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3D Visualization of the Geographical & Organizational Structure of the Grid

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Abstract — **Enhanced and interactive visualization techniques are a key issue in improving the ability of users to comprehend and work with large data sets. Various techniques have been used in the past incorporating different media and applied to a wide range of application domains. In particular, 3D data representation often provides a more enhanced and intuitive user approach than a two dimensional approach. In this paper, we discuss several data visualization techniques with an emphasis on hierarchical data structures. We present a case study involving the implementation of a Web based application enabling 3D visual access to Grid network monitoring data. Geographically distributed computing nodes are arranged into "farms", which further contain a number of organizationally distributed "clusters". The implemented visualization incorporates a geographical presentation of farms on a 3D model of the Earth, and compares two tree-based techniques for the visualization of hierarchically organized clusters and nodes. We discuss the technology used to implement such an application and the achieved user benefits in terms of an enhanced display.**

I. INTRODUCTION

Information visualization is a growing area of both interest and research as it is becoming the key that provides the ability to successfully comprehend, analyze and work with data [1]. Various application domains that have been the focus of data visualization include large information spaces, software engineering, databases, network monitoring, data mining, and multi-user collaboration.

Hierarchical visualization, also known as tree structures, is a collection of nodes (representing information) where each node in the structure has a unique parent (node above it in the hierarchy), but may have none or many children (nodes below it in the hierarchy) [2].

In this paper, we focus on the 3D visualization of hierarchical data structures and compare the applicability of two tree-based techniques in the area of Grid network monitoring data. In addition, we incorporate a geographical presentation that further enhances the user interface.

The traditional presentation of hierarchies usually consists of a 2D representation where child nodes are positioned under their parents. Representing trees in 2D limits both the depth and the breadth of the tree that can be viewed at a single time. On the other hand, visualization of hierarchies is often related to data structures that can be translated to 3D data spaces, while visualization uses 3D graphics to display the results. In this way, visualization techniques succeed in simultaneously showing a greater number of nodes. Several visualization techniques are described in the following text where the goal of each is to display a structure in such a way that a large percentage of the hierarchy, if not the entire hierarchy itself, is visible without extensive scrolling.

We present a case study involving the implementation of a Web based application enabling 3D visual access to Grid network monitoring data. Grid technologies have been described as supporting the sharing and coordinated use of diverse resources in distributed "virtual organizations" – that is, the creation, from geographically and organizationally distributed components, of virtual computing systems that are sufficiently integrated to deliver desired quality of service [3]. Our goal was to implement a service that would provide a user with a view of the monitored network hierarchy, in addition to the values of various monitoring parameters for different Grid sites. Geographically distributed sites are termed "farms", which further contain a number of organizationally distributed "clusters".

To visualize the geographical organization of the monitored network, the *Virtual Reality Modeling Language (VRML)*, an *ISO* standard for representing 3D data transmitted over the WWW is used [4]. Farm locations are mapped to a 3D model of the Earth. The foundation for such a presentation is the successful transformation of standard geographical coordinates (longitude/latitude) into geocentric coordinates used for presentation in 3D space. We thus use techniques developed by the GeoVRML Working Group [5] of the Web3D Consortium.

The logical organization of monitored clusters and nodes within particular farms is visualized using two different 3D tree based techniques for comparison purposes: Cone trees [6] and Burst trees. The application is developed in a modular fashion, with a separation between actual data collection and the implemented visualization technique (independent of data meaning). This allows for the application to be easily reused for a wide range of domains involving hierarchical data simply by adapting the data collection interface.

The paper is organized as follows. First, we briefly describe several visualization techniques suitable for visualizing hierarchical data structures. Next, we demonstrate and compare the applicability of two chosen techniques in a case study and discuss implementation issues. Finally, we present the results of the implementation in the form of a Web based application providing an enhanced display of network monitoring data.

II. Visualization Techniques

An effective approach to the organization of a large number of items, be it files, streets or family names, is to group them and to repeat this step recursively. Hierarchical structures are very effective when looking to locate desired pieces of information, but the content and organization of large structures is hard to grasp. A number of methods have been developed to allow a user to view large hierarchies. An overview of some popular methods involving tree representations is given bellow:

- Cone trees [6] – elements of a hierarchy are placed at the tips and along the bases of 3D transparent cones, allowing for a great amount of hierarchical information to be viewed simultaneously. Interactive techniques allow users to collapse and expand parts of the structure. An example application domain is the visualization of directory hierarchies (Fig. 1).

