Three-Dimensional EncCon Tree

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Abstract

This paper describes a three-dimensional extension of a enclosure+connection layout technique, called EncCon tree. The three-dimensional visualization includes layout and navigation. The layout algorithm directly generalizes the two-dimensional EncCon tree layout algorithm to three-dimensional space in which nodes at the same level of the hierarchy are placed onto the same plane. The interactive navigation uses standard three-dimensional viewing techniques which include view transformation, rotation and zoom.

1 Introduction

Graph and tree visualization has been widely used in many application domains in business, system and networks analysis, and others. A graph and a tree commonly include a set of nodes and a set of edges to represent entities and relationships between entities respectively. Graphs generated in real-world applications could be very large with thousands or perhaps millions of nodes, such as citation and collaboration networks and the World Wide Web (WWW). As the result of rapid increasing of the size in networks, the large scale visualization has become one of the hottest topics in Information Visualization. The question about how to comprehensively display large graphs on the screen becomes the key issue in graph visualization.

Research in graph and tree visualization in two-dimensional (2D) space can be roughly classified into two main streams the *enclosure* and the *connection*. They are both effective approaches for the visualization of hierarchies and which one we should use depending primarily on the properties of the data in a particular application domain. *Connection* approach displays the relationships of information explicitly by drawing a set of graphical edges in the diagram that gives users an immediate perception of the relationships. Techniques in this approach, named a few, are *Hierarchical View* [12], *Radial View* [4], *Balloon View* [8], *NicheWorks* [17], *Rings* [14]. *Enclosure* approach is usually a better solution in term of optimizing the use of display space. However, techniques in this approach do not show explicitly the relational structures of information. This can cost extra cognitive effort of viewers to understand the relational structures that are presented implicitly in the enclosure manner. Techniques in this approach, named a few, are *Tree-maps* [6], *Cushion Tree-maps* [15], *Squarified Tree-maps* [3], *Voronoi Treemaps* [2]. Some techniques combine both the *enclosure* and the *connection* concepts into one so that it could take the advantages of both above approaches. Although techniques in this approach need further improvement, they have shown some interesting initial results. Techniques in this approach are *Space-Optimized Tree* [10] and *EncCon Tree* [11].

Three-dimensional (3D) graph and tree visualization techniques are another approach that uses an extra dimension to achieve the display of more information on the screen. These techniques also aim to provide the "natural look" of the information. Three-dimensional layout algorithms can also use enclosure to partition the layout or use node-link diagrams in their displays. Although 3D techniques are not always better than 2D techniques [16], this approach could provide an alternative way to present the information in different applications. Some 3D visualization techniques for graphs and trees are *Cone Tree* [13],

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Botanical Visualization [7], *3D Narcissus* [5], *3D Hyperbolic Browser* [9], *Information Pyramids* [1].

1.1 Motivation

With the fast growth of technology, hardware devices for supporting three-dimensional graphics have become more and more powerful. The price of such devices is decreasing rapidly. This makes three-dimensional information visualization more feasible on a normal personal computer compared to a decade ago.

EncCon Tree [11] is a layout algorithms which it is aimed to optimize the display space while retaining the clarity of the display by using a node-link diagram. The success of these layout algorithms motivates us to study the feasibility of extending the algorithm in three-dimensions. In short, the model reuses the two-dimensional layout algorithms to display the hierarchical data in three-dimensional (3D) space so that nodes at same level are projected onto the same plane. This property aims to provide not only an alternative approach to the visualization, but also a more realistic look to the three-dimensional model as well as a possible improvement of the clarity in layout. We now present the technical detail of the layout and navigation of the 3D EncCon tree.

2 Layout Algorithm

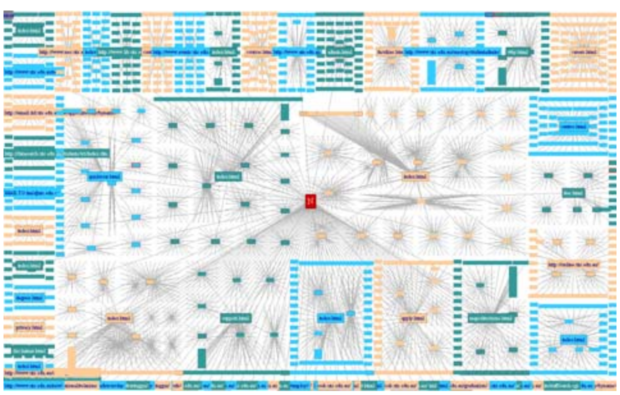

Figure 1. An example of two-dimensional visualization with a large dataset using EncCon Tree.

