Multiple Views in 3D Metaphoric Information Visualization

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Abstract

In exploring large volumes of information, more often than not, one single visualization is not sufficient for grasping the whole data set. This may be due to different reasons: the screen real-estate is limited, the user's capacity for comprehending a large data set also has limits, different views or perspectives of the same data may be needed to grasp all the details, and so on.

Multiple visualizations allow the user to explore large amounts of complex information more easily and rapidly. We believe that one of the strengths of 3D metaphoric information visualization will emerge from the combined use of several interacting tools, each potentially depicting different views of the information. This paper presents work done on using multiple views for the visualization of abstract information via metaphoric representations.

1 Introduction

Challenges regarding how we visualize information are being posed not only by the sheer quantity of data and the limited space for visualizing it, but also by the diversity of tasks the user wants to perform. Besides, the user does not always have a specific task, such as a question that needs a concrete answer. Frequently, the task is more exploratory than targeted – in what is commonly designated as data exploration [5] – and may change as new data is apprehended. The user then needs different visualizations, eventually simultaneous, to accomplish different goals.

In addition, and contrary to scientific visualization where the information has an intrinsic natural representation, in the case of abstract data there is no "correct" way to display the data, or one that is valid for every application scenario.

This paper presents work done on multiple visualizations in the context of the CyberNet project [4]. The CyberNet project uses the concept of *service* to define the data set to be visualized and *visual metaphors* to depict the abstract information. We have developed several different visualization tools that use three-dimensional metaphoric worlds to depict the information. Each visualization tool uses different visual metaphors according to the data to be visualized and the user's task, thus providing multiple views.

This paper is organized as follows: Section 2 presents some related work regarding multiple views. In Section 3 we describe our approach. Sections 4, 5, and 6 present some examples of multiple views relating to the visualization of a Network File System (NFS), network data, and web server logs, respectively. Finally, in Section 7, some conclusions are drawn.

2 Related work

Related work in the field of multiple views has increased substantially in the last few years. This may be due to an increase in the amount of information to be visualized, and to the realization that one single view is no longer sufficient. Also, the computing overhead need to implement and display multiple visualizations is less and less relevant as the computing power increases exponentially – especially for the graphics, where the improvements made a noticeable difference.

In a work dealing with information retrieval applied to provide tourist information to the ancient city of Nara in Japan – WING (Whole Interactive Nara Guide) – [6] presents a multiple view system with four different views. The four views are called Map, Content, Category, and Index View. All the views are linked together so that a name chosen in the Index View is located and displayed in the Map view, for instance. The system integrates smoothly a visualization technique, a keyword search technique, and a category search technique.

[12] also presents an integrated information visualization system that allows for multiple views. It comprises an information-centric workspace (Visage), a tool for creating integrative visualizations for the workspace (SAGE), and a tool for dynamic user interaction (SDM – Selective Dy-

namic Manipulation). The combination of these three systems enables the user to communicate with the workspace in multiple complimentary ways.

More recently, [11] distinguishes between multiple views and multiform visualizations: multiple views describe multiplicity in visualization (various realizations of the data depicted in separate windows); multiform visualizations describe a change in the visual representation method (the visualization is depicted in a different form). It also presents five groups of reasons to use multiple views, how to generate multiple views from different stages of the visualization data flow model, and a multiple views checklist to help developers. Throughout this paper we will use the term multiple views to express multiplicity, even when there is a change in the visual representation method.

[8] introduces a taxonomy for multiple windows coordinations. It proposes a generalized multiple window coordination capability, so that the user can create custom environments for information seeking. It uses two basic user actions – selecting items and navigating views – to arrange coordination in a 2x3 matrix, identifying three possible combinations for coordinations: selecting items $\longleftrightarrow$ selecting items, navigating views $\longleftrightarrow$ navigating views, and selecting items $\longleftrightarrow$ navigating views. The putative applications are demonstrated with mockups.

The Snap-Together Visualization, presented in [9], provides a user interface for users to “snap” visualizations together. It enables users to specify their own coordinations between different visualizations in order to construct custom data-exploring interfaces. Snap interconnects visualizations tools developed by other researchers in the field, and allows for constructing coordinated browsers to rapidly explore and navigate data and relationships.

