Interactive, Tree-based Graph Visualization

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Outline

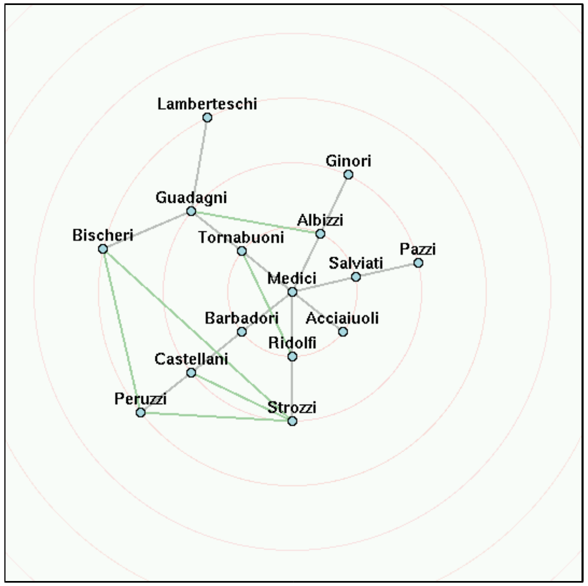
- Introduction / Graph visualization
- Graph drawing
- Graph animation
- Evaluation

Our Contributions

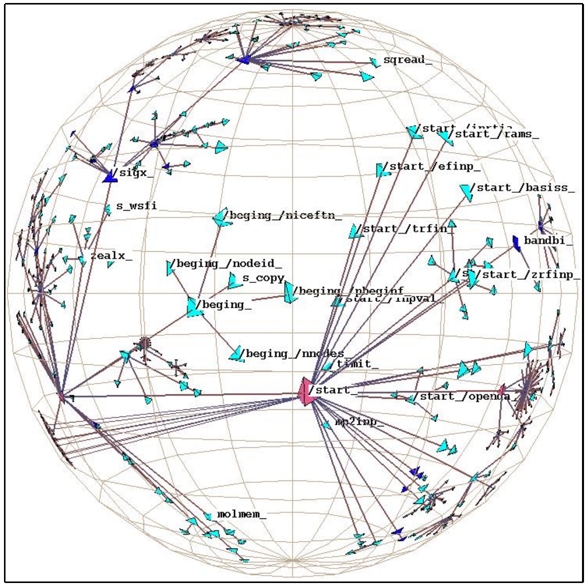
- Graph drawing algorithm
- Graph animation algorithm
- Experimental analysis

Graph Visualization

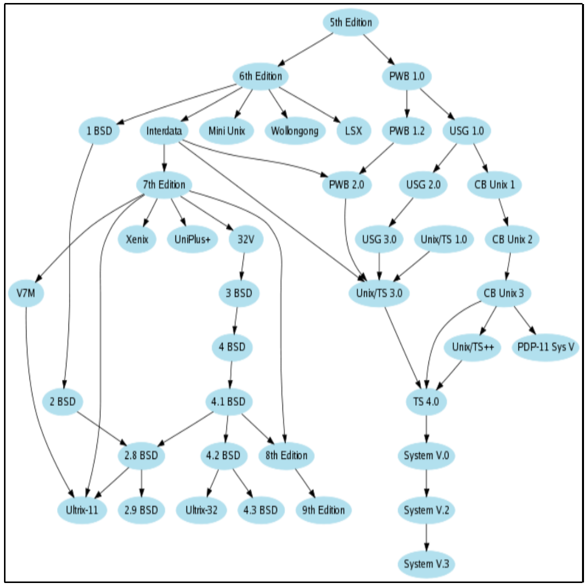
- “Pictures” of graphs
- Helps to easily detect patterns
- Many applications



From Yee et al. [27]



From Munzner [18]



From GraphViz [14]

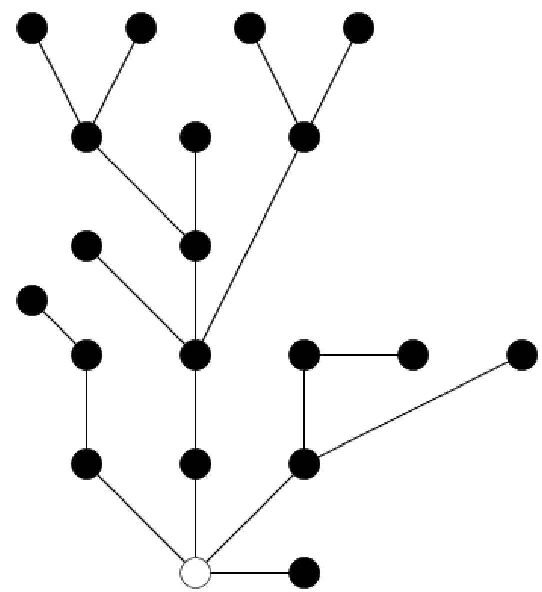
Graph Drawings

- What makes a drawing readable/useful?
- Prior research on drawing characteristics:
  - Usability studies [21,17,25]
  - Experiments using eye-tracking systems [12]
- **Minimizing edge crossings greatest impact**
- Not all graphs can be drawn without edge crossings.

Our Research

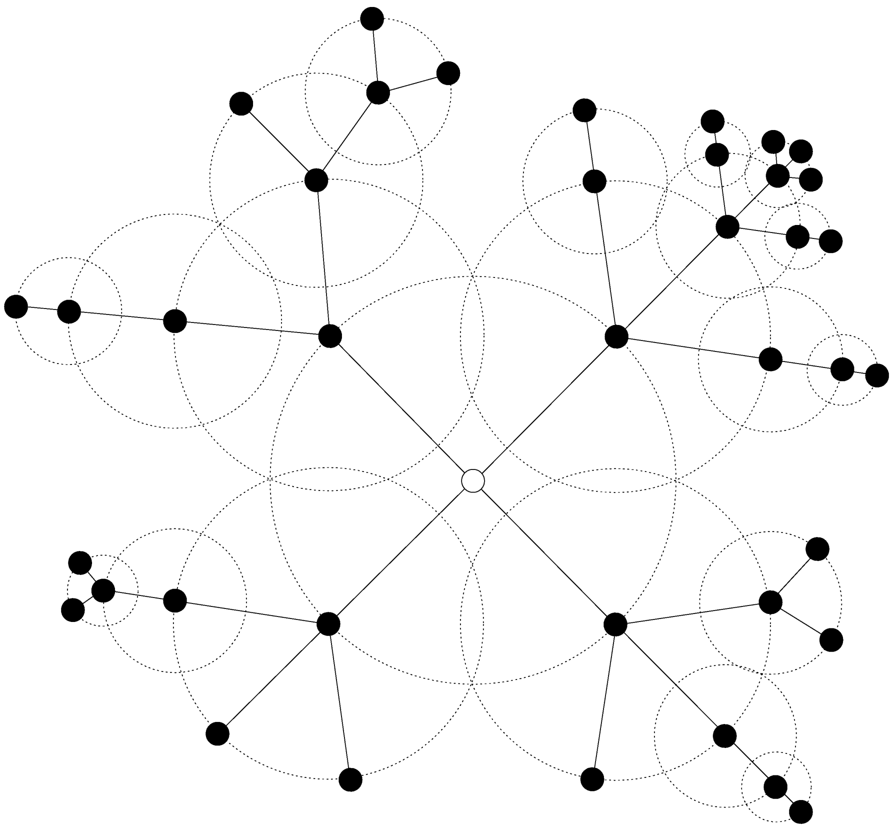
- How to address the problems of edge crossings when visualizing graphs?
- Trees as an inspiration:
  - Ubiquitous in nature.
  - Always planar

From Thierry Lombry / NASA



Context-free Radial Layout Graph Drawing Algorithm

- Spanning-tree-based drawings
- Each vertex is positioned relative to its parent
- Preserves connectivity between root and children
- Subtrees are drawn on a series of overlapping circles