Our layout algorithm is responsible for positioning of all nodes in a given hierarchical graph or a tree in a three-dimensional geometrical space, including a vertex subset $\{v_1, v_2, ..., v_n\}$ in *V* and a cluster subset $\{v'_1, v'_2, ..., v'_n\}$ in *V'*. A clustered graph *C* = {*G, T*} is derived by a general graph *G* = {*V, E*} and a cluster tree *T* whose leaves are in

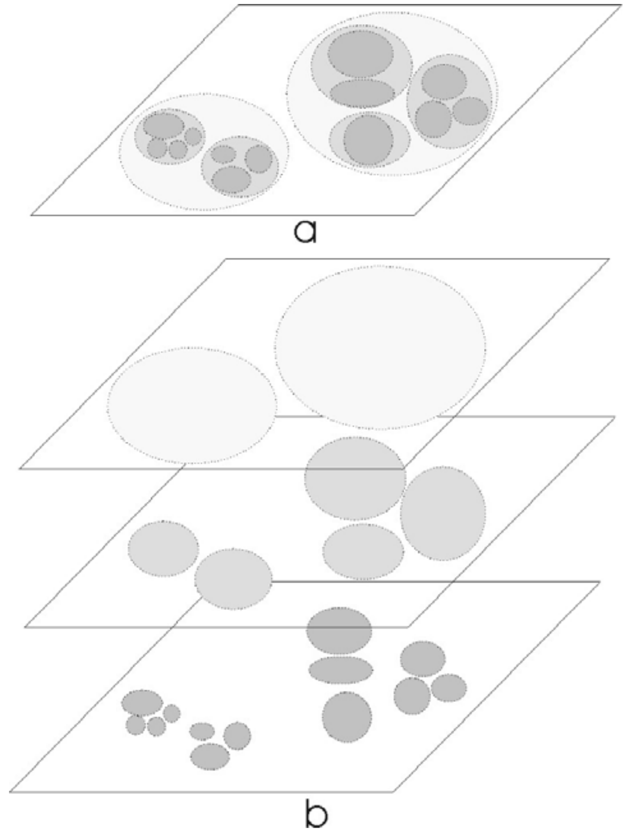

Figure 2. An example of projecting a 2D layout onto planes in 3D space.

V. Each cluster $v'_i = C'$ is a sub cluster graph, contains a subset of *V* given by the leaves of the sub-tree *T'* rooted at *r'*. The root *r'* of the sub-tree *T'* is also called a super-node. The super nodes are not displayed in our visualization but they are used for partitioning process of calculating the local region for sub cluster graph. For the partitioning of clustered graph *C*, We define a virtual tree consisting of a set of super-nodes for area division. We define a super-node $r(v'_i)$ for each cluster v'_i.

The layout algorithm of this 3D technique is a generalization of 2D EncCon tree layout algorithm [11]. The 2D layout of a graph or a tree is first achieved using 2D EncCon, the final layout is then computed by projecting the layout onto different planes in three-dimensional space. The algorithm is described by following processes:

2.1 2D Layout

First, the x-coordinate and y-coordinate value of every node is calculated using the modified 2D EncCon tree layout algorithm [11]. Technically, EncCon is an *enclo-*

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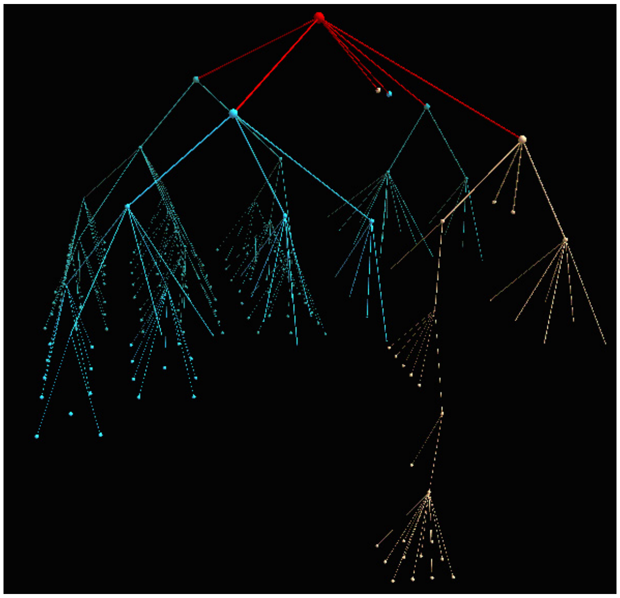

Figure 3. An example of thee-dimensional visualization with a dataset of 170 nodes.

