Advanced Data Visualization

CS 6965

Fall 2019

Prof. Bei Wang Phillips

University of Utah

Lecture 21

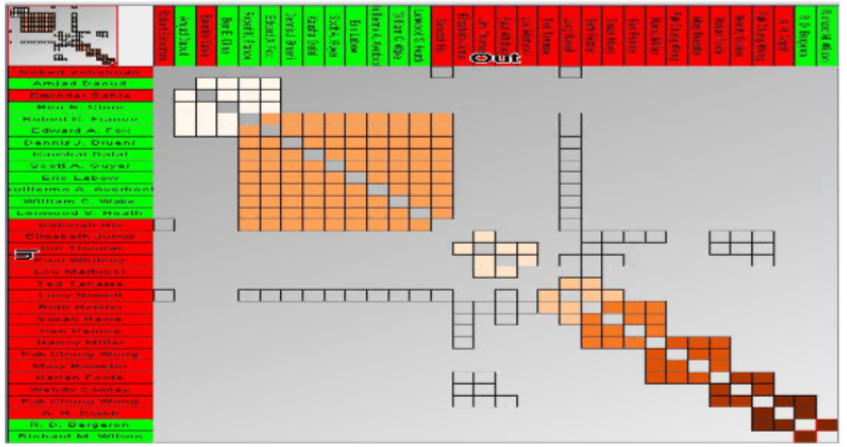
Graph Layout

NV

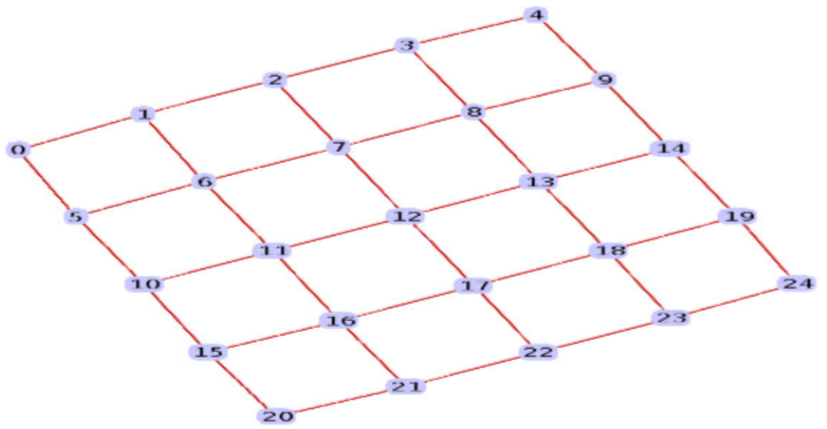
Graph Layout: A Brief Overview

TarawnehKellerEbert2011

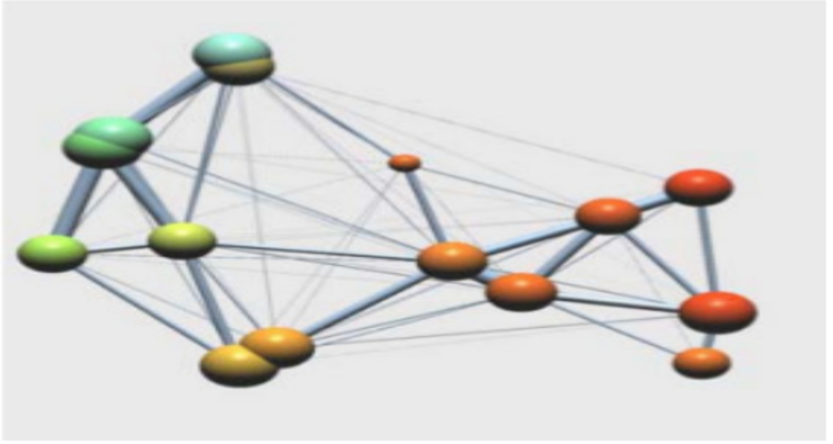
http://drops.dagstuhl.de/opus/volltexte/2012/3748/pdf/13.pdf



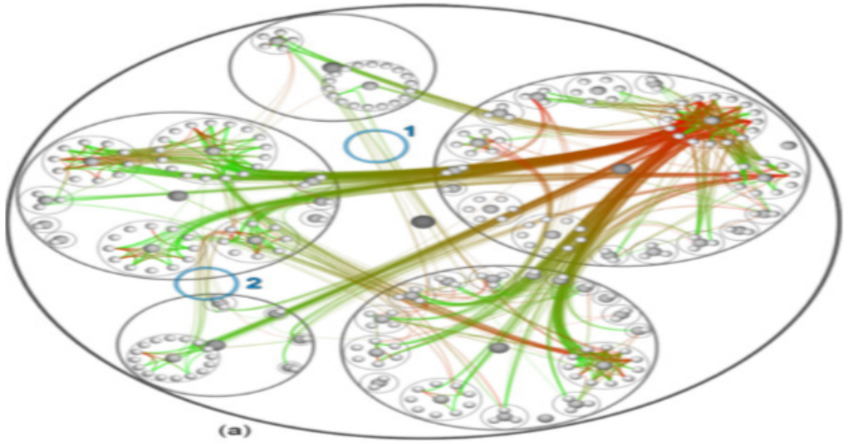
(a) Matrix visualization layout [21].



(b) Example of a force-directed layout.



(c) Clustering example by [54].



(d) Edge bundling example by[23].

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Graph Vis: layouts + interactions

1. Node-Link Layouts
   1. The Spring Layout Algorithm: Force-directed layouts
   2. Topological Feature-Based Layout
   3. Planar Graphs
2. Tree Layout
   1. Node-Link Tree layout Algorithms
   2. Space-Filling Techniques
3. Matrix Visualization
4. 3D Layout
5. Nodes and Edges Clustering

- Interaction Techniques
  - Zooming and Panning
  - Focus+Context Techniques

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Node-Link Layouts

Criteria and examples

Desirable criteria:

Computation of the coordinates of the nodes and the representation of the lines:

- Nodes and edges should be evenly distributed.
- Edge-crossings should be minimized.
- Depict symmetric sub-graphs in the same way.
- Minimize the edge bending ratio.
- Minimize the edge lengths, which helps readers detecting the relations among different nodes faster.
- In cases where the data is inherently structured, distribute the nodes into different layers. This increases the understandability of the underlying graph.

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Topological Feature-Based Layout

Pipeline contains 4 phases:

1. Decomposition: graph is decomposed into many sub-graphs based on the topological features of each internal sub-graph.
   - E.g. if the nodes in one sub-graph are topologically connected among each other in form of a tree, then the set of nodes are grouped together representing a meta-node.
   - 7 topological features: trees, complete graphs, bi-connected components, clusters, etc.
2. Feature layout: meta-nodes (or grouped sub-graphs) are laid out.
3. Crossing reduction: eliminate the crossing ratio in the produced layout.
4. Overlap elimination: change the node sizes in the final layout to ensure that no nodes overlap each other.