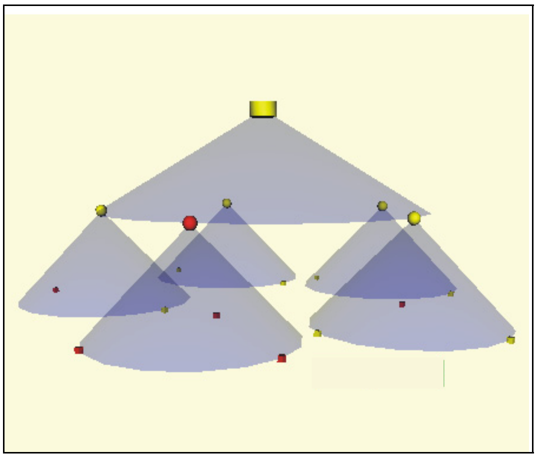

Figure 1. Cone trees

- Hyperbolic tree 3D [7] – Provide graphical representations in hyperbolic space, allowing information to be viewed amid less clutter by moving areas of interest to the foreground. Such an approach has been used to visualize the structure of sections of the World Wide Web (WWW) (Fig. 2).

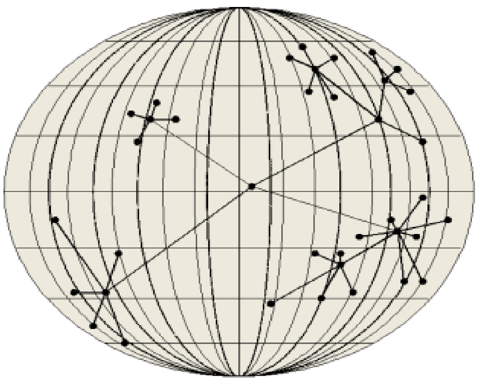

Figure 2. Hyperbolic tree 3D

- Botanical trees [8] – Interesting for displaying huge hierarchical data structures consisting of many levels and items, e.g. file system (Fig. 3). Branches, leaves, and their arrangement in a botanical tree may easily be viewed despite the large number of elements.

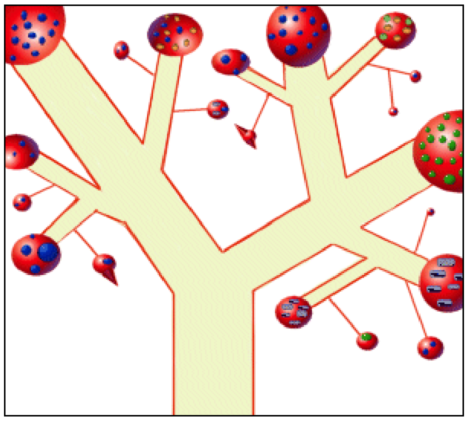

Figure 3. Botanical trees

- Burst trees - Exploit interactive animation and 3D graphics in the same way as cone trees. Application domains could include network topology, directory structure, etc. (Fig. 4).

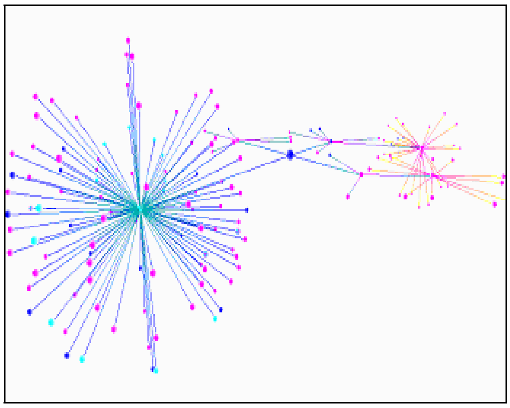

Figure 4. Burst trees

All of the mentioned visualization methods concentrate on the appearance, accessibility and usability of the data and aim to provide a user friendly and intuitive interface.

III. Our Approach

The proposed approach to visualization of Grid network monitoring data compares the two tree-based techniques. Integration with a geographical representation further enhances the user display.

The visualization essentially consists of two integrated parts: the geographical representation of monitored farm locations based on a mapping to a 3D model of the Earth, and the tree-based representation of the monitored hierarchy within each farm. Elements of the hierarchy may be colored using different colors to represent corresponding values of collected monitoring parameters (e.g. a node or cluster may be colored red to indicate an average load of 0.5-1.0).