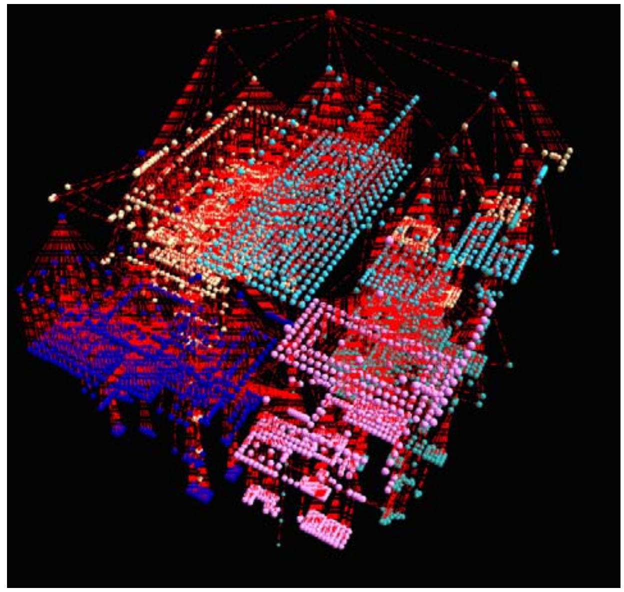

Figure 4. An example of thee-dimensional visualization with a large dataset of 6500 nodes.

sure+connection approach for visualizing and navigating large hierarchical information in a two-dimensional space. The layout algorithm maximizes the utilization of display space by using enclosure partitioning approach. EncCon uses a rectangular division method to partition the layout so that it provides the user a more straightforward way to perceive the relational information. The partitioning ensures each vertex to be bounded by a rectangular local region. The area of each local region of a vertex is equal to the sum of the local region areas of all its child vertices. Thus, the value of a vertex's local region area is proportional to the number of the vertex's descendants. A sub-hierarchy is drawn within the rectangular boundary of the sub-root vertex. The local regions produced by the EncCon layout algorithm are square-like rectangles. In this partitioning process, the width and height of the display are normalized as one-unit scale. This step ensures the utilization of the display space of the display space on each plane when the layout of each hierarchical layer is projected onto a plane. Figure 1 shows an example of the visualization of a large structure in 2D using EncCon Tree layout algorithm in which the utilization of display space is very high in this example.

2.2 Projecting onto Planes

Next, the z-coordinate value of each node is calculated based on its level that nodes with the same level have the same z-coordinate value. This step is formalized as a projection of the entire hierarchy on the different planes. The number of planes in equal to the number of levels of the hierarchy. These planes are placed along the z-axis. Although the distance between two planes can be adjusted and varied for each level, this prototype only applies the same distance between each two planes. Figure 2 presents an example of the projection a 2D layout onto different planes to form a 3D layout. Figure 2a shows the actual 2D layout of the entire hierarchy, Figure 2b shows 3D view when projecting three levels of the hierarchy onto three different planes.

Suppose that the z-coordinate value of the root node is z = 0 and the distance between two planes is D, the z-coordinate value of a node at level k is calculated by the formula:

$$z = -kD \quad (1)$$

Finally, the *(x, y, z)* coordinate value of every node is recalculated to translate from the normalized coordinate system to the real display system corresponding the view-point.

Figure 3 and Figure 4 presents two examples of thee-dimensional visualization of the EncCon tree layout that uses the datasets of respectively 170 nodes and 6,500 nodes.

2.3 Edge Occlusion's Minimization

Although the three-dimensional visualization from this algorithm performs quite well on these datasets (see igure 3 and Figure 4), the overcrowded look of edges could reduce the visualization quality. This problem normally occurs with a very large dataset on nodes having several child nodes (see Figure 4). To overcome this occlusion, we modify the representation of edges by replacing straight-line links with bended links. Technically, an edge is not drawn directly from a parent node to a child node through a straight-line link, but a bended link including two segments. The first segment is drawn from this node to the center of the rectangular local area of its child nodes. And the second segment is drawn from this center point to a child node. Figure 5 and Figure 6 shows examples of the visualization from this modification that uses the same datasets as Figure 3 and Figure 4 respectively.

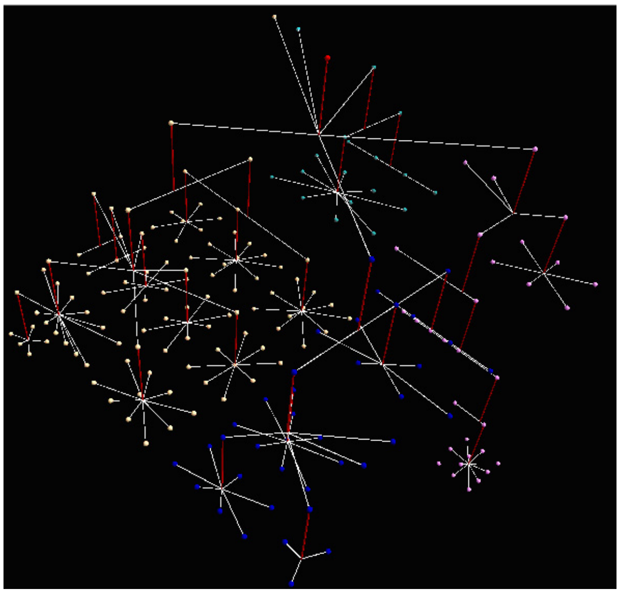

Figure 5. An example of thee-dimensional visualization with the same dataset as Figure 3 using the modification of edge layout.

