PhylloTrees:
Harnessing Nature's Phyllotactic Patterns for Tree Layout

Sheelagh Carpendale†
Department of Computer Science
University of Calgary

Anand Agarawala‡
Department of Computer Science
University of Calgary

ABSTRACT

We explore the use of nature's phyllotactic patterns to inform the layout of hierarchical data. These naturally occurring patterns provide a non-overlapping, optimal packing when the total number of nodes is not known a priori. We present a family of expandable tree layouts based on these patterns.

CR Categories: I.3.3[Computer Graphics]:display algorithms

Keywords: Graph layout, information visualization, phyllotactic patterns, tree visualization

1 INTRODUCTION

Hierarchically structured data sets or trees occur with sufficient frequency that tree visualization approaches continue to be a reoccurring research topic. Trees arise naturally due to data characteristics as in the case of family trees, phylogenic trees, and file structures, as well as arising from common methods of information organization. One example involves creating categories and subdividing these categories, thereby imposing a hierarchical structure that can be useful in information access and navigation. The resulting hierarchies lend themselves to be visualized as trees. While many tree visualizations exist (for survey see [1]) increasingly massive data sets, expanding computational power, and still relatively limited display space makes this a topic of ongoing interest.

We add a family of layout variations to the growing number of tree algorithms. The inspiration for these 3D layouts comes from Cone trees [5] and phyllotactic patterns [6]. PhylloTrees offer several advantages. They are fractal and therefore self-repeating, making it easier to comprehend a large numbers of nodes, as one only needs to understand one principle shape. They support interactive manipulation yielding many layout possibilities through the adjustment of two parameters. They provide the ability to visualize quite large hierarchies. PhylloTree layouts can handle growth in the numbers of nodes at any level without requiring significant restructuring. Expandable layouts are of interest because information visualizations often have to contend with dynamic data that is not fully specified a priori. A common example is our personal computer data files where it may be necessary to add nodes any level during use.

Tree layouts that can handle large numbers of nodes (~100,000 nodes) such as Botanical [3], Fractal [4], and PolyPlane[2] trees have been developed. Fractal trees extend Cones trees [5] using the same form factor, Botanical trees create layouts resembling natural trees, and while the PolyPlane algorithm is easy to implement, finding the best partitioning in their approach is NP hard.

†e-mail: sheelagh@cpsc.ucalgary.ca
‡e-mail: anand@cpsc.ucalgary.ca

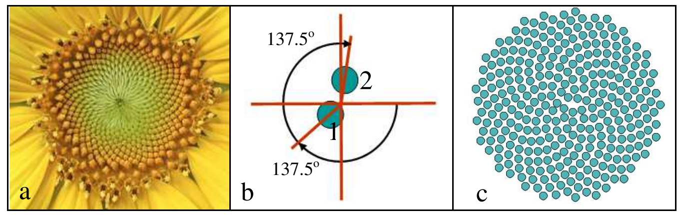

Figure 1: Development of the phyllotactic pattern

2 CREATING PHYLLOTACTIC TREES

Phyllotactic patterns are common in nature. Familiar examples include the placement of seeds in a sunflower (Figure 1a) and the organization of the scales on a pineapple. Vogel [6] gave the following mathematical description of a phyllotactic pattern for constant-sized objects in a plane. Polar coordinates for the nth object are

$$r = c\sqrt{n}\,, \quad \phi = n \cdot 137.5°, \quad n=1,2,\ldots$$

where c is a constant. Figure 1b shows the positioning of two nodes $n=1$ and $n=2$, and Figure 1c shows the algorithmically generated pattern with 300 nodes. The angular constant for sunflowers is 137.5° and has been shown to provide optimal packing without introducing overlapping [6]. Adjustments to the angular constant and the spacing constant c provide a rich palette of layout possibilities. Figure 2a shows a simple tree with a root and 50 children nodes that have been laid out using the angular constant 137.5°. The view from the bottom (Figure 2b) shows the emerging spirals with closely packed nodes. In Figure 2c the spacing constant has been adjusted to allow more space for the addition of second level children nodes.

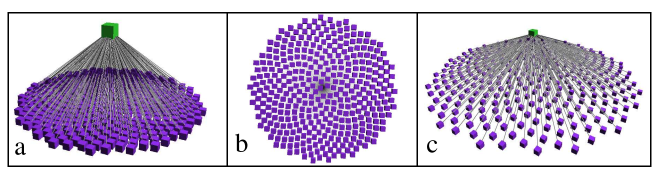

Figure 2: Single level tree, angular constant=137.5°; varying spacing constant adjusts the space between nodes

Figure 3a includes 6 secondary child nodes for each of the 50 primary children nodes. One can see that the secondary children are becoming crowded. This crowding can be addressed by increasing the spacing constant. In Figure 3b the primary children's spacing constant has been increased and now allows for 30 secondary children. Alternatively, the angular direction of a parent node can be used as the principle angular direction of the children nodes. The angular direction of a node is defined as the angle created by the edge connecting the node and its parent. Figure 4a illustrates this, showing how the secondary children groupings are now extended as continuations of the primary child's layout direction. Figure 4b shows this same layout from below, revealing the additional space. By calculating the distance to the closest node neighbour we can automatically determine an appropriate spacing constant for each level.