After ascertaining that, although multiple views systems are common and helpful, little specific guidance was available for the persons designing them, Baldonado and Kuchinsky [1] established a set of guidelines to help designers. These guidelines are divided in two sets: *when* to use multiple views and *how* to use multiple views. For each guideline, a justification is given, and the pros and cons of using it are assessed. We have used these guidelines to validate our use of multiple views.

3 Our approach

The related work cited above (e.g., [12] [9] [11]), as well as some other earlier work not described here (e.g., [10] [13] [7]), may use different approaches to multiple views, but all agree on one thing: multiple views can help making sense of information – the ultimate goal of information visualization. However, multiple views must each bring some added value. They must shed new light on the representation, in order to be useful.

According to Baldonado’s et al. work on guidelines for using multiple views [1], there are four rules to help deciding when multiple views should be used:

Rule of Diversity states that multiple views should be used when there is diversity of attributes, models, user profiles, levels of abstraction, or genres.

Rule of Decomposition states that complex data should be partitioned into multiple views to create manageable chunks and to provide insight into the interaction among different dimensions.

Rule of Complementarity states that multiple views should be used when different views bring out correlations and/or disparities.

Rule of Parsimony states that multiple views should be used minimally.

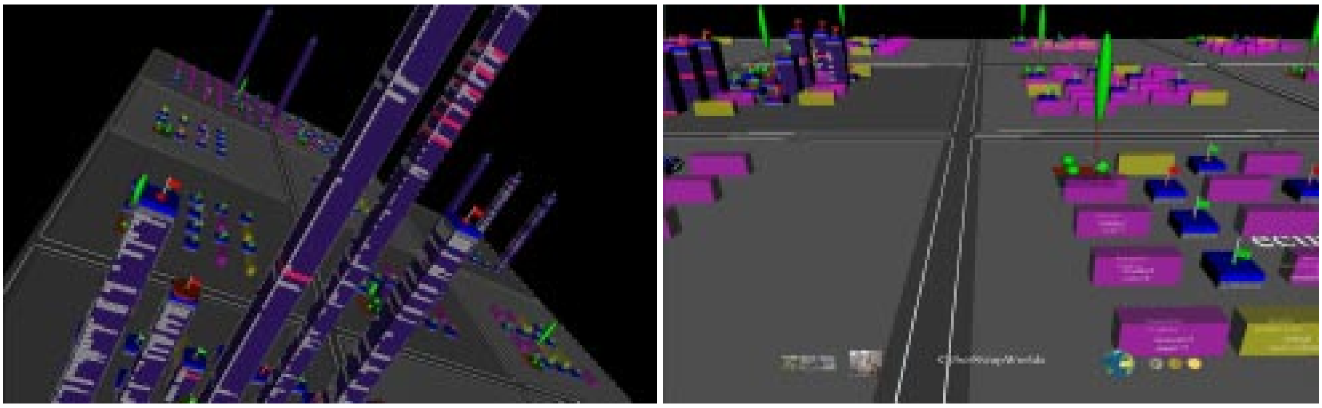
Our tools comply with the guidelines above. For instance:

- we have created multiple views when the target audience is diverse or when the attributes changes, as is the case for the web server analysis tool (Section 6). This is in accordance with the *diversity* rule.
- we have divided a large volume of data, in order to concentrate on a smaller set, so that the data that interests most the user is made to stand out clearly (NFS visualization, Section 4). This complies with the rule of *decomposition*. We also provide a global overview of all the data, so that the user is able to get the whole picture – we find that having a general overview is always useful to acquire context knowledge.

These are only two illustrative examples (more examples can be provided, also for the other rules of complementarity and parsimony) that stress our approach to multiple views. In general, they are created when the data changes, the target audience changes, the data under the spotlight changes, or the change in the visual representation brings out a detail that otherwise would probably go unseen.