ArchambaultMunznerAuber2007

Topological Feature-Based Layout

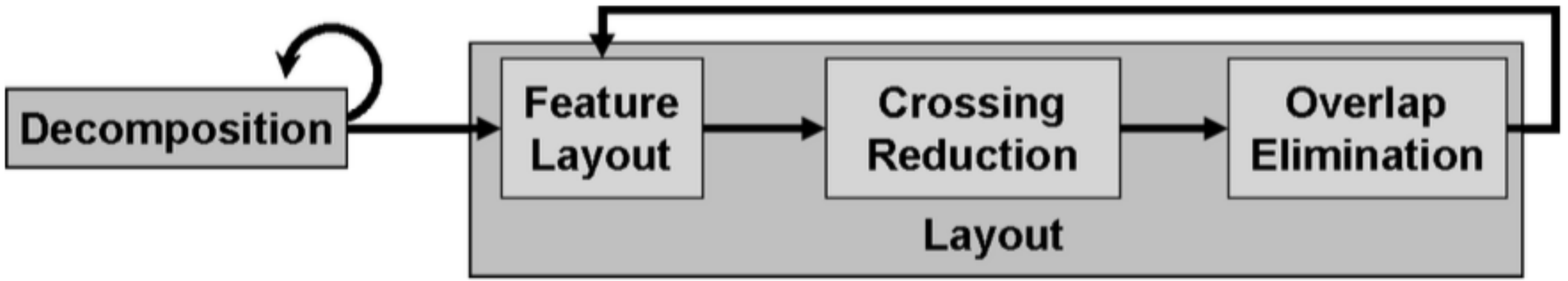

Fig. 1. TopoLayout algorithm phases.

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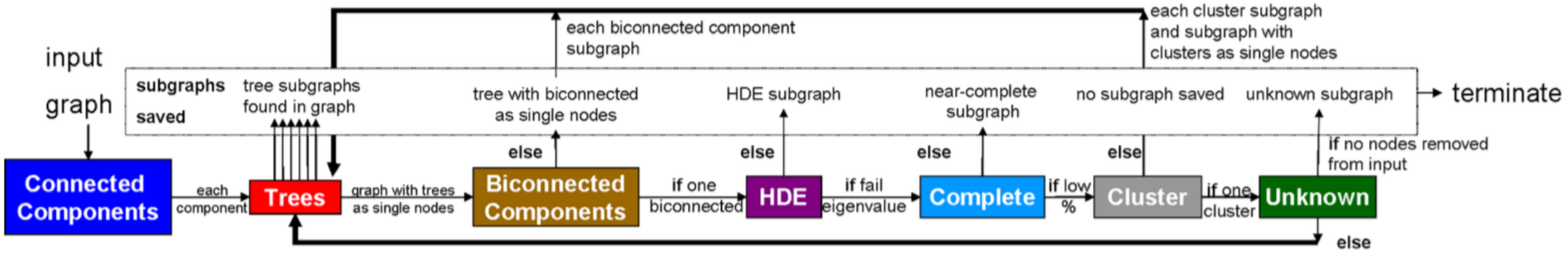

Fig. 3. Decomposition phase for TopoLayout. Detection algorithms in boxes coloured by feature type as in Figure 2. If a clause on a horizontal is true, we transition along the arrow. Otherwise, we follow the vertical arrow to save some subgraphs and recursively decompose others. Bold arrows indicate the recursive cases.

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Feature Hierarchy

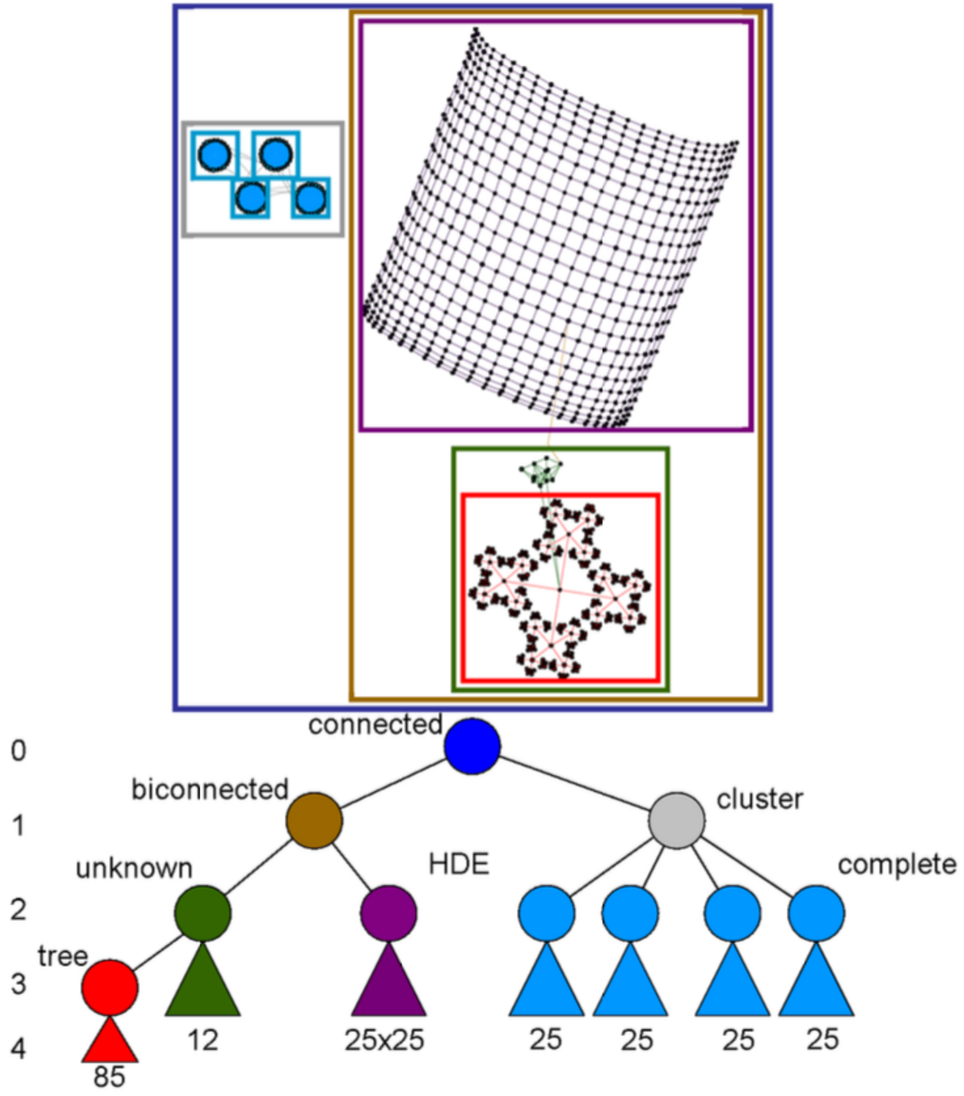

Fig. 2. Feature hierarchy after decomposition, with topology encoded by colour. **Top**: Layout annotated with bounding boxes to show hierarchy structure: meta-nodes encompass the subgraphs of their children. **Bottom**: Diagram of feature hierarchy, with levels enumerated and nodes labeled by feature type.