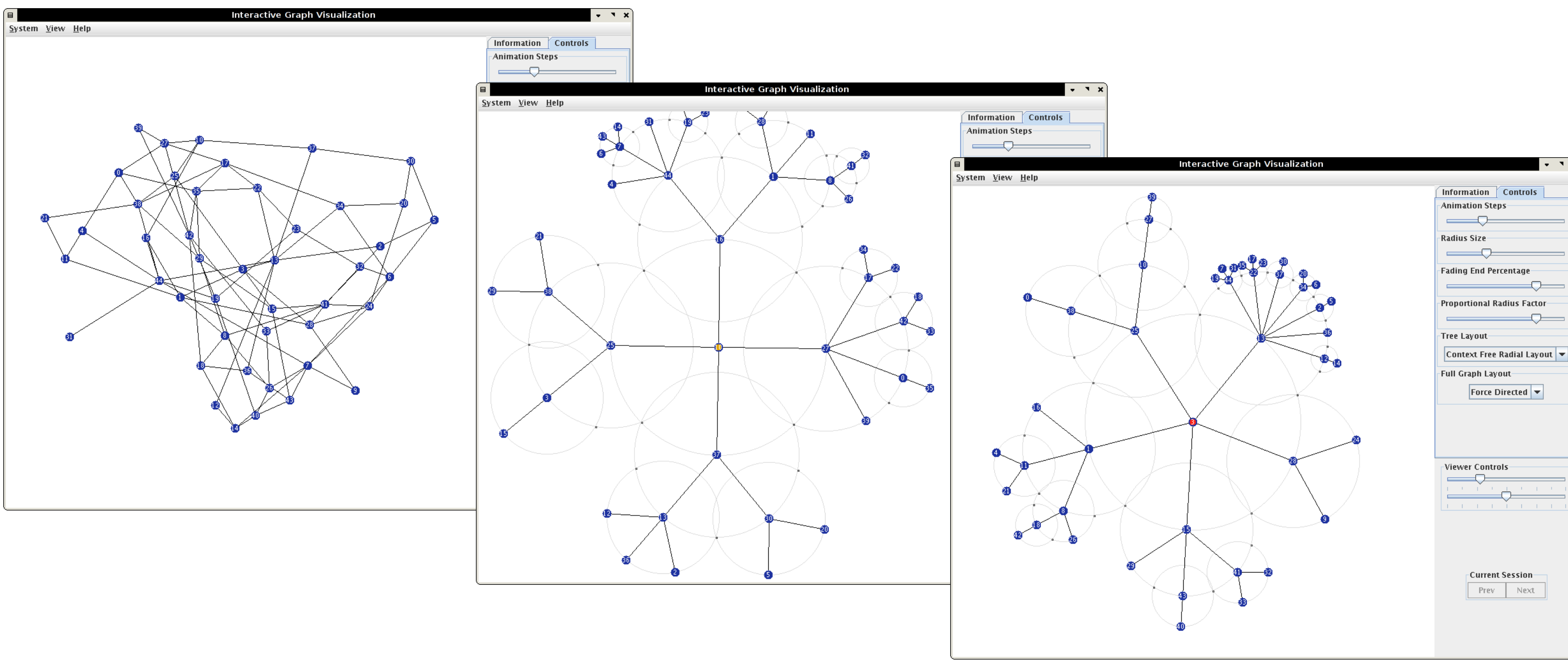


Problems

- Single spanning tree view is a biased view
- Tree layouts are dependent on the root selected
- Removing edges removes information
- We need an interactive approach!

Interactive Graph Visualization

- View the graph through a sequential number of spanning-tree-based drawings
- Reintroduce information over multiple drawings
- Can return to the full graph drawing



Related Work

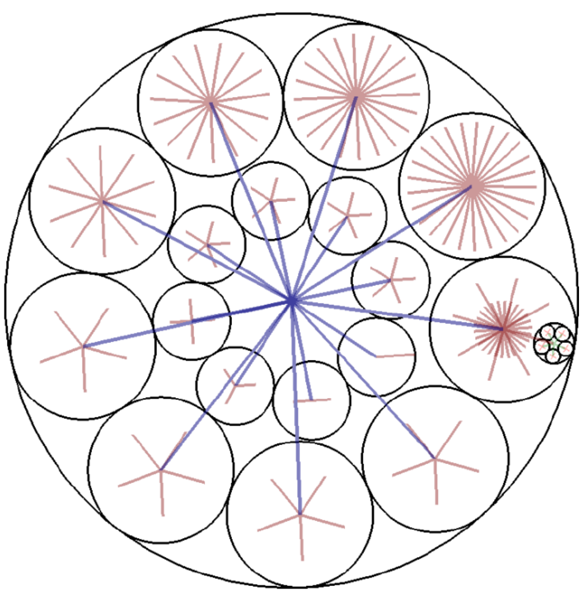
- *Graph Drawing* – Battista et al. 1999 [2]
- *Algorithms for Drawings Graphs* – Battista et al. 1994 [1]
- *Graph Visualization and Navigation in Information Visualization* – Melancon et al. 2000 [10]
- Incremental Exploration:
  - North 1996 [20]
  - Eklund et al. 1999 [6]
  - Huang et al. 1998 [11]
- Focus+Context:
  - Sarkar et al. 1992 [22]
  - Schaffer et al. 1996 [23]

Related Work

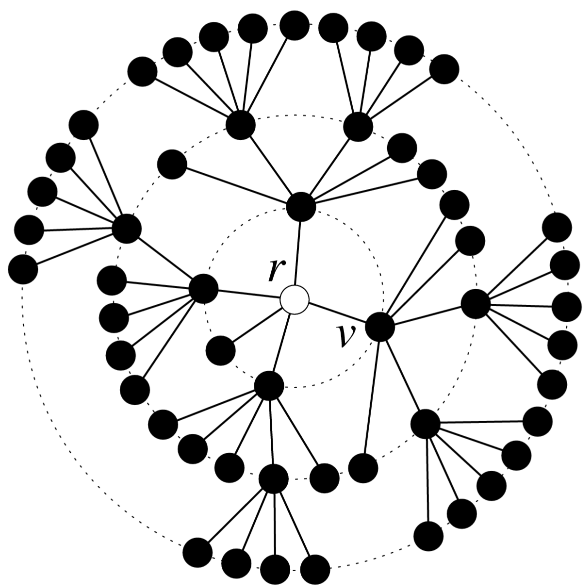
- Graph animation:
  - Eades et al. 1991 [5]
  - Huang et al. 1998 [11]
  - Friedrich et al. 2002 [8]
  - Friedrich et al. 2002 [9]
  - Diehl et al. 2002 [3]
  - Nesbitt et al. 2002 [19]
- Radial layout animation:
  - Yee et al. 2001 [27]
  - Jankun-Kelly et al. 2003 [13]

Related Work: Radial Layout Drawings

- Methods for drawing rooted trees:
  - Eades 1992 [4]
  - **Yee et al. 2001** [27]
  - Melancon et al. 1998 [16]
  - Wills 1999 [26]
  - Teoh et al. 2002 [24]



From Teoh et al. [24]



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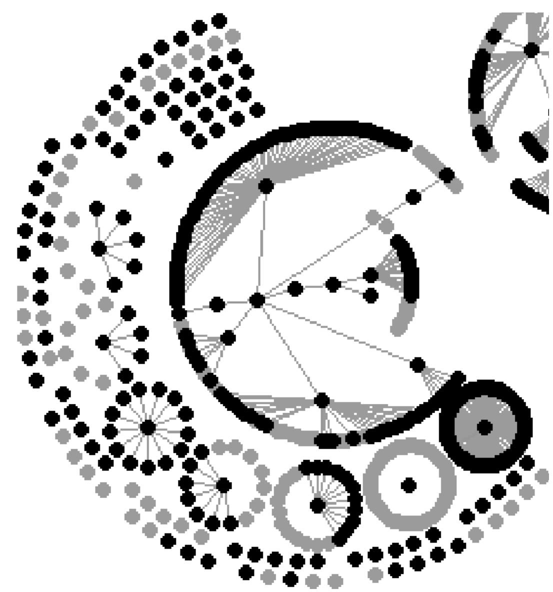
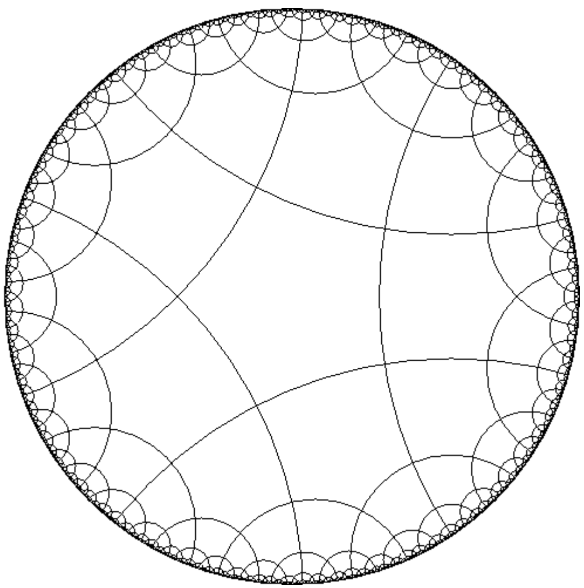