4 NFS visualization

We have developed a visualization tool to represent information regarding the Network File System service (NFS service). This service is characterized by an enormous amount of data. We have developed several views for the NFS service: one to visualize all the data set and others views that display only a subset of the NFS data. These other views, representing a reduced amount of data, allow for the emphasis to be put on the relevant data under



(a) Overview (financial district) (b) Overview (residential district)

Figure 1. NFS visualization using a city metaphor.

scrutiny for that particular visualization. Furthermore, the visualization of smaller subsets reduces the risk of overwhelming the user with a large volume of complex data, some of it not relevant for the particular task in question.

For the NFS service visualization tool we have used the city metaphor. This metaphor revealed itself an appropriate choice due to the large number of mapping parameters available to map the NFS data, which has a high dimensionality. In the city metaphor, information is visualized using the structure of a real world city. In our implementation there are districts, residential blocks with low height houses and also financial blocks with tall office-resembling buildings. There are also roads and trees.

The metaphor is quite easy to grasp as the hierarchical relations are evident from theirs real world counterparts: cities contain districts, that contain blocks, that contain houses and buildings, and so on. The visual effect is quite impressive and provides lots of different elements and visual parameters to map information on. On the other hand, the city metaphor is not recursive – thus, it is not a valuable option for visualizing recursive services. In the next sections we present some of the multiple views available for the NFS service visualization, using the city metaphor.

4.1 Overview

Figure 1 shows two views for the whole data set describing the NFS service. This general overview allows, nonetheless, for immediate knowledge regarding the NFS service. For instance, the user can easily identify servers and clients. A computer is mapped on a district and each disk is represented by a building; additionally, each client mounting that disk is a floor on the building. On the other hand, each imported disk is mapped on a house. In this way, "financial" districts, i.e., districts with tall buildings, identify unambiguously servers. Mutatis mutandis, "residential" districts, i.e., districts with low houses, clearly identify the clients. This is a powerful visual perception immediately evident upon first inspection.

4.2 Disk size

Figure 2 (a) depicts a visualization of information regarding the NFS service. The data represented in a subset of the data represented in Figure 1. The emphasis is put on the size of the disks and on identifying disks that are system's partitions.

In view of the foregoing, in Figure 2 (a) the size of the disks is mapped to the height of the buildings. For the houses representing the imported disks, the color hue maps whether the disk is a system disk or not. The user can thus easily identify large disks and which of their imported disks are non-system disks.

4.3 Disk status

The data displayed in this view is a subset of the NFS set. The focus is on disk status: the number of users mounting the disk and the number of open filehandles they have. The information regarding the users and the filehandles is immediately perceived as is uncluttered by other non-relevant data.

Figure 2 (b) shows a visualization of this information. In this view, each disk is represented by a district (square), and each client mounting that disk is represented by a building. The number of open filehandles is mapped on the number of windows present in each building.

(a) Disk size view

(b) Disk status view

Figure 2. NFS visualization using a city metaphor.

5 Network data visualization

Regarding network data we have developed different visualization tools, each focusing on different aspects of the network, and using different visual metaphors. In the next sections we will give examples for the visualization of network topology, workstation data, and file systems information.

5.1 Network topology

We have developed a network topology visualization tool for depicting the topology of a computers' network – we have used Eurécom's intranet as an example. Due to the strong hierarchical characteristic of the network topology service and the fact that the number of different entities to be visualized was relatively small, the conetree metaphor was a manifest choice.

The conetree metaphor is fairly omnipresent in information visualization reference bibliography [14] [2] [3]. This metaphor is generally associated with displaying hierarchical information due to the immediate visible hierarchy appearance. It is a recursive metaphor so it is able to map recursive data. However, the number of different visual parameters available for mapping information is quite limited.

A conetree metaphor is thus used to display the network topology and some additional information regarding the network's performance, as is depicted in Figure 3 (a). The hubs are cones with a blue box at the top and the switches are visualized as red boxes. The machines connected to a given hub are represented as spheres placed at the base of the corresponding cone.

The connections between the different elements – switches, hubs, and machines – are depicted as cylinders. Additional data is mapped on the cylinders: the size corresponds to the transmission bit-rate of the connection and the color saturation to the packets' loss rate. The hub's rate of lost packets is mapped on the color saturation of the cone.