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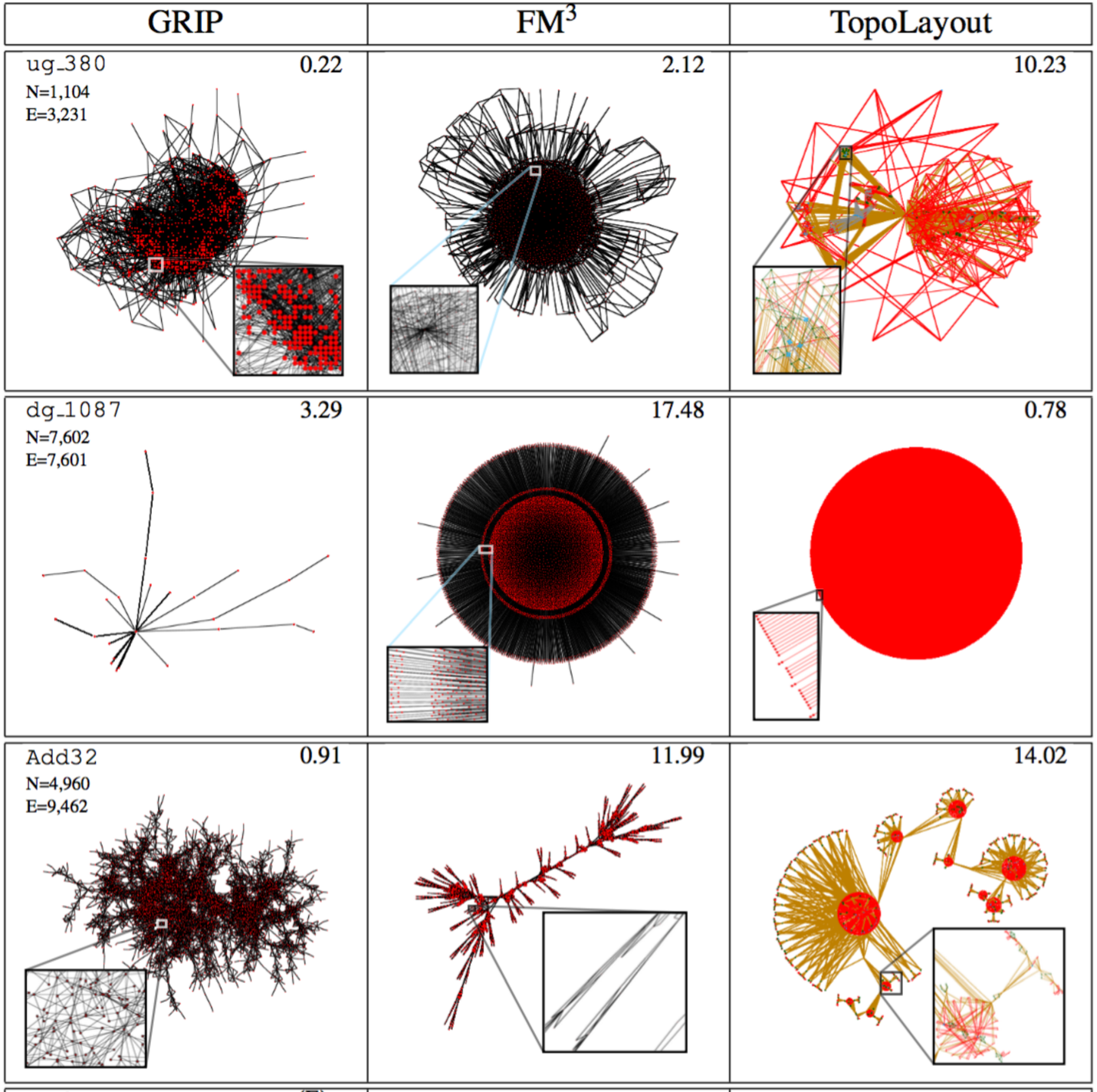


ArchambaultMunzner
Auber2007

Discussions

- TopoLayout Extensions?
- The power of flexibility
- Feature based graph analysis and visualization

Challenge: directed graph layout

Two step approach:

- First, layer the graph nodes: assign a layer for each node and placing the nodes into the corresponding layer.
- Second, reduce the edge-crossings and the node overlapping.

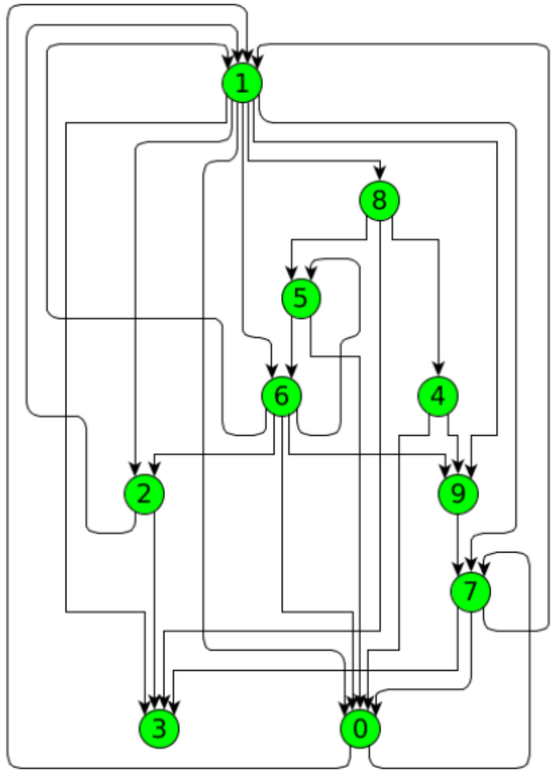
SugiyamaTagawaToda1981

L-Drawing of directed graphs

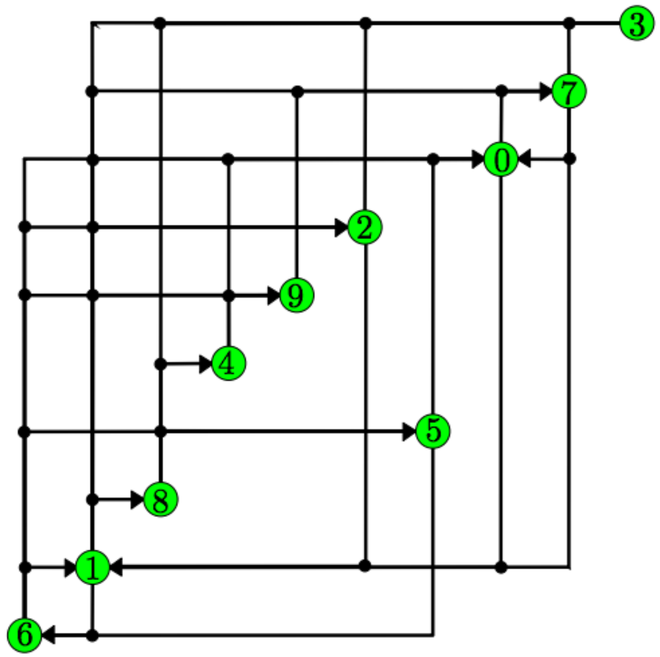
Combine Orthogonal Graph Drawing with matrix representation:

- Each vertex has exclusive x- and y-coordinates and each directed edge has two orthogonal segments, one leaving the source vertically and one entering the destination horizontally.
- Edges are allowed both to overlap and to intersect.
- Graphically, the joint between the horizontal and the vertical segment of an edge is drawn as a small circular arc, allowing the user to easily identify the edges even in the presence of overlaps and intersections
- The matrix is symbolically represented by the edges, that identify the portions of the rows and columns that have to be followed to connect adjacent vertices

