM integration viewpoint).

So in order to be managed, a node must communicate with an object provider (e.g. through SNMP) that pushes all management information to an object manager responsible of its domain.

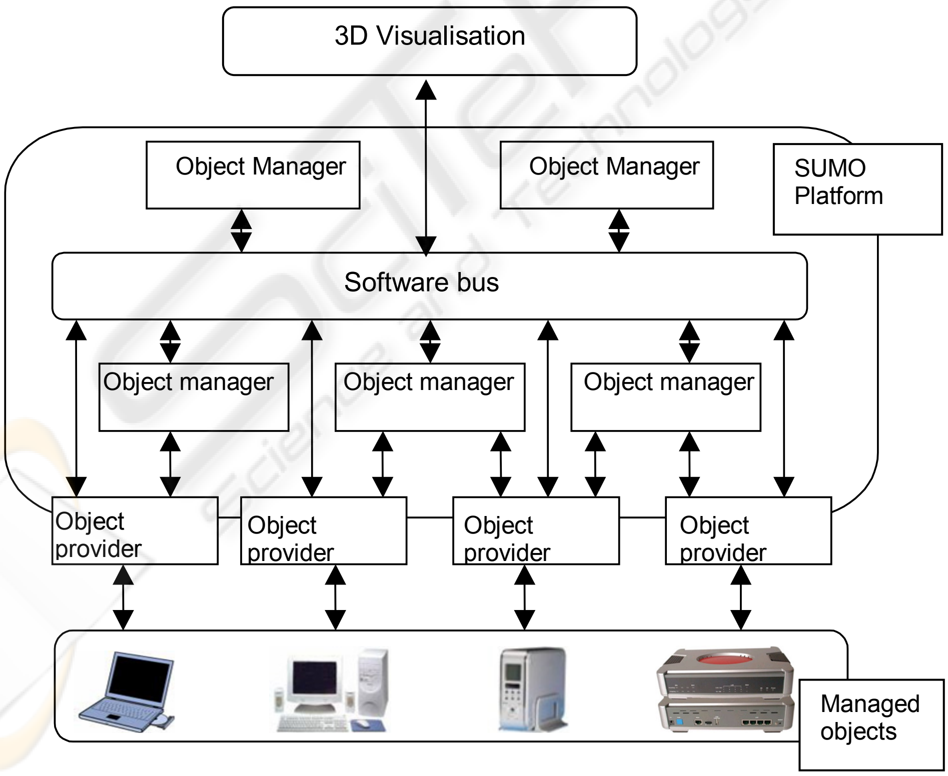

Figure 3: Software architecture of our system.

5.1 Implementation

To ensure portability and durability of solutions, all components of the system are developed in Java. All 3D components are created with Java3D. The user interface application communicates with the object managers using CORBA.

When the network becomes complex, it may not be easy for one administrator to ensure efficiently all tasks. Therefore we plan to modify our system so that two or more users can collaborate in order to manage network.

Actually, the visualization application runs on a laptop with a 1.8Gh processor. The graphic card is an X200 series ATI. But the only requirement of our application is an OpenGL or DirectX supported card. As most current graphic cards support DirectX this is not a big requirement.

6 CONCLUSION AND FUTURE WORK

Managing complex systems is always a great challenge and the technology progress makes this task more complex. We can see through the many tools currently in use that their usefulness depends not only on the visualization quality, but also and mostly on their capability to model all resources to be managed. Another important remark in creating an effective visualization is that the metaphors should not be chosen abusively in order to avoid small interpretation problems or a possible complete misunderstanding of the system. The connections between the data must also be shown in order to facilitate the understanding process because they reflect the relational structures of the managed resources.

We have developed a tool allowing users to explore, in 3D, objects and their dependency relationships. Instead of developing and implementing new platform we have coupled our tool with CAMELEON, a CORBA/java/CIM based management system (SUMO, 2005). In order to let users select and display interesting data or events the tool will soon be associated with a query system (using CQL – CIM Query Language). Another goal is to refine the semantic aspects with views customisation.

In the future, the CIM_Indication class will be exploited for system diagnostic. For example, we plan to add 3D sounds that will attract the user's attention to a problematic event (errors, faults, power downs…). Moreover, as Java3D loads a lot of 3D files, our tool will easily be modified to include environmental models such as buildings. This will allow the user to see the real location of the faulty element.

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