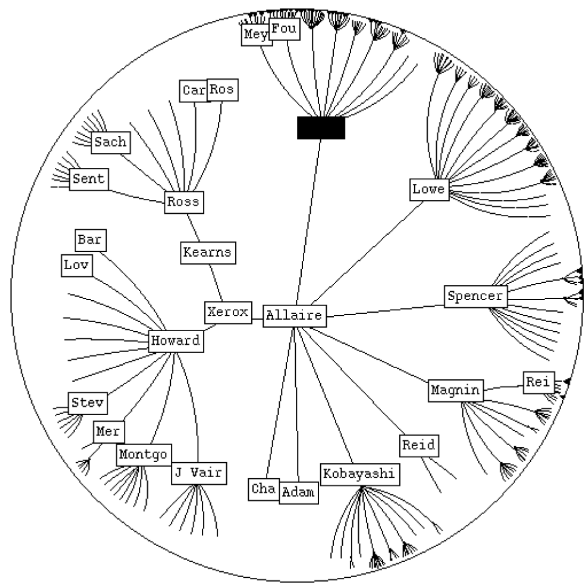
From Melancon et al. [16]

Related Work:
Hyperbolic Layout Drawings

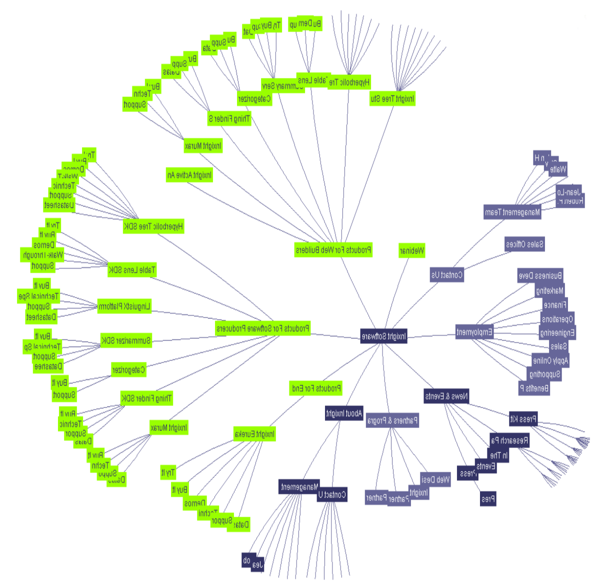
- Space-filling layout on the hyperbolic plane
- Projection into Euclidean space/plane
- Distant elements are displayed with less space
- Examples:
  - Lamping et al. 1995 [15]
  - Munzner 2000 [18]



From Curtis T. McMullen / Harvard



From Lamping et al. [15]

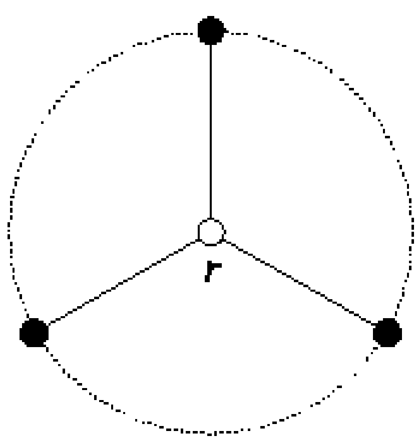


From Inxight Software, Inc.

Drawing Algorithm (1)

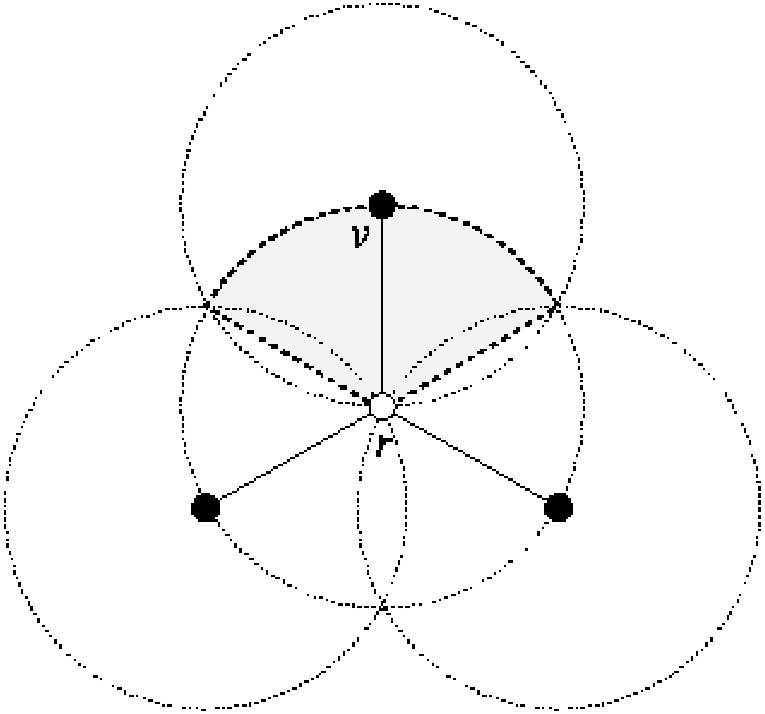
Drawing Algorithm (1)

- Root is placed at the center
- Containment circle centered at root
- Root's children are positioned evenly on this circle



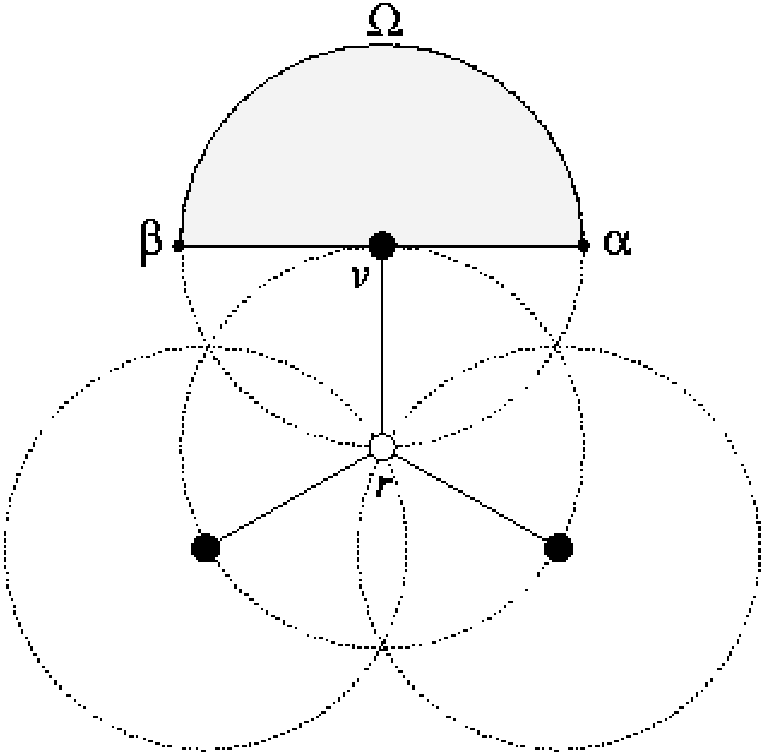
Drawing Algorithm (2)

- Root's children are allocated equal-sized circles



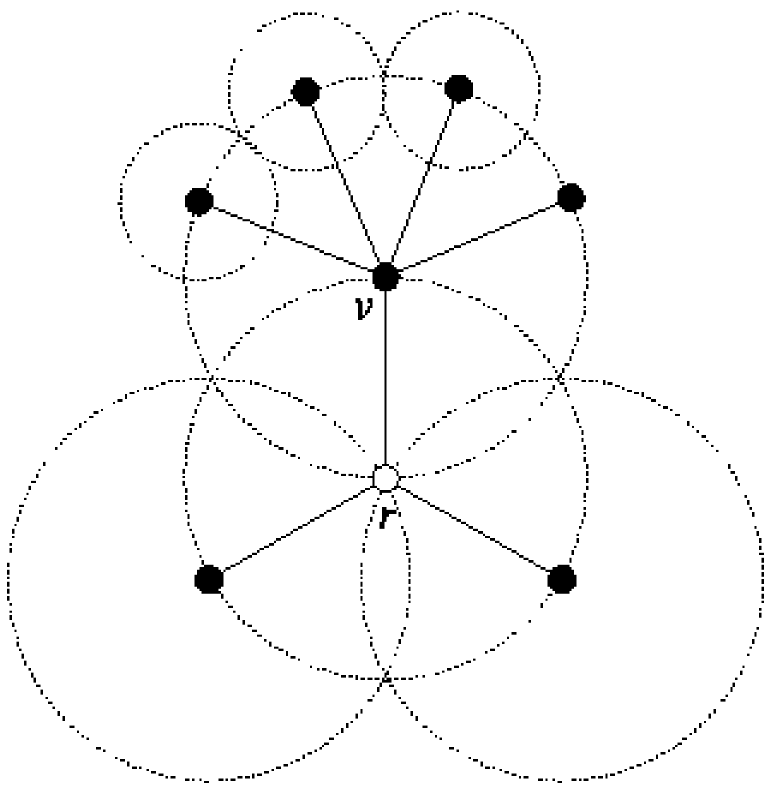
Drawing Algorithm (3)