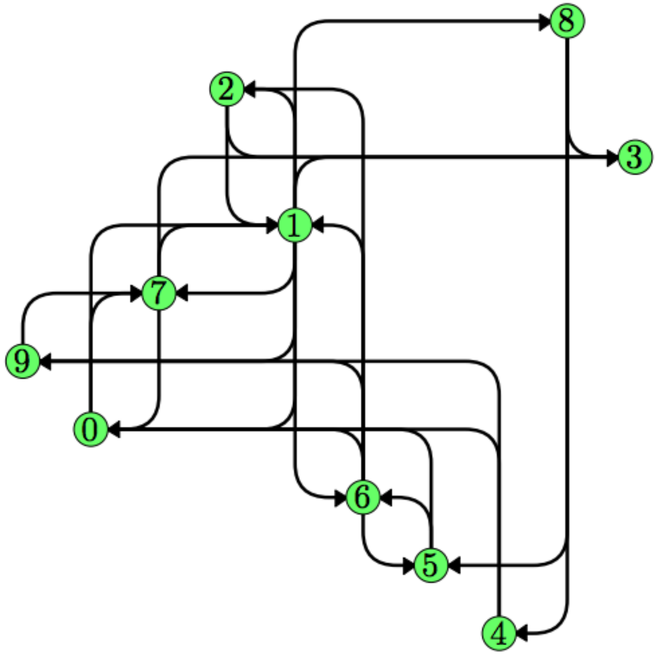
L-Drawing of directed graphs



(a)



(b)



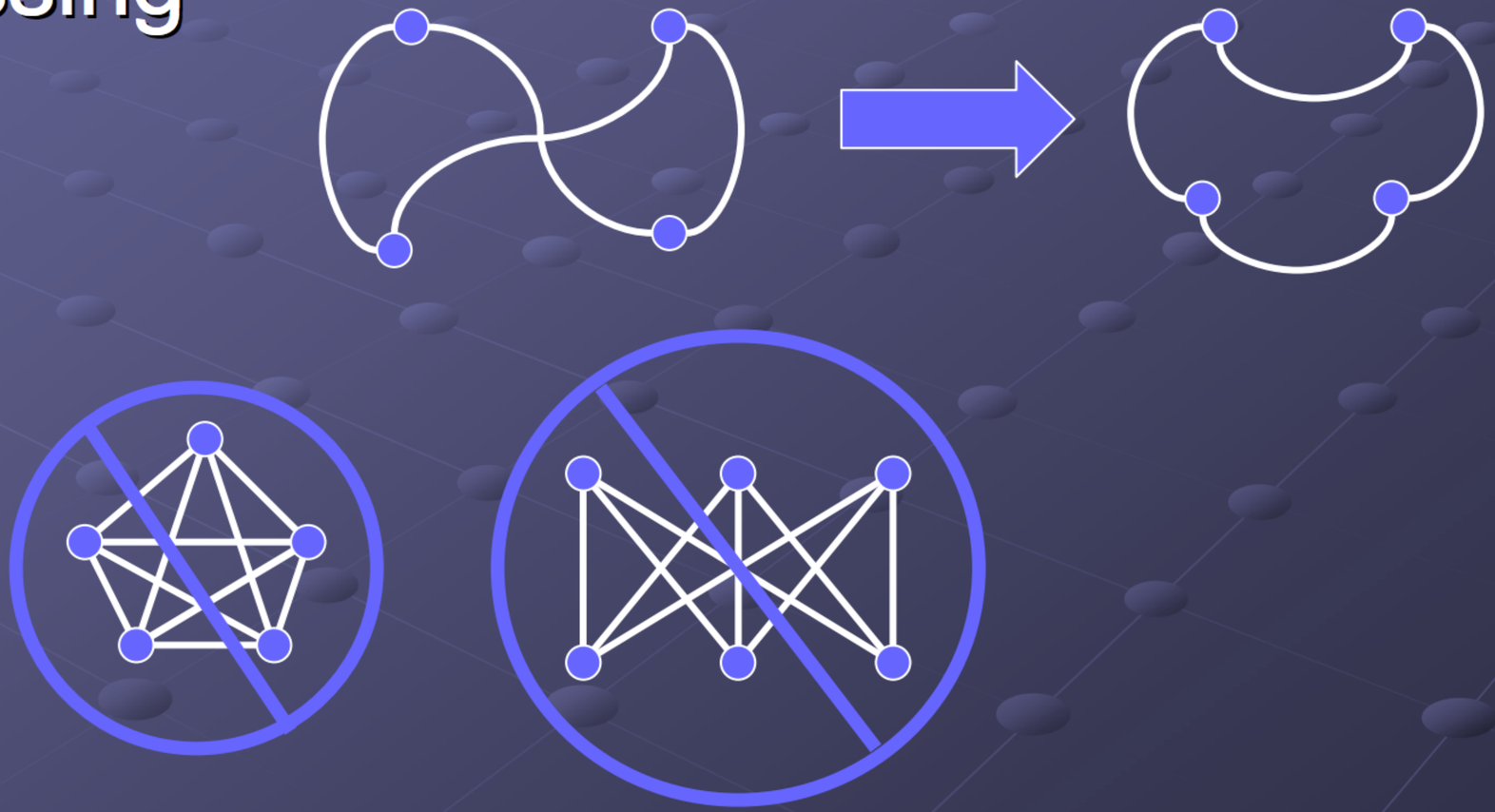
(c)

AngeliniLozzoBartolomeo2015

Planer Graph Layout

- Graphs that can be drawn without edge crossings
- Pre-requisites:
  - Testing whether it is possible to draw the given graph without edges crossings or not.
  - Finding a planar layout algorithm satisfying the required application constrains.
- Schnyder's Algorithm

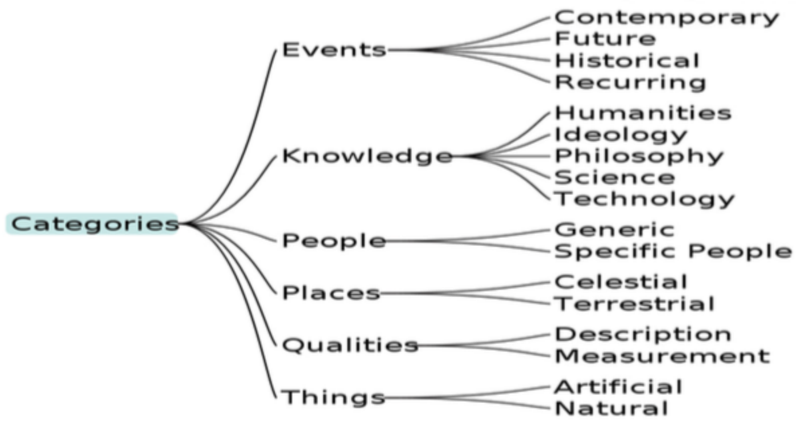
- A Graph G=(V,E) is a Planar Graph if it can be drawn in the plane with no edges crossing



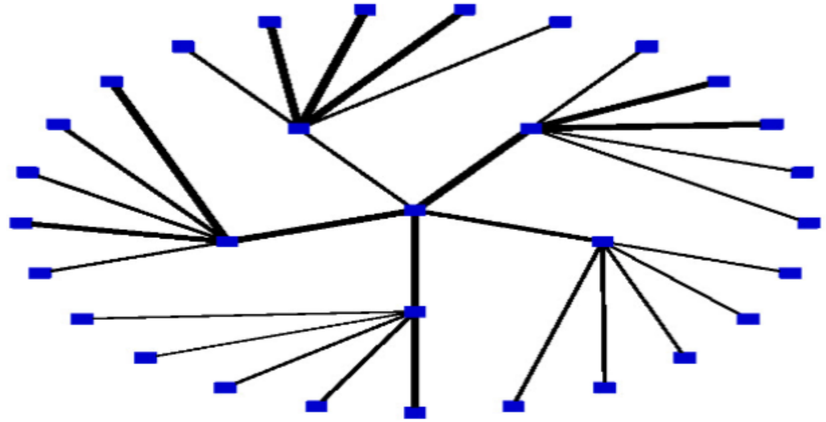
https://pdfs.semanticscholar.org/9c89/7e65499cc6caacabd8abab6071010b03248c.pdf
Slides by Jon Harris