5.2 Workstation data

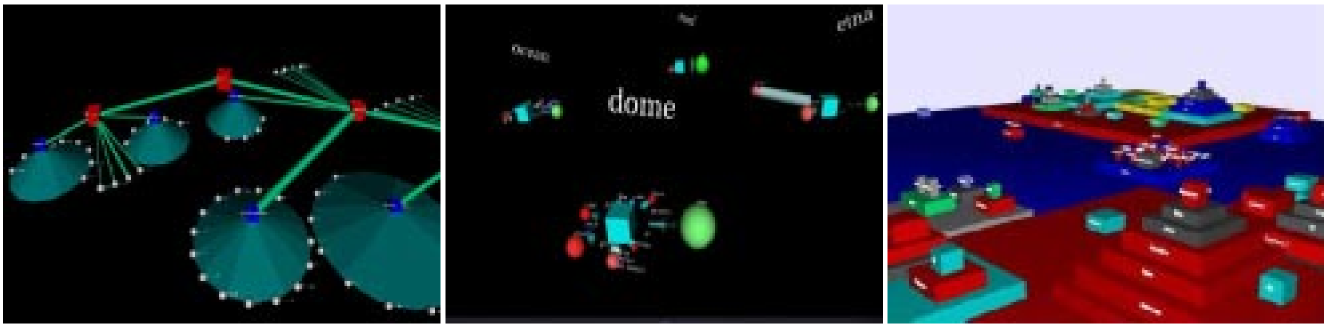
Figure 3 (b) shows information regarding workstations. The metaphor used is a solar system metaphor. The solar system metaphor, in our current implementation, is fairly simple. It uses stars, planets, and satellites to map information. The structure is given by the orbits of the various elements. The hierarchical organization is provided by the different orbital relationships: planets are attached to a star and satellites are attached to a planet.

In Figure 3 (b) workstations are depicted as stars (cubes) with planets, representing users, orbiting around. The users are mapped on spheres – color hue corresponds to the Unix group, size to memory usage, and color saturation to CPU time. Between the workstation and the users, satellites represent user processes that are mapped as cylinders. The mapping on the cylinders visual parameters is coherent with that of the spheres: size $\equiv$ memory and color saturation $\equiv$ CPU.

5.3 File system data

In order to visualize the contents of large file systems we have developed a file systems visualization tool. The visual metaphor that revealed itself more adequate to display large volumes of hierarchical information, as is the case with file systems, is the pyramid metaphor.

Like the conetree, the pyramid metaphor is also recursive. It uses the concept of nested pyramids to display infor-



(a) Topological view (conetree) (b) Workstation view (solar system) (c) File system view (pyramid)

Figure 3. Network data visualization using different visual metaphors.

mation. It is also usually associated with the visualization of large hierarchies of information.

Conceptually, the pyramid metaphor is similar to the conetree metaphor, using a hierarchy of pyramids instead of cones. Also the number of different elements and visual parameters it provides for information mapping is quite similar to the conetree metaphor. However, we feel that for very large hierarchies, the pyramid metaphor has a better performance than the conetree metaphor: the visual clutter is reduced in the former. This might be explained by the bottom-up construction of the pyramid metaphor that allows for an uncluttered view from above, in opposition to the conetree metaphor that uses a top-down construction.

Multiple views have been developed to be able to exploit (visualize) the file system according to different parameters. Essentially, the file system's structure is always encoded in the same manner – hierarchically with nested pyramids – and the data under scrutiny is color coded (color hue). In the multiple views, the color hue can thus encode the file type, the file owner, the file date, or the file security details. Figure 3 (c) shows an example of color hue encoding the file type.

6 Web server data visualization

The analysis of Web server logs is a hot topic nowadays particularly because of the e-business explosion. Our objective was to design a Web server logs visualization tool that uses 3D technology to present the information to the user. The information is displayed in different 3D metaphoric worlds, customized according to the needs (e.g., temporal, geographic representation), or the target audience (e.g., web master, sales personnel).