A. Geography-based Visualization

The geographical position of monitored farms is assigned in the geodetic latitude/longitude coordinate system. We represent the Earth with an ellipsoid rendered in 3D Cartesian space and with an appropriate applied texture. To properly position farm locations on the Earth's surface, geodetic coordinates are transformed into geocentric (Euclidean) ones. The *GeoTransform package*, a *Java* package that contains routines for performing efficient conversions between different geographic coordinate systems, is used for this purpose. Farm locations are represented as small spheres on the Earth's surface. The presentation is interactive in that it allows users to click on farm shapes and expand tree structures that visualize the monitored hierarchy. In case of inhomogeneous distribution of farms (several farms on a close geographical location) an additional layer in hierarchical structure can be introduced in order to avoid overlapping of nodes.

B. Tree-based Visualization Methods

We selected two methods that we demonstrate as applicable for the visualization of Grid network monitoring data. The first is a *Cone Tree* method introduced in [6] and is generally considered a very intuitive way of displaying hierarchical structures. There have been only few empirical studies of its effectiveness. A formal user study using a cone-tree-based file system visualization showed that although Cone Trees are not suitable for all tasks, users "were enthusiastic about the cone tree visualization and felt it provided a better 'feel' for the structure of the information space" [9].

Certain limitations, concerning structure limitation and scene rendering, arise when the Cone Tree method is used with a very large number of elements and/or levels. Thus, a Burst Tree method is used as an alternative in cases where a large number of children nodes exist. In a Burst Tree, each parent node is associated with a burst having children distributed on the end of each line represented with any geometry (Fig. 4). Every child may also be a burst, if it has children of its own. Using bursts instead of cones as the basic structure visualization technique has several advantages, e.g., significant reduction of occluded region, thus a sharp increase in the number of displayed nodes, and better rendering performance for the same number of nodes.

IV. Implementation

The data source used by our application is a central data repository provided by the MonALISA system [10]. The MonALISA system provides a distributed monitoring service and was in this case used to monitor AliEn Grid sites (http://alien.cern.ch/). A Web Service based interface was specified allowing us to retrieve data regarding the monitored configuration and monitored parameter values (e.g. load, input/output rate, etc.).

Development issues focused on the creation of a Web-based application capable of running on standard commercial browsers without installation of additional software. Thus we chose *Shout3D* [11] technology as an efficient solution. *Shout3D* uses *Java* technology to enable interactive 3D content delivery over the Internet. When a user visits a page with *Shout3D* content, both the interactive 3D content and a *Java* applet that displays the content are downloaded. In this way a user can view a 3D scene without the need for additional plug-ins. The basic *Shout3D* applet will simply display a scene. In order to enable object manipulation and scene navigation, another applet, called *ExamineApplet*, is used. It allows a user to view an object or a whole scene from any direction. For instance, by dragging the mouse horizontally or vertically, the user will rotate the camera around the object(s). In order to zoom in or zoom out, user should hold down the <CONTROL> key and drag up or down. To move the object(s) left, right, up or down, the user should hold down the <SHIFT> key and drag.

As previously mentioned, data is collected from a central repository through a Web Service based interface. The result is a hierarchical data structure specified using the eXtensible Markup Language (XML). In addition, we collect the geographical coordinates of farms. The input data is then transformed to VRML format and rendered in a Shout3D applet.

To extend application presentation capabilities, all sorts of different *Shout3D* parameters, needed for accurate rendering of a *VRML* file in the *Shout3D* applet and easy manipulation, were added. For instance, the names of different scene elements are displayed in the *Shout3D* applet when a user points on them with a mouse. Furthermore, a user has the ability to completely examine the hierarchical structure in as much an elegant way as possible.

V. Results and Discussion

The result is a Web-based application that is capable of visualizing the monitored Grid network configuration within a 3D representation of the Earth.

A snapshot of the application, showing the network configuration using the Cone Tree method in 3 different cities displayed using the *Shout3D ExamineApplet*, is given in Fig. 5.

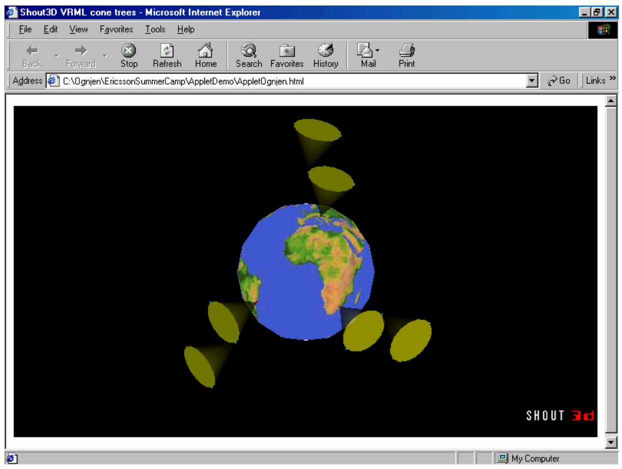

Figure 5. Grid network geo-presentation using Cone Tree method

The structure may also be presented using the Burst Tree method (Fig. 6). Displayed nodes may be colored to represent different monitoring parameter values. A user can click on any displayed farm to open a farm configuration, which depending on the chosen application is displayed as either a Cone tree or a Burst tree. Moving the mouse pointer over each node, a label is shown bearing the name of that node.