2
Tree Layouts

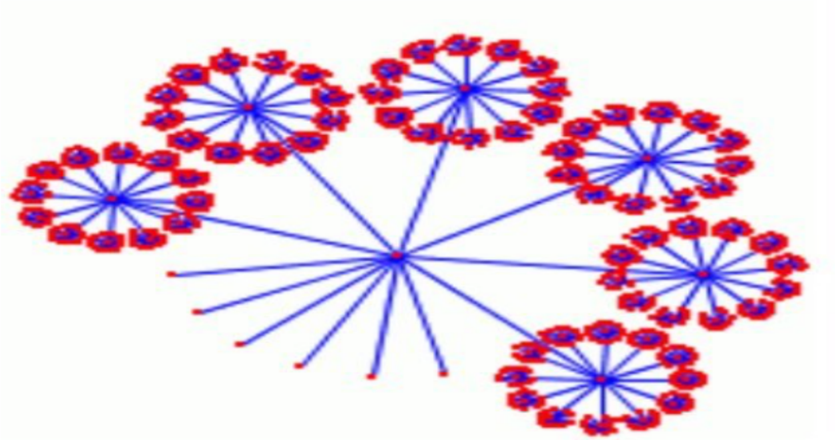
Node-Link Tree Layout



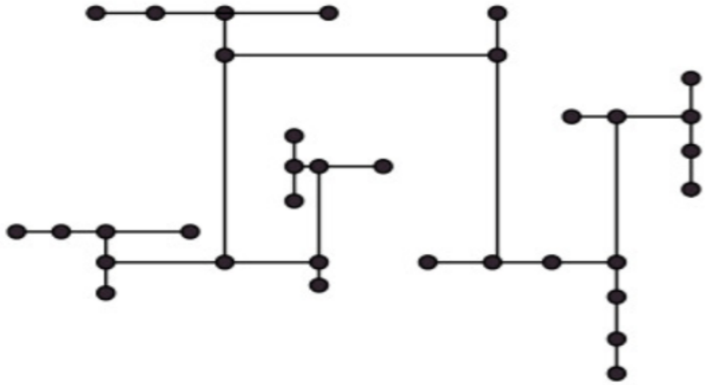
(a) Classical tree layout, produced with [19].



(b) Radial tree layout Example.



(c) Balloon tree layout: produced by [22].



(d) H-Tree layout: produced by [22].

Figure 2 Tree Layout Examples.

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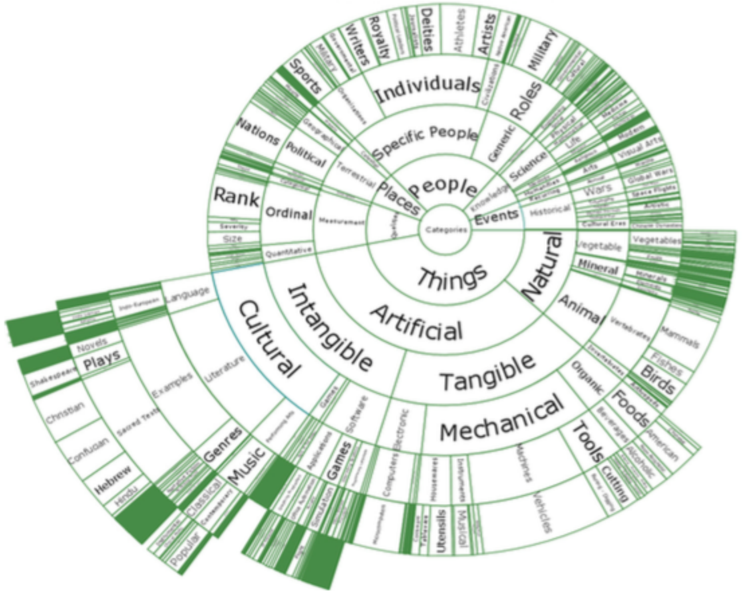
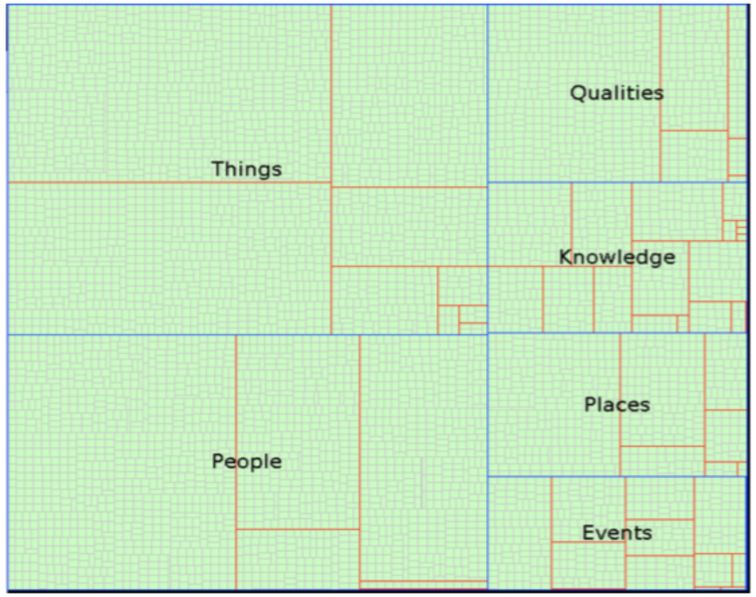
Space-Filling



(a) SunBurst layout.



(b) TreeMap layout.

Figure 3 Examples of space-filling techniques [19].