- Calculate the area for the next subtree level



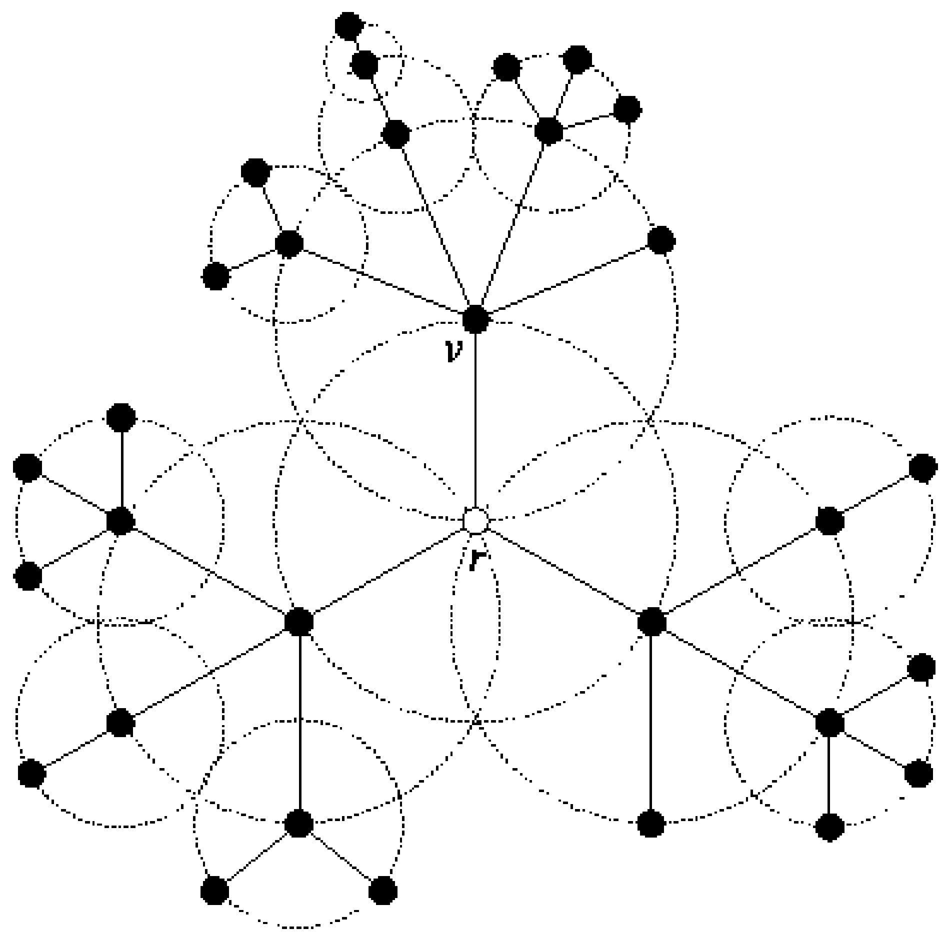
Drawing Algorithm (4)

- Process continues down each subtree



Drawing Algorithm (5)

- Final layout
- Runs in *O(n)* time



Demo

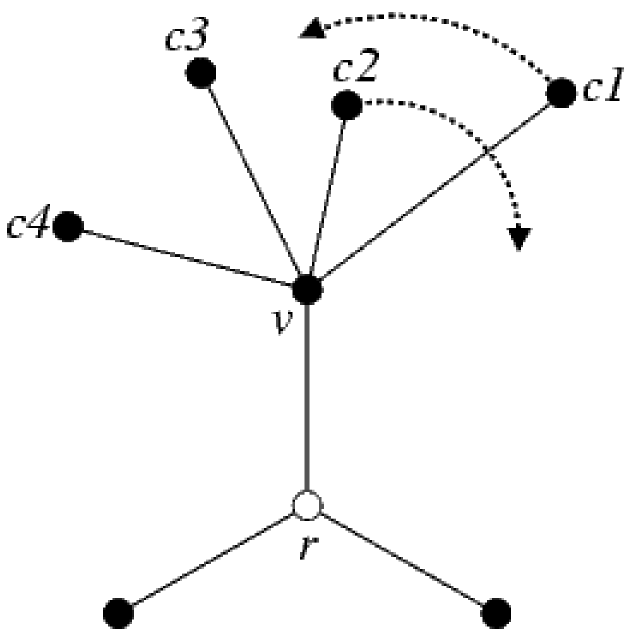
- Randomly generated graph:
  - Erdos-Renyi model [7]
  - 30 vertices
  - 10% probability edge connectivity
- Initial force-directed graph drawing
- Spanning-tree-based drawings

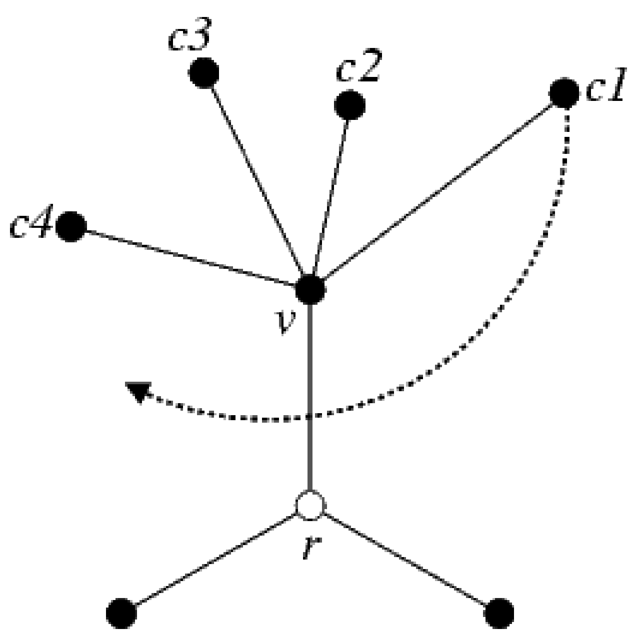
Animation Algorithm

- Smoothly transition between graph drawings
- Vertices move on radial paths
- Help users relate one drawing to the next

Animation Goals

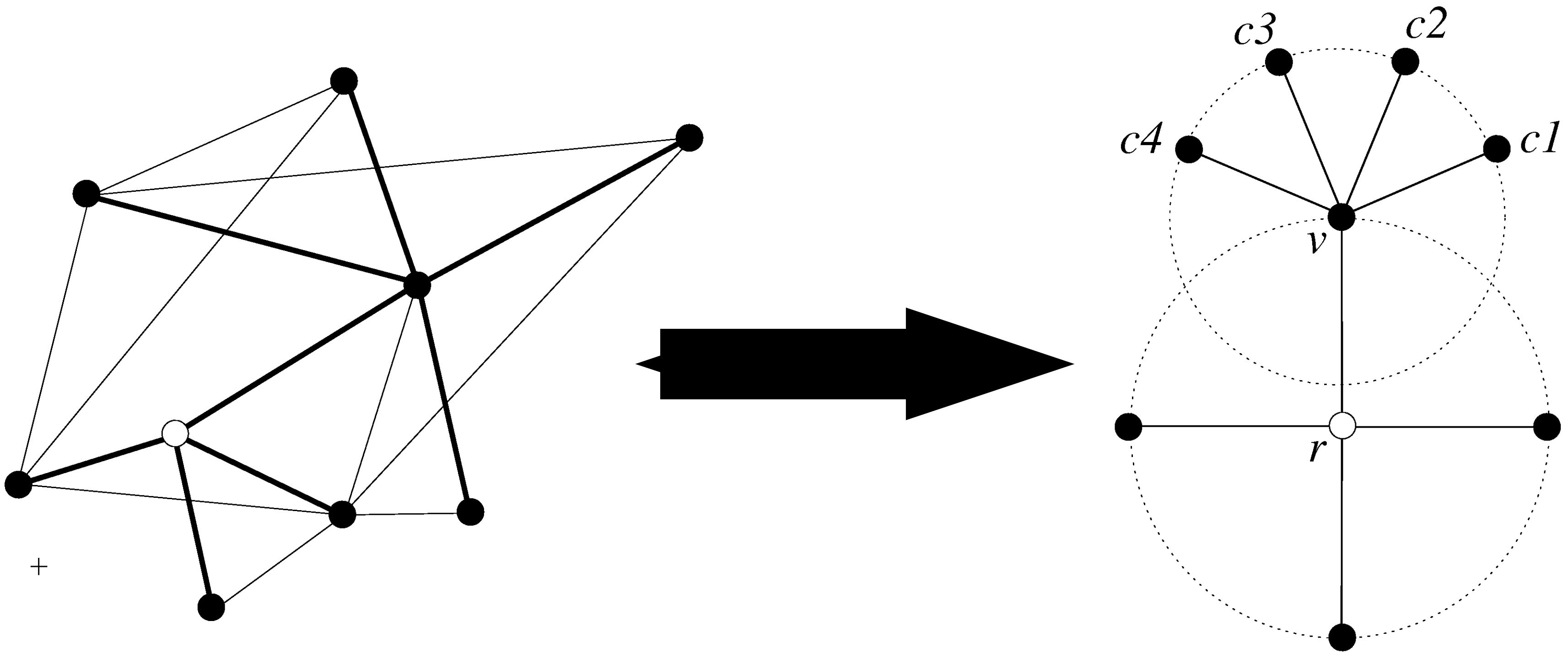
- Minimize the number of edge crossings
  - Sibling vertices
  - Parent-child with parent-grandparent