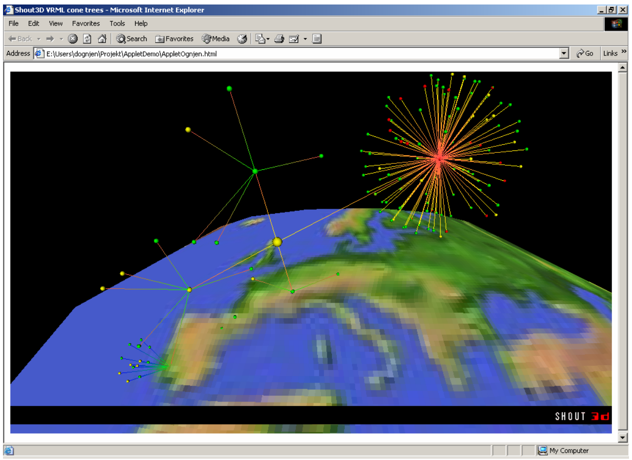

Figure 6. Grid network geo-presentation using Burst Tree method

The third option enables a user to view the hierarchical structure in a more detailed way (Fig. 7). This interface offers the user the ability of choosing between a number of monitoring parameters to be viewed. An example is shown in Fig. 7.

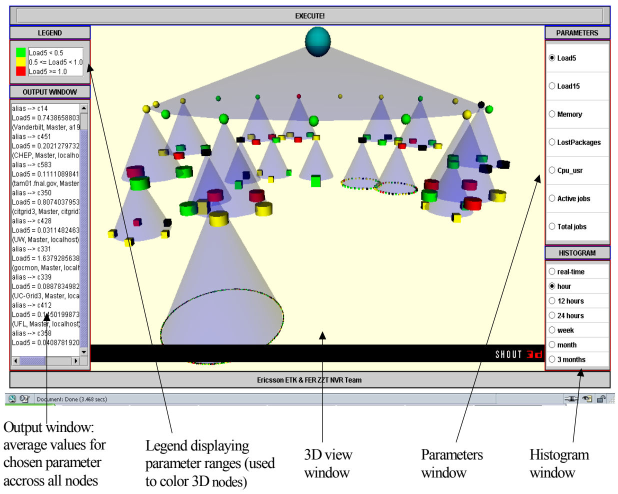

Figure 7. Detailed structural view including monitoring data presentation

The developed application showing geographical locations of Grid sites may be used to present Grid networks on Web sites to regular or occasional visitors. Enhanced displays incorporating more information (e.g. monitoring parameter values) may be in particular interest to a network administrator in need of being able to quickly view and analyze data, and take corrective actions where needed. The application is developed in a modular fashion, with a separation between actual data collection and the implemented visualization technique. This allows for the application to be reused for a wide range of domains involving hierarchical data simply by adapting the data collection interface.

VI. Conclusion

The focus of this paper was to discuss several data visualization techniques with an emphasis on hierarchical data structures. We present a case study involving the implementation of a 3D Web-based application providing visual access to the geographical and organizational structure of a Grid network, with corresponding monitoring data. The application incorporates a geographical presentation of Grid farms on a 3D model of the Earth, and two tree-based techniques for the visualization of hierarchically organized clusters and nodes. The study of actual effectiveness of proposed applications defines future work guidelines.

The proposed solution was implemented using *Shout3D* and *VRML*. *Shout3D*, as a promising technology, combined together with *VRML*, provides us with the ability to easily display scenes and navigate through them in a standard Web browser. Cone trees have proved to be a very intuitive way of displaying hierarchical structures in 3D, but when they are used with a huge number of elements and/or levels, slight difficulties, concerning structure interpretation and especially speed of scene rendering, arise. Thus a Burst tree method is implemented as an alternative to be used when a large number of children nodes exist.

The developed application addresses the interests of different types of end users. Regular and occasional Web visitors can observe the geographical structure of the Grid. Users of the Grid (e.g. researchers) can access specific farms and retrieve data about the status of particular jobs they have submitted. An administrator, on the other hand, would prefer a full network view with access to various parameters concerning network status in order to take corrective actions as needed.

Acknowledgment

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