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3
Matrix Visualization

MatrixExplorer

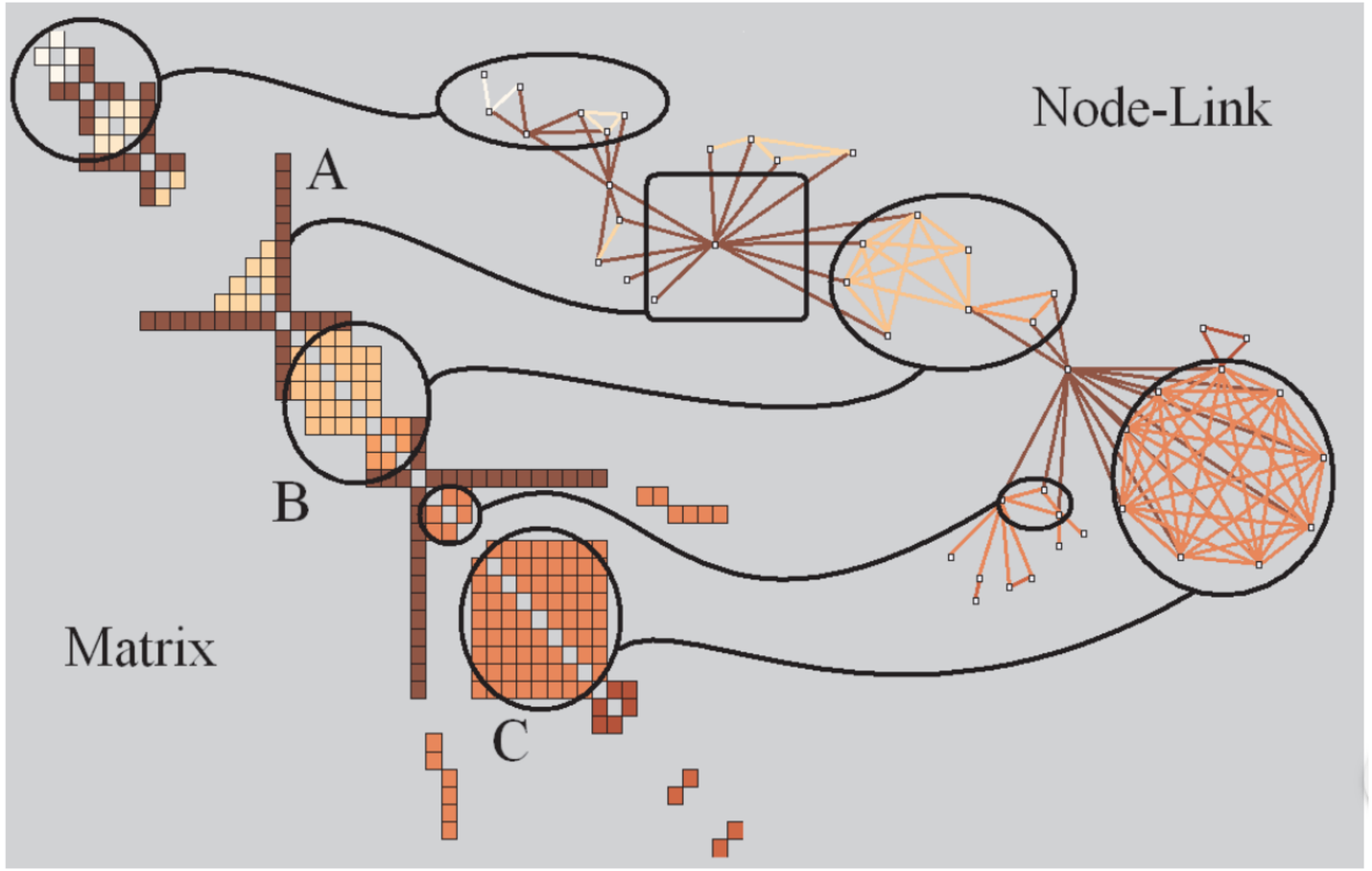


Fig. 3. Visual patterns in Matrix and Node-link representations of social networks. A represents an actor connecting several communities, B a community and C a clique (complete sub-graph).

HenryFekete2006

4

3D Layout

TreeCube

Extension from TreeGraph

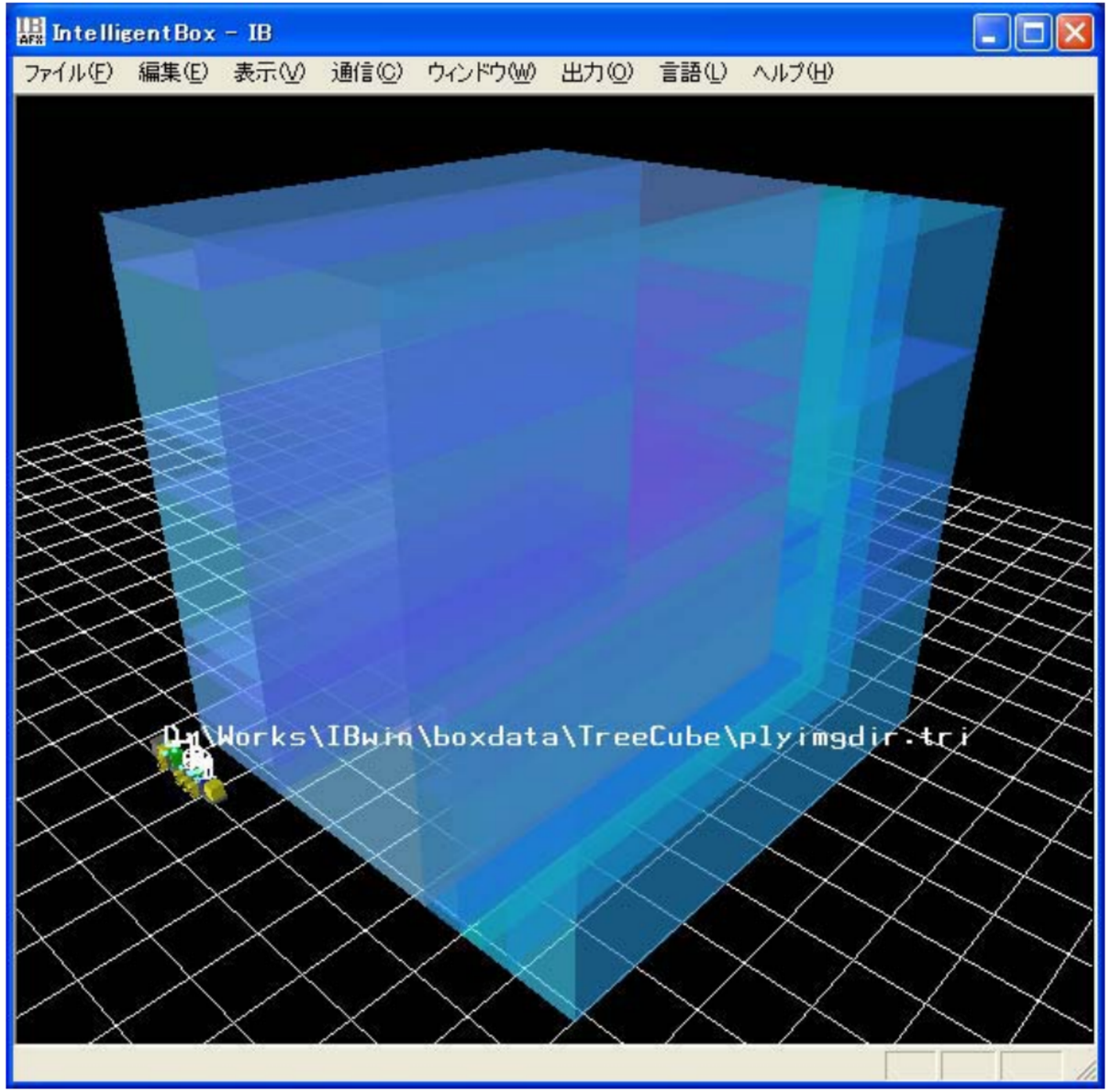


Fig. 2: Layout example of hierarchical information by the slice-and-dice treecube algorithm.

TanakaOkadaNiijima2003

True Cube

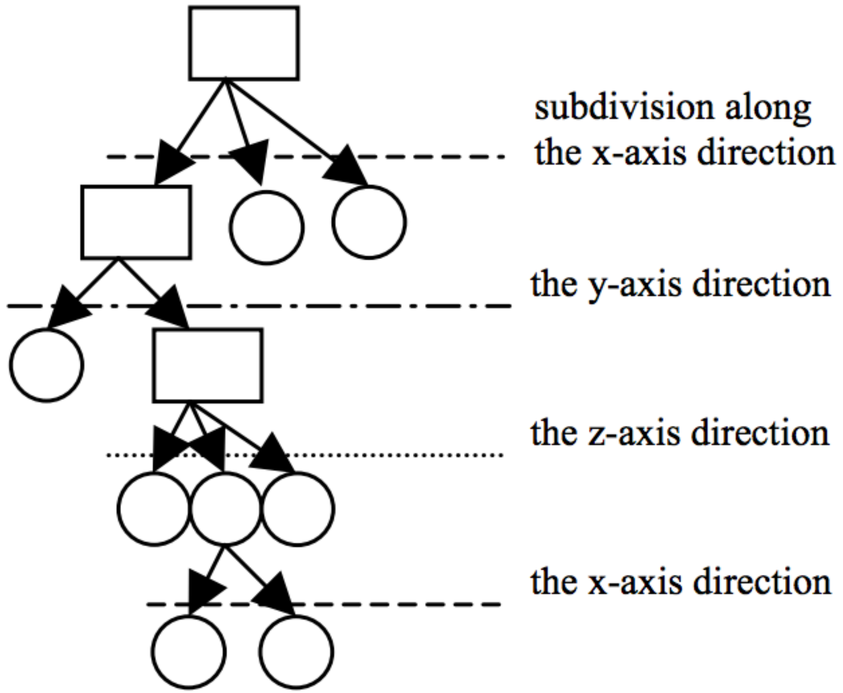


Fig. 1(a): Hierarchical information and the direction of the subdivision operation in its each level.

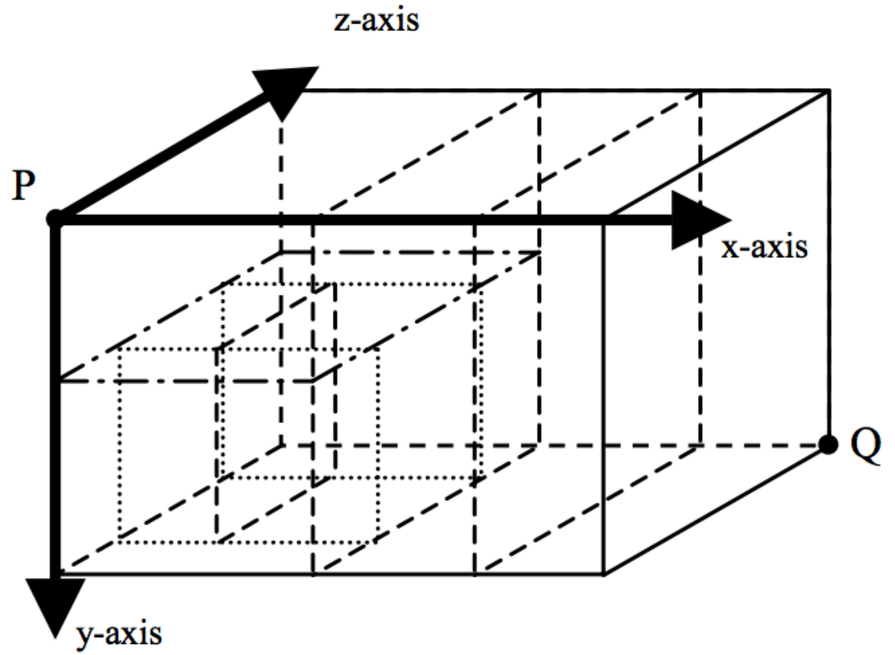
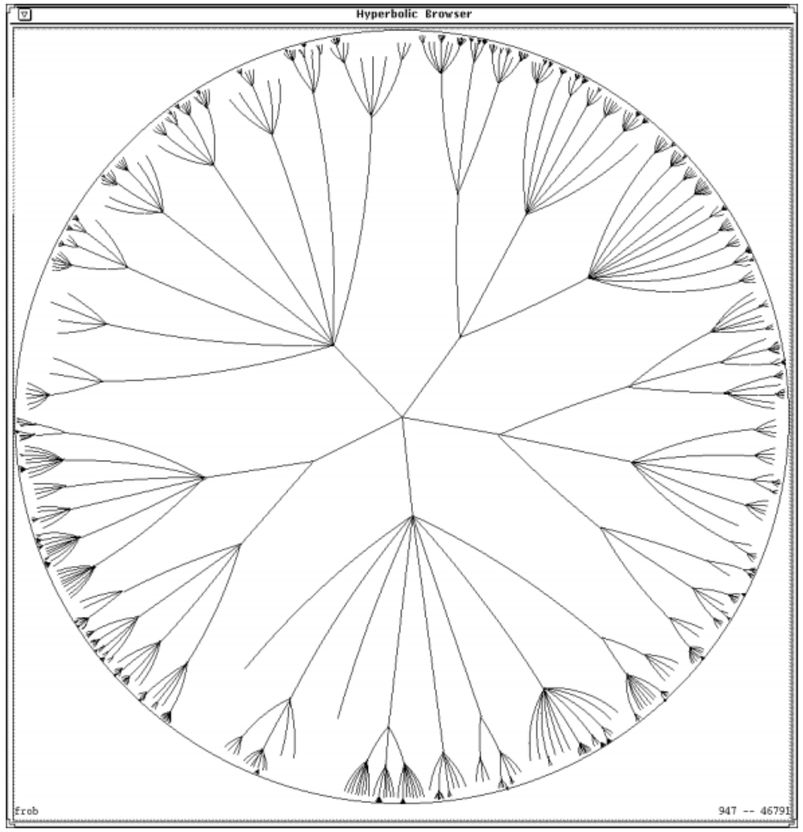
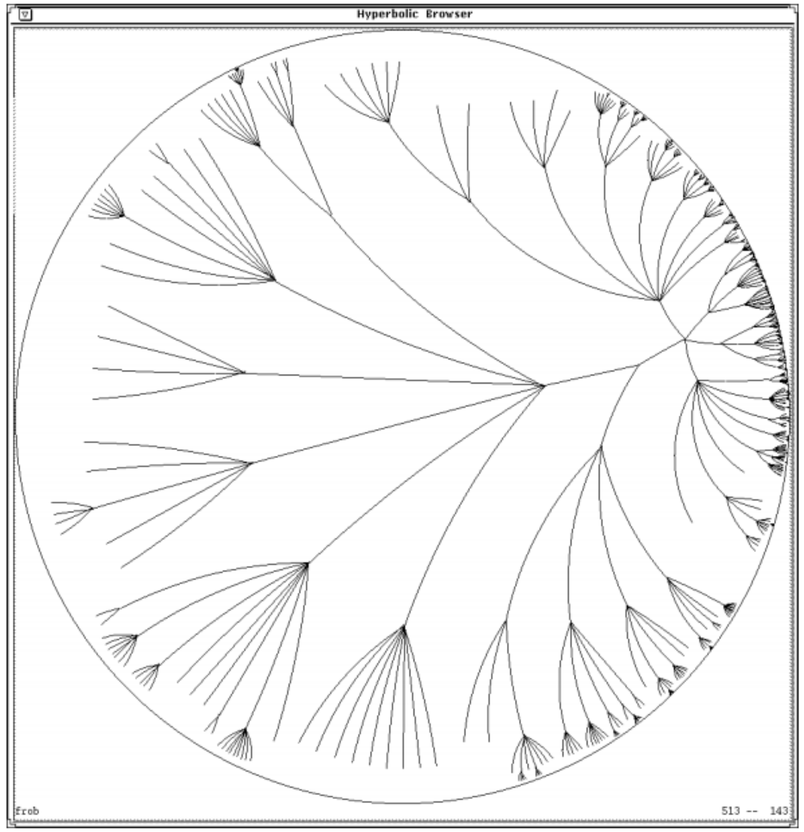


Fig. 1(b): Slice-and-dice treecube layout of the hierarchical information shown in Fig. 1(a).

TanakaOkadaNiijima2003

Hyperbolic graph layout

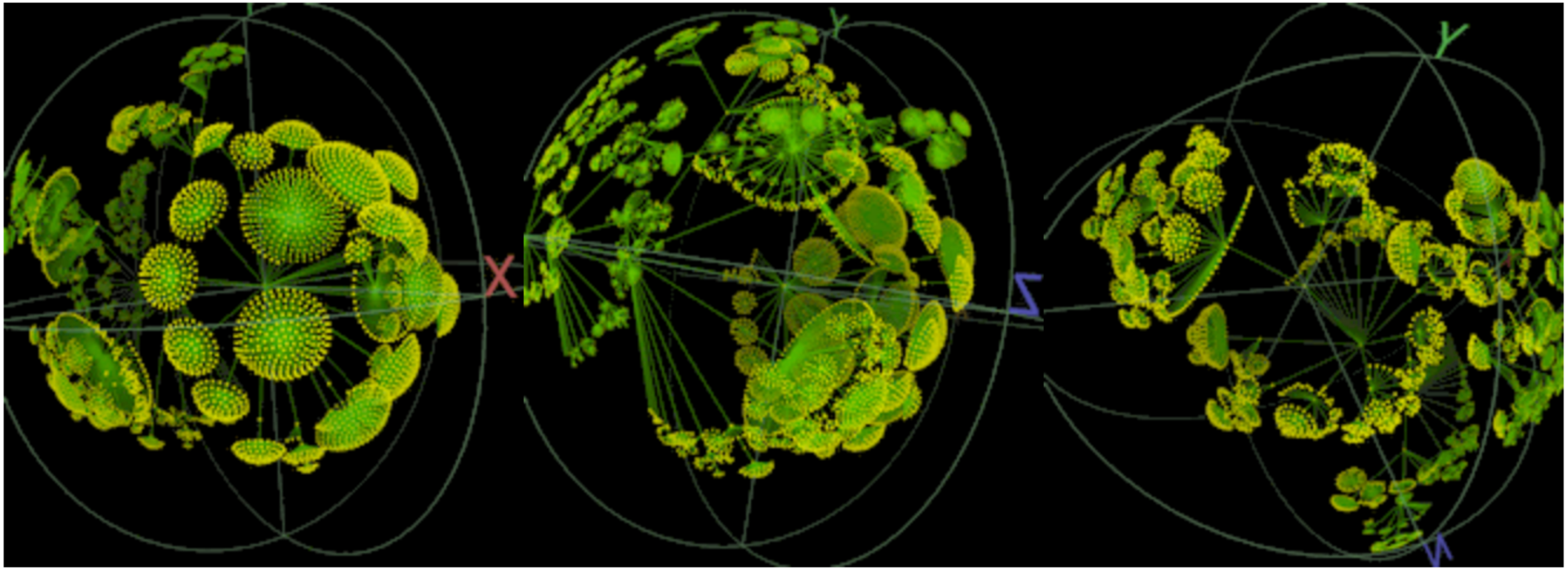




LampingRaoPirolli1995

(3D) Hyperbolic graph layout

CVS Repository (18,474 nodes and 18,473 links)



http://www.caida.org/tools/visualization/walrus/

Immersive Graph Visualization

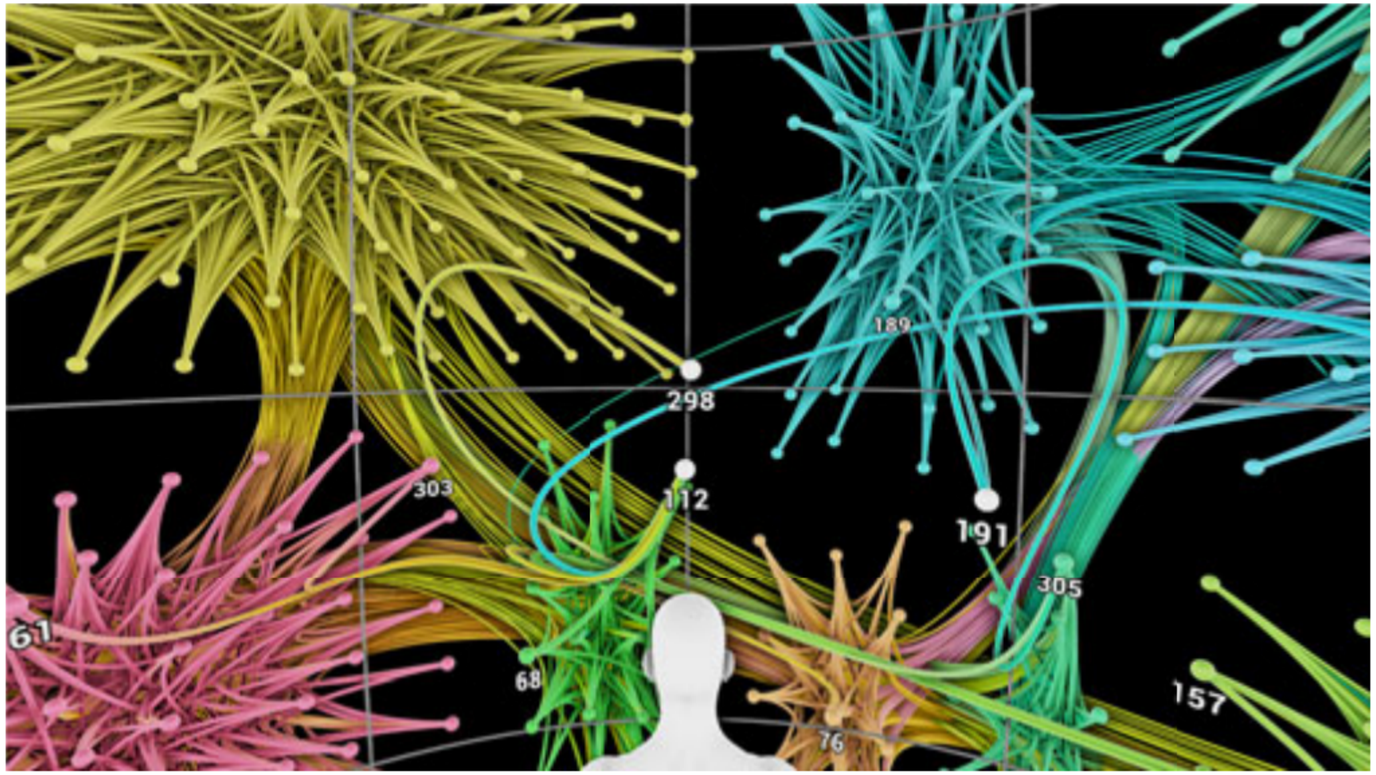