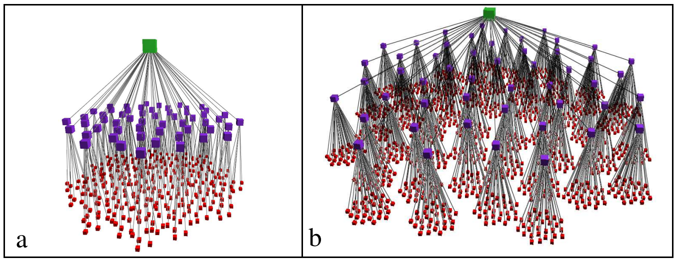

Figure 3: Using the primary children's spacing constant to provide more space for secondary children.

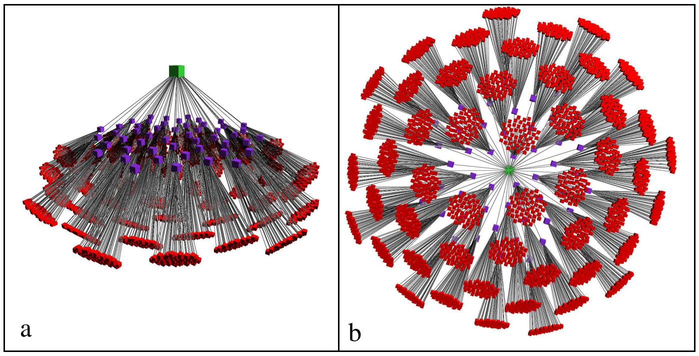

Figure 4: Using angular direction of primary children to form the principle direction of the secondary children.

While the angular constant of 137.5º provides optimal packing, many other angles also provide interesting layouts, though the node spacing is not as regular. In Figure 5 the angle 344.2º has been used. Figure 5 also illustrates the addition of nodes. In Figure 5b, 5 more primary children nodes have been added to the 50 in Figure 5a. Figures 6 and 7 display layouts using angular constants of 9º and 141.5º respectively. Figure 8 adds a third level to the layout of 31,250 nodes and uses an angle of 15.5º.

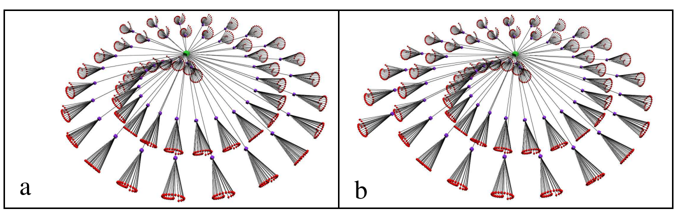

Figure 5: Expanding the tree. 50 primary child nodes (a) increases to 55 (b). Angular constant of 344.2º

3 CONCLUSIONS

We introduce the use of phyllotatic patterns to create tree layouts. The phyllotactic angular constant of 137.5º offers optimal packing with an expandable layout. Since in information visualization the focus is often on creating visualizations for data where the exact number of nodes is not known a priori, algorithms that can handle increases and decreases in the number of nodes gracefully are an asset. PhylloTrees offer a readily available family of layouts through adjustments of two parameters: the angular constant and the spacing constant.

ACKNOWLEDGEMENTS

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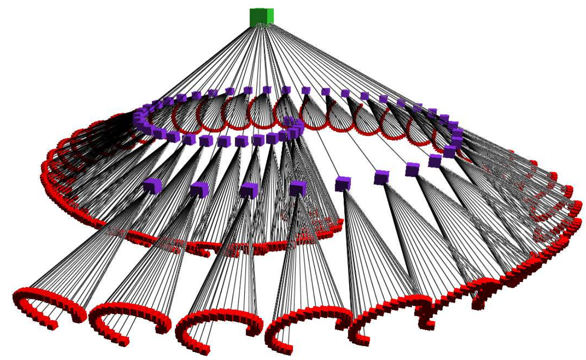

Figure 6: Using an angular constant of 9º

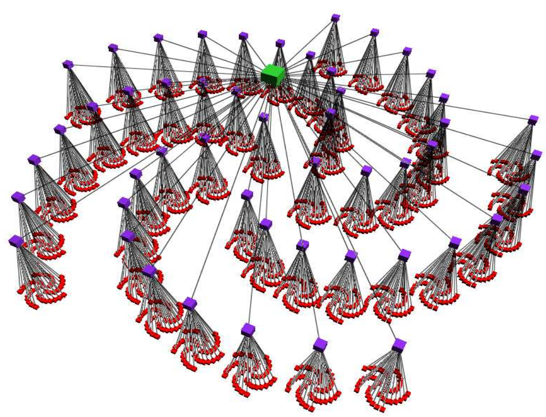

Figure 7: Angular constant of 141.5º

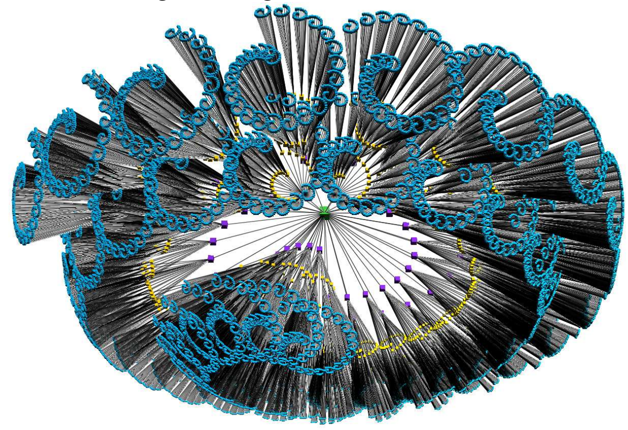

Figure 8: A 3 level tree, angular constant 15.5º, 31,250 nodes