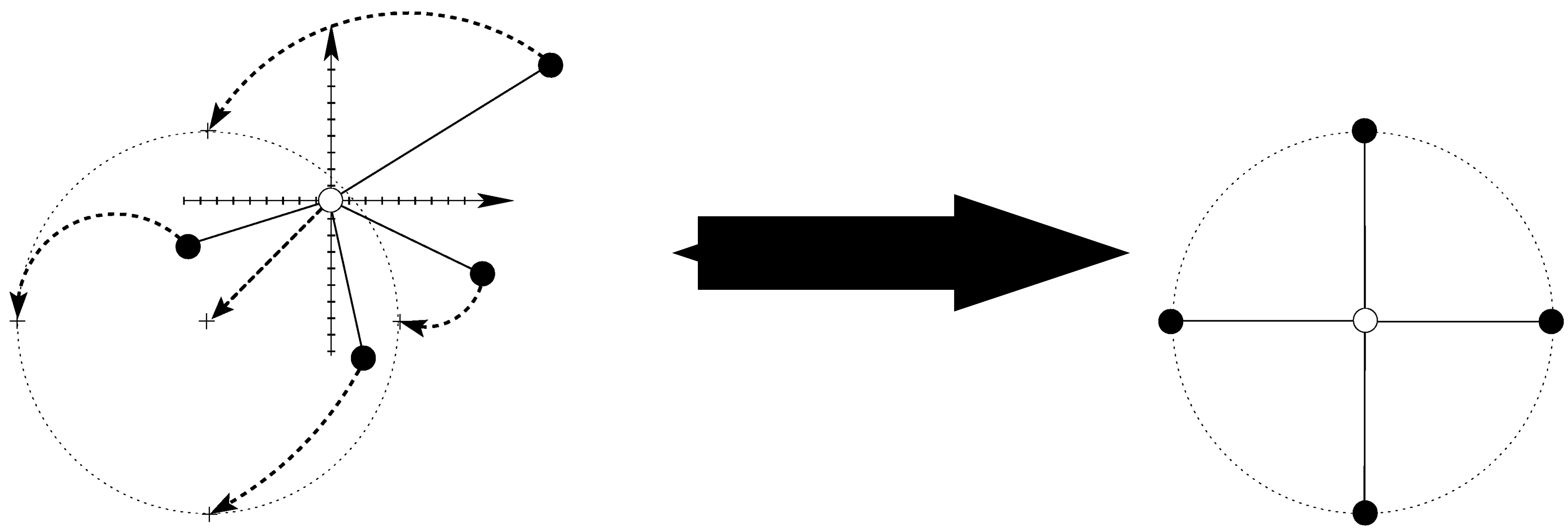
Animation Algorithm (1)

- Calculate polar coordinates to new parent in old drawing
- Calculate polar coordinates to parent after the animation in the new drawing
- Calculate deltas for each child



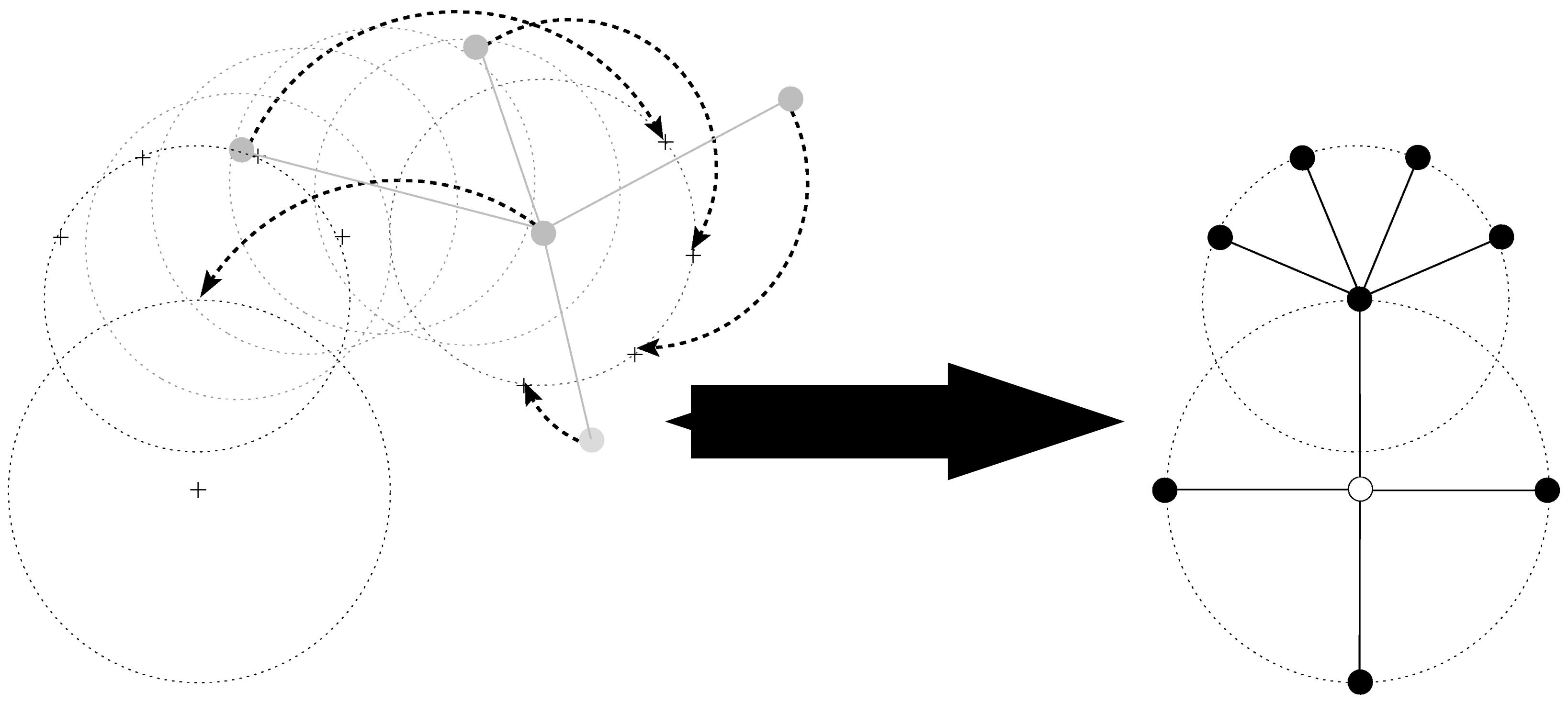
Animation Algorithm (2)

- The root moves in a straight-line path to the center
- The root's children move from an interpolation of their polar coordinates
- Children's coordinate system centered at parent



Animation Algorithm (3)

- Vertices move relative to their parent
- Minimal rotational movement
- No crossings between siblings