The implementation is fairly simple at present. There are three data types that we visualize: the number of hits, the traffic generated, and the number of hosts. This information is represented in three different views: geographic view, temporal view, and site view. Both the data and the view are selected from a selector interface.

6.1 Geographic view

The geographical diagram allows the user to situate and compare data from a geographic perspective. The metaphor used is a landscape metaphor. The landscape metaphor uses a information landscape to visualize data. The information is placed in a virtual landscape, usually using the shape of a vertical bar or 3D spike. It was inspired by the File System Navigator [15].

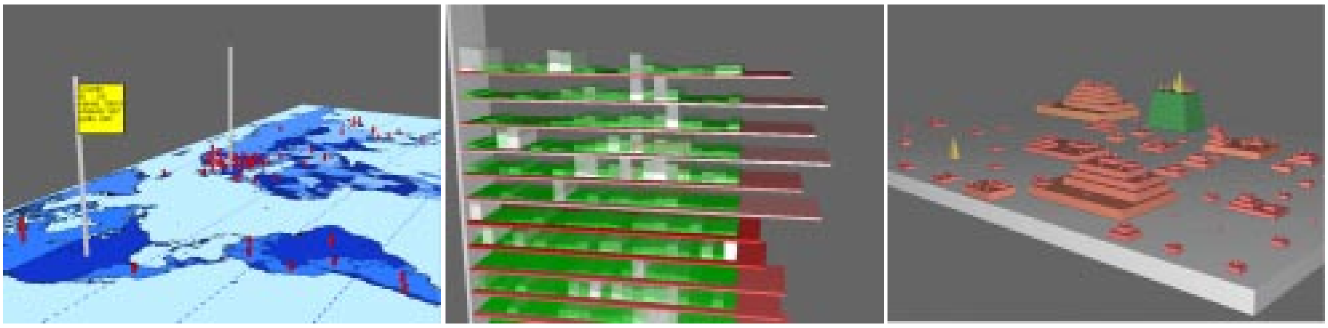
In the geographic view (Figure 4 (a)) we have used an information landscape with a world map to encode position. Details-on-demand are available by selection.

Although there is basically only one element (the vertical bar) to map information on, this metaphor is interesting because position can be effectively used to encode information – as in Figure 4 (a) where the position on the world map encodes country information.

6.2 Temporal view

The temporal view allows the user to compare data in a temporal manner. This view uses a library metaphor to display the temporal data. The data is represented in a library containing several bookshelves; each bookshelf is subdivided into shelves upholding series of books.

There are three levels of segmentation: bookshelves, shelves and books – where data is sorted respectively by week, by day, and by hour. The hierarchical structure is provided by the fact that bookshelves contain shelves and shelves contain books. Figure 4 (b) depicts the temporal view for the web server logs visualization tool.



(a) Geographic view (landscape) (b) Temporal view (library) (c) Site view (pyramid)

Figure 4. Web server logs visualization tool using different metaphors.

6.3 Site view

The site view is a representation of the actual hierarchy of the web site – directories and pages. This view allows for visualizing the most popular pages, for instance, or the files that are more frequently downloaded.

Figure 4 (c) shows an example of the site view. Again, as in the case of the file system visualization (Section 5.3), the metaphor used to represent the hierarchical organization of the web site is a pyramid metaphor. The structure of the web site is mapped on the structure of the pyramid and the actual information regarding, for instance, the popularity of the pages, is color mapped.

7 Conclusions

Multiple views per se are not a guarantee of a useful visualization tool. Their usage must be justified and they must bring some added value to the tool. This added value priority is to ease user's task – this entails a better user visual perception and comprehension of the data displayed.

In this paper we present some of our work on multiple views, illustrated by examples taken from the visualization tools that we have implemented. In the examples that we gave, we tried to always present the motivation behind each different view. The multiple views have been validated in a number of different tools for different applications, ranging from network topology visualization, to file systems visualization, or to web server data analysis.

Further work should be done in the field of user interaction and the combined use of different tools. The ultimate goal would be to create a global information workspace where all the services were integrated. Up until now, this integration is not transparent to the user – each tool constitutes a different application.

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