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GerbilSphere: Inner sphere network visualization

David S. Shelley, Mehmet Hadi Gunes *

University of Nevada, Reno, United States

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ABSTRACT

Advanced techniques are needed to understand the underlying topologies of large complex networks. This paper introduces a novel way to address the issue of visualizing large-scale network topologies. We propose an inner sphere visualization method that projects the network topology on the inside of a sphere. User navigation around the network is accomplished through moving the sphere around the user's point of view. Previous research has shown that the spatial cognition ability in humans greatly affects the usefulness of a user interface. In this direction, we performed two empirical experiments to test the usefulness of viewing topologies on a sphere compared to a flat surface. The user study indicates that network navigation on a sphere is faster but can also be confusing. Thus, we add guidance tips to create a more intuitive user interface and to improve navigability. Our inner sphere visualization method is implemented as a tool for dynamic interactive network visualization called GerbilSphere (available at http://cse.unr.edu/~mgunes/gerbilSphere).

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1. Introduction

The surge of information only strengthens our need to find better methods to sort through it and visualization of information exploits our visual perception abilities [1]. Visualizing network data helps with the detection of its underlying patterns [2]. However, effectively visualizing large networks is a challenging task. Usability of visualization becomes obsolete when the user can no longer maintain the context of the entire graph. Large graphs suffer from node occlusion and edge clutter which makes them difficult to explore and understand. Edge clustering allows better exploration and interpretation by combining groups of edges that flow in the same direction. The time and the space complexities of certain visualization algorithms may also make them impractical when applied to large graphs. By combining visualization techniques with user interaction, it becomes practical to visualize larger networks that otherwise would not be possible [3]. Interaction also allows presenting more information about an object from the network. Moreover, animation may be used to convey history of topological changes [4].

Through the visualization of large graphs, such as the Internet, we are able to detect underlying patterns and structures. The primary issue with visualizing the Internet is occlusion. The Internet consists of millions of connected entities and showing them all at once on a normal size screen would cause many objects to occupy the same space. Many techniques have been developed to lessen the impact of occlusion. Some visualizations show different elements of the Internet and often provide users with 3D maps to guide browsing of the network. It was believed that these 3D interfaces were capable of displaying more information than a single 2D display, and that users would learn more about the Internet by flying through a 3D space [5]. Often new techniques to visualization improve the aes-

* Corresponding author.
E-mail address: mgunes@unr.edu (M.H. Gunes).

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thetics without providing empirical user studies that show the usefulness of the techniques [6]. Further empirical studies on 2D vs 3D user interfaces have shown that 2D is often better.

In this paper, we present GerbilSphere which is an inner sphere 2D system for the dynamic visualization of the Internet topology. This paper also contributes an empirical user study that tests the usefulness of the inner sphere method against a traditional flat method for network topology visualization and navigation.

2. Previous work

The main issue with visualizing large networks is occlusion. The Internet consists of millions of connected systems and showing all of them on a screen would cause multiple objects to occupy the same space preventing any understanding of the network. The amount of pixels on a screen can present a problem requiring multiple screens to successfully maintain the context of a network. Depending on the network being visualized, different layout and interaction approaches seem to work better. Layouts are often judged by their aesthetics such as even distribution of nodes, minimization of edge crossings, uniform length edges, and ability to obtain meaning.

2.1. Layout approaches

A common approach to layout networks is to use forces between network components. The basic idea is to apply an attractive force between connected nodes and a repulsive force between disconnected ones. Computations of these forces are usually calculated in several rounds to arrive at an ascetically pleasing graph layout. The *spring force model* is based on a system of springs where each edge in a given network is replaced with a spring and each vertex is replaced with a steel ring [7]. After constructing a graph with connected steel rings and springs, the system is released to become stabilized, hopefully into a more pleasing layout. Starting with an arbitrary initial positioning, the algorithm computes the attractive and repulsive forces between the nodes and updates positions in a series of discrete time steps.

The force layout model was enhanced with graph theoretic force computation, which is based on the distances between the nodes [8]. This approach requires identification of shortest paths [9] before the force computations. Later, a global graph temperature, which cooled down as time progressed, was added to the force model [10]. In order to reduce the time complexity, the plane is split into a grid and the repulsive forces are applied only to nodes in the same and surrounding grids. To obtain faster convergence, force calculation order of nodes is randomly determined [11]. Additionally, for each node, the last movement (i.e., the last impulse) and the calculated local temperature are stored. Force directed layout of node clusters are also computed using radial spread and angular gap [12]. Finally, force directed layout approaches have been applied to non-euclidean surfaces [13].

Alternatively, the *multilevel decomposition model* groups nodes into clusters to form a new graph and the clustering repeats recursively until a desired threshold is met [14]. An important challenge in this approach is defining a method to extract a coarse graph that preserves the important features of the original one. The approach has been improved with a grid variation of the graph temperatures in the computations [15]. Moreover, 2-level hierarchical models have been proposed [16].

2D layout approaches can often easily be adapted to drawing in 3D. For instance, the distances between points in 2D can easily be calculated in 3D allowing a conversion of 2D force directed layouts into 3D [17]. One of the advantages of using 3D is that the new dimension can be used for the placement of additional information on the screen. However, a major disadvantage is that occlusion can occur where objects closer to the user are drawn over the objects that are farther away. Occlusion problems can be alleviated by allowing the user to navigate and rotate the graph choosing the visible section. Additionally, the transparency of objects can reduce occlusion.

Moreover, the *cone tree layout* maps the nodes of a hierarchical tree into a 3D space [18]. The nodes of the tree are rotated so as to reveal nodes that are occluded. *Hyperbolic tree layouts* use a spanning tree as the backbone for the layout [19]. Using a spanning tree, a graph that otherwise is not a tree is transformed into one. The H3 hyperbolic quasi-hierarchical approach improves the amount of information with which a user can visually interact [20]. However, occlusion still occurs when looking through the hyperbolic space.

2.2. User interaction

As the size of a network increases, the ability of the user to navigate through the data becomes more important. Parts of the network that appear occluded may become visible as the user navigates his/her way around. Important aspects of user navigation include the ability to zoom into an area for increased detail and zoom out to obtain the context of the whole graph [21]. Visual cues are used to add to the depth perception of a given user interface. 3D interfaces are capable of displaying more information on a screen than 2D as users fly through the 3D space [5].

Zoom + Pan is a mechanism that allows a user to see more than would normally be possible when visualizing large networks [22]. Due to the limit of the number of pixels on the screen, large networks can not be displayed as the number of nodes may exceed the number of pixels. Allowing the user to pan essentially simulates having a larger display. The pixels that once were filled with information now have passed that information to adjacent pixels. The pixels with no adjacent pixels are not able to pass the information so that part of the image