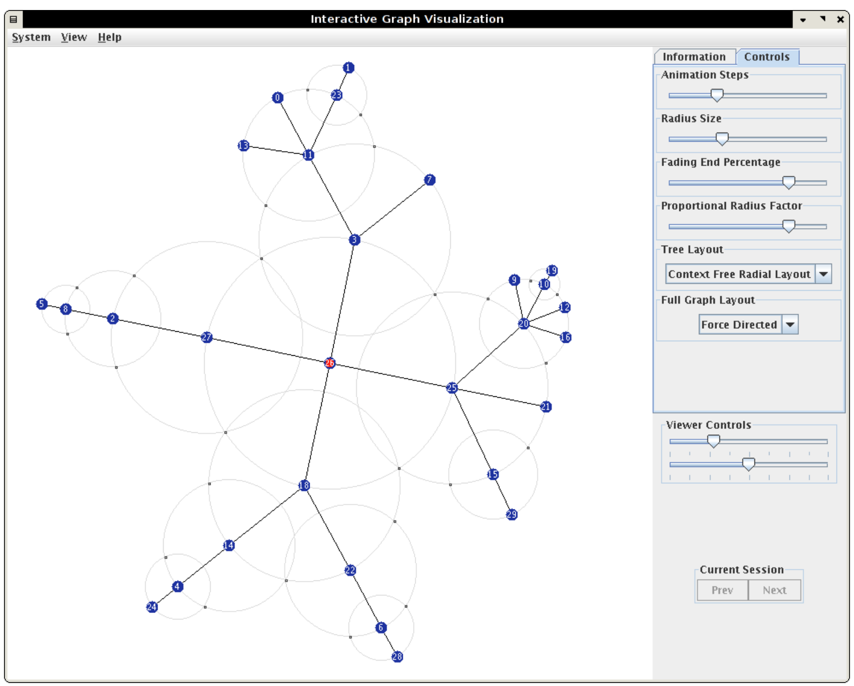


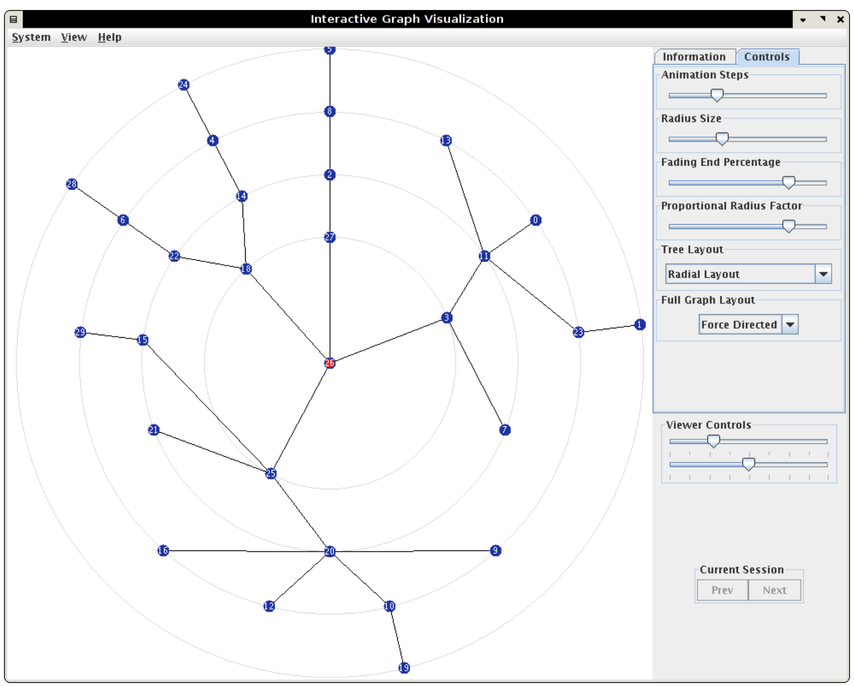
Demo

- Randomly generated graph:
  - Erdos-Renyi model [7]
  - 30 vertices
  - 10% probability of edge connectivity
- Initial force-directed graph drawing
- Spanning-tree-based drawings
- Animated transitions
- Fading of graph elements [8]
- Slow-in, slow-out timing [27]

Experimental Analysis

- Evaluate our visualization scheme
- Compare against Gnutellavision from Yee et al. [27]





Measurements

- Edge Crossings
  - Transient crossings
  - Final layout crossings
- Sibling Edge Lengths

Methodology

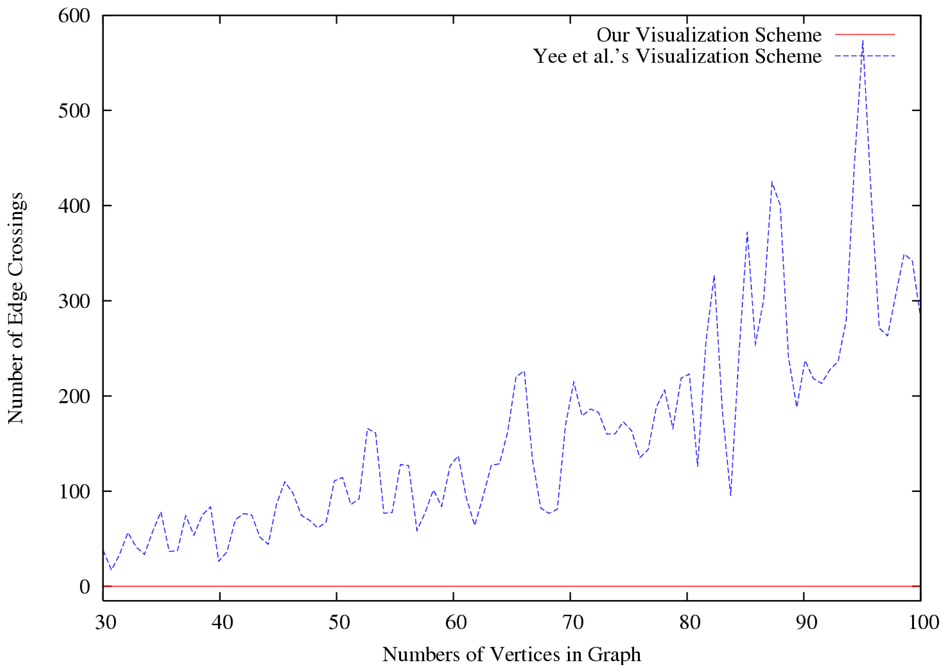
- Graph order - 30 to 100 vertices (inclusive)
- 10 trials per graph size
- Average measurements for all trials per graph size
- Randomly generated graphs
- Randomly selected root vertices

Experiment 1:
Isomorphic Tree Transitions

- Measure transitions between drawings of two spanning trees T_1 rooted at r_1 and T_2 rooted at r_2, where $r_1 \neq r_2$ and $E(T_1) = E(T_2)$.
- Count the crossings between all edges

Experiment 1:
Isomorphic Tree Transitions

- Our algorithms produce zero crossings.
- Yee et. al's algorithms:
  - Vertices move on the shortest radial path
  - Preserve the edge direction of the new root with its parent from previous drawing