2.4 Interactive Navigation

The interactive navigation uses standard three-dimensional viewing techniques including *view transformation*, *zoom* and *rotation*. The *view transformation* is a shifting image when a user interactively drags the display to a desirable location. This navigation allows the user to focus onto a particular area or a substructure from the entire visualization. The zoom navigation can enlarge a focus substructure so that more detail of the information, i.e. node labels and attributed properties, can be further display. Finally, the visualization can allow the user to rotate visualization the image to obtain a desirable view of the structure. Figure 7 illustrates the visualization of

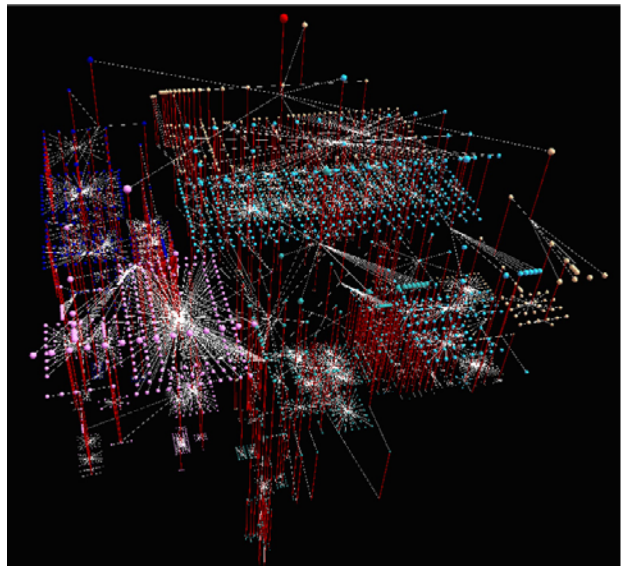

Figure 6. An example of thee-dimensional visualization with the same dataset as Figure 4 using the modification of edge layout.

the entire University of Technology, Sydney (UTS) web site-map. And Figure 8 shows the visualization of the web site-map during a navigation state.

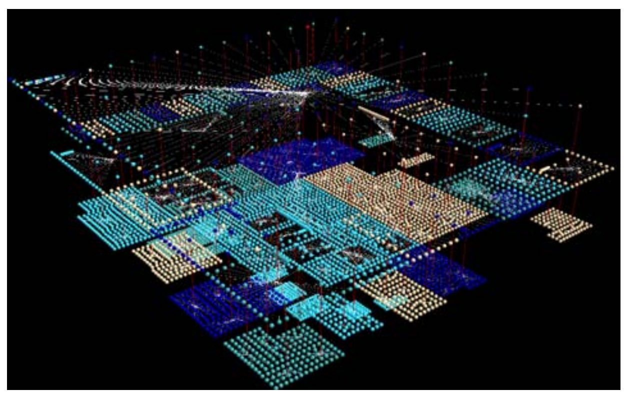

Figure 7. The 3D visualization of UTS's web site-map.

3 Conclusions

This paper has presented an ongoing three-dimensional extension of the 2D EncCon tree visualization. The layout extends the original two-dimensional EncCon tree into a three-dimensional space. This property aims to provide not

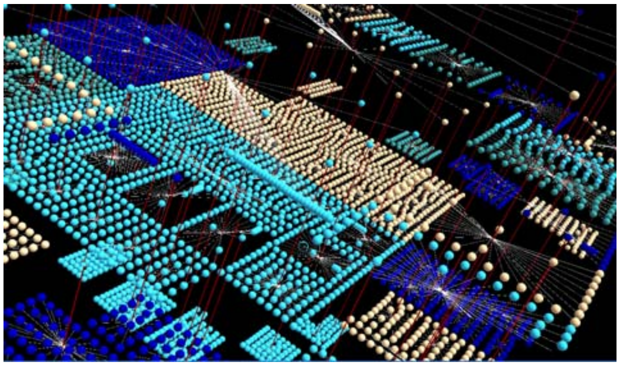

Figure 8. The 3D visualization of UTS's site map.

only an alternative approach for the visualization, but perhaps a more realistic look of the three-dimensional model as well as a possible improvement of the clarity in layout. We use two different edge representations, the straight-line and the bended-line, to implement this three-dimensional EncCon tree. This three-dimensional system is just at the initial state and there is still need for improvement. However, this initial work shows a good potential in developing alternative visualization of clustered graphs or trees.

Acknowledgements

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