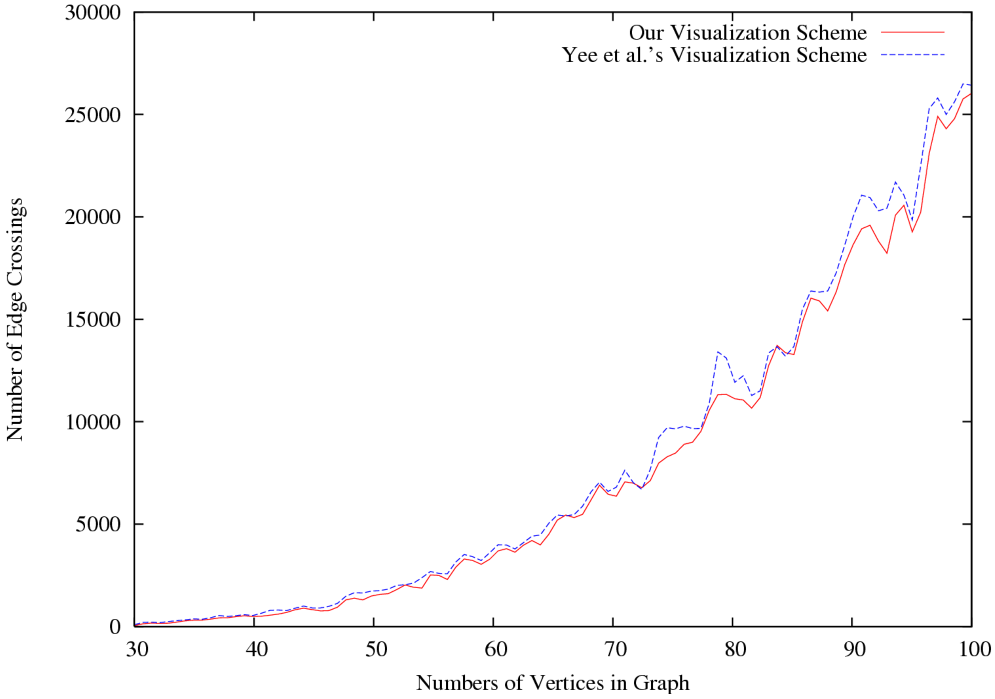
Total Edge Crossings

Experiment 2:
Spanning-Tree-to-Spanning-Tree Transitions

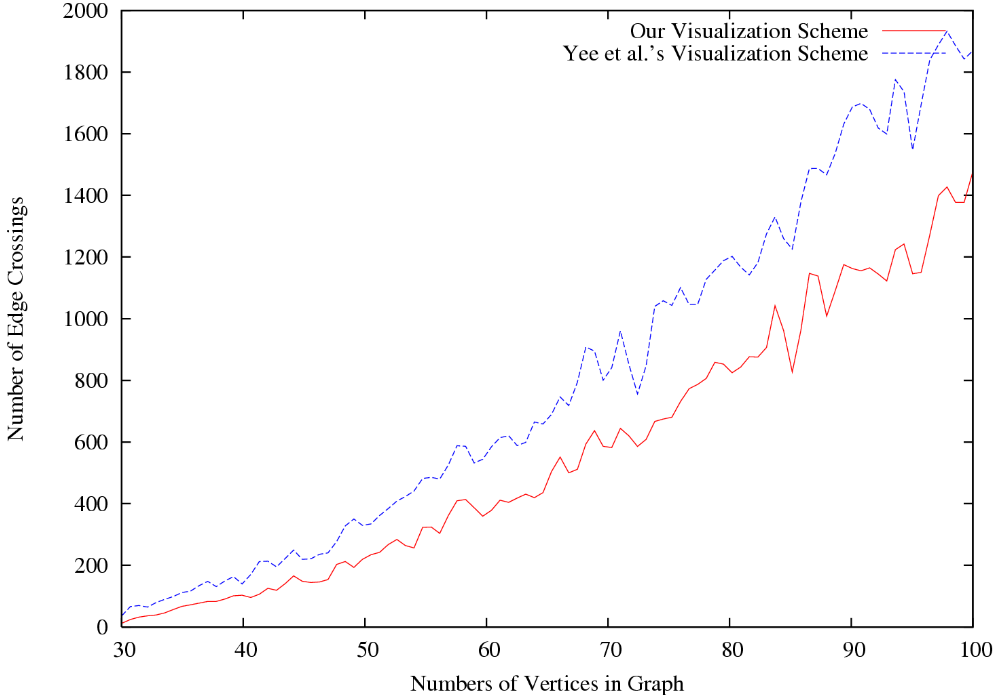
- Measure transitions between drawings of two spanning trees T_1 rooted at r_1 and T_2 rooted at r_2, where $r_1 \neq r_2$ and $E(T_1) \neq E(T_2)$.
- Count the crossings between all edges

Experiment 2:
Spanning-Tree-to-Spanning-Tree Transitions

- Results



Total Edge Crossings



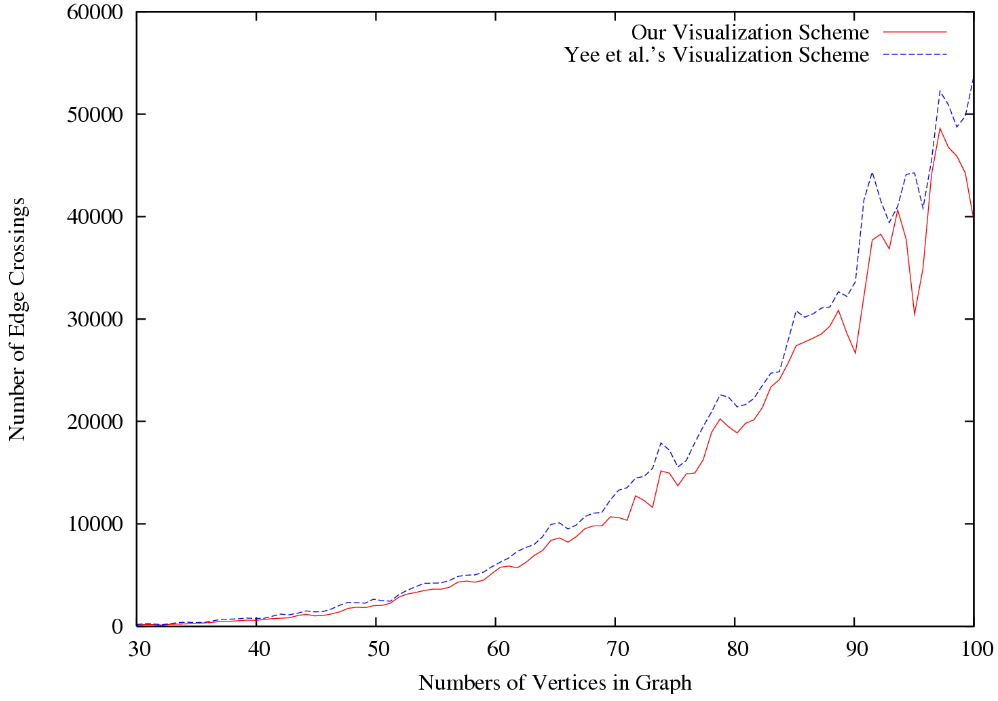
Final Layout Edge Crossings

Experiment 3:
Full-Graph-to-Spanning-Tree Transitions

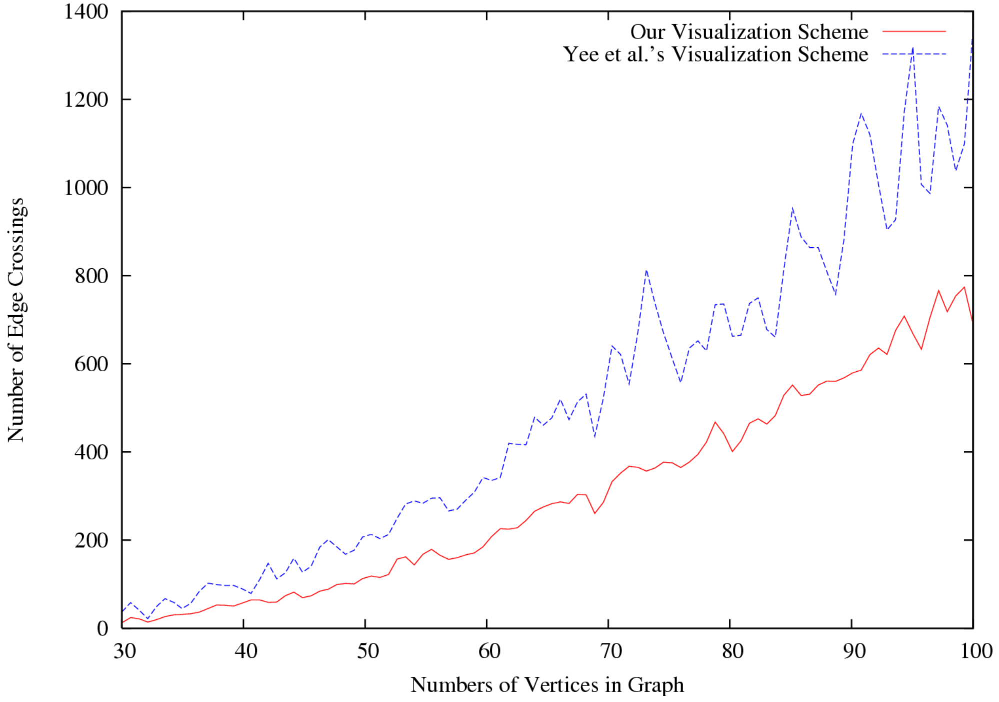
- Measure transitions between a force-directed layout drawing of the full graph to a spanning tree drawing rooted at randomly selected vertex.
- Count crossings between all edges
- Scenario is specific to our visualization system

Experiment 3:
Full-Graph-to-Spanning-Tree Transitions

- Results



Total Edge Crossings



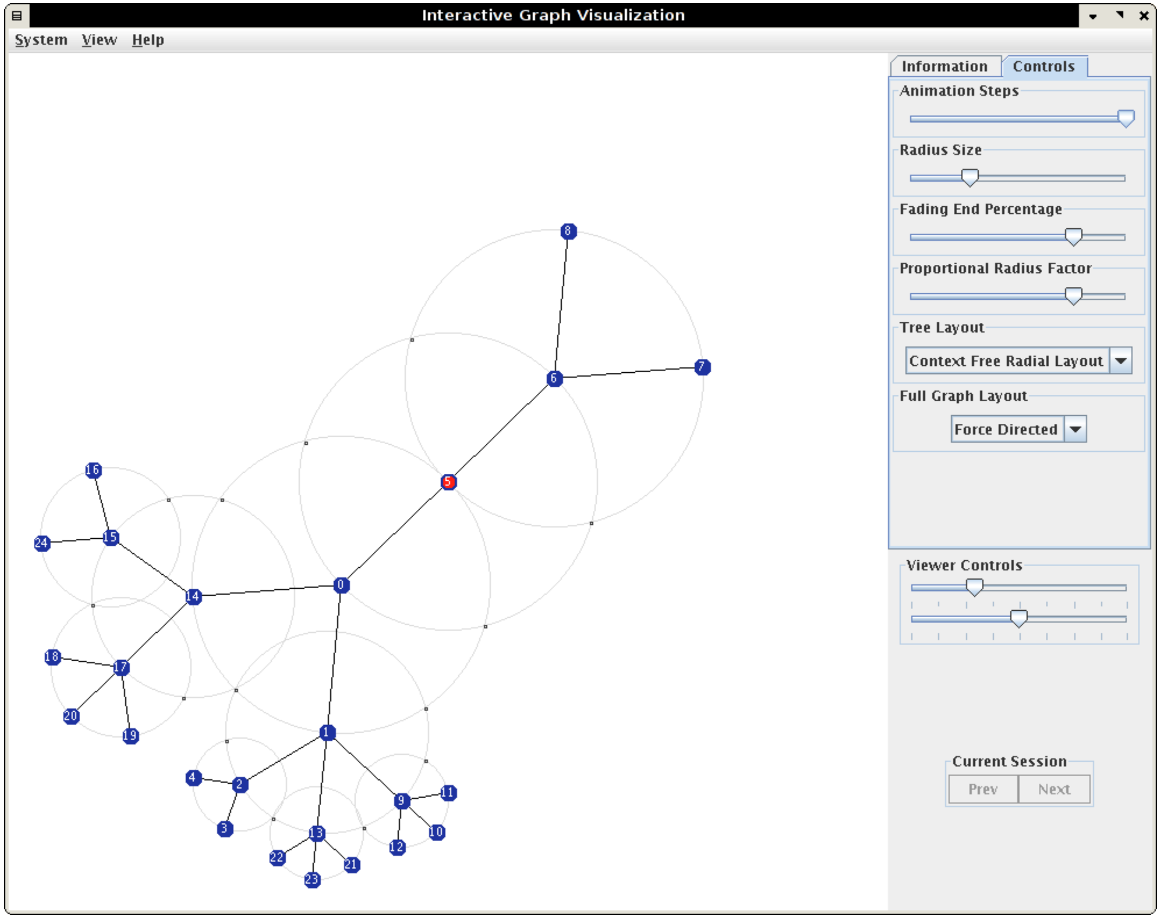
Final Layout Edge Crossings

Experiment 4:
Spanning Tree Sibling Edge Lengths

- Measure the edge lengths of sibling vertices in a spanning tree drawing.
- Static spanning tree drawings
- Mean length and mean standard deviation for each graph size

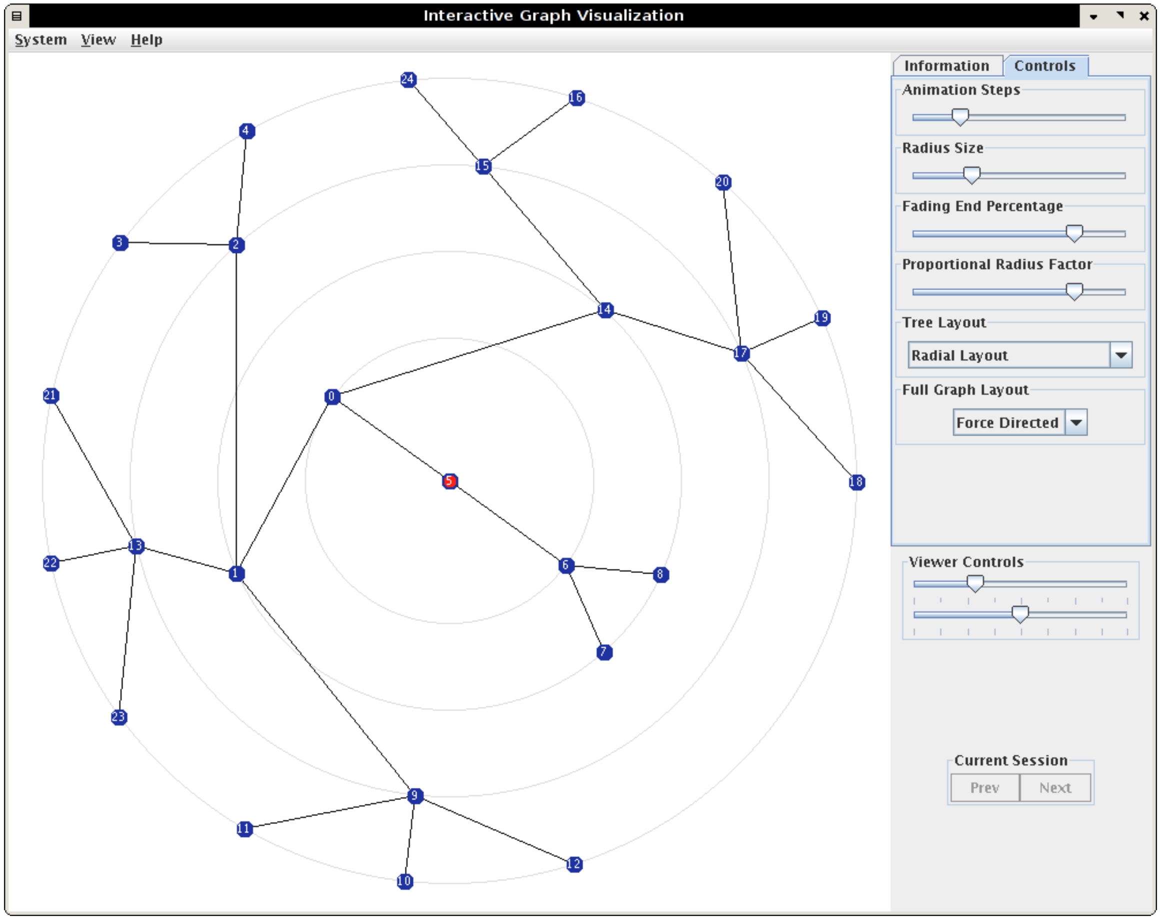
Experiment 4:
Spanning Tree Sibling Edge Lengths

- Our algorithm:
  - Siblings are equidistant to their parent.
  - Edge length conveys depth to the root.



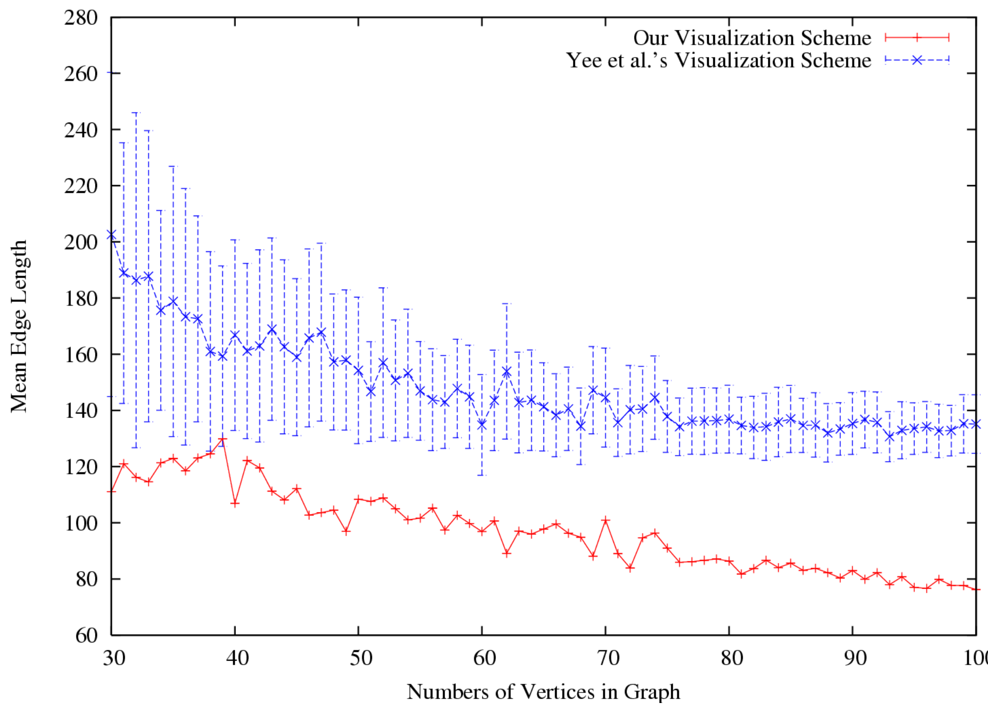
Experiment 4:
Spanning Tree Sibling Edge Lengths

- Yee et. al's algorithm:
  - Vastly different sibling edge lengths
  - Difficult to perceive parent-child relationships



Experiment 4:
Spanning Tree Sibling Edge Lengths

- Results



Mean Length of Sibling Edges with Standard Deviation

Discussion

- Our drawings make structural properties apparent
- Our transitions produce fewer edge crossings
- Users can make better judgments about graphs

Future Work

- Behavioral experiments
- Graph animation aesthetics
- Guarantee planarity

Conclusion

- Graph drawing algorithm
- Graph animation algorithm
- Experimental analysis
- References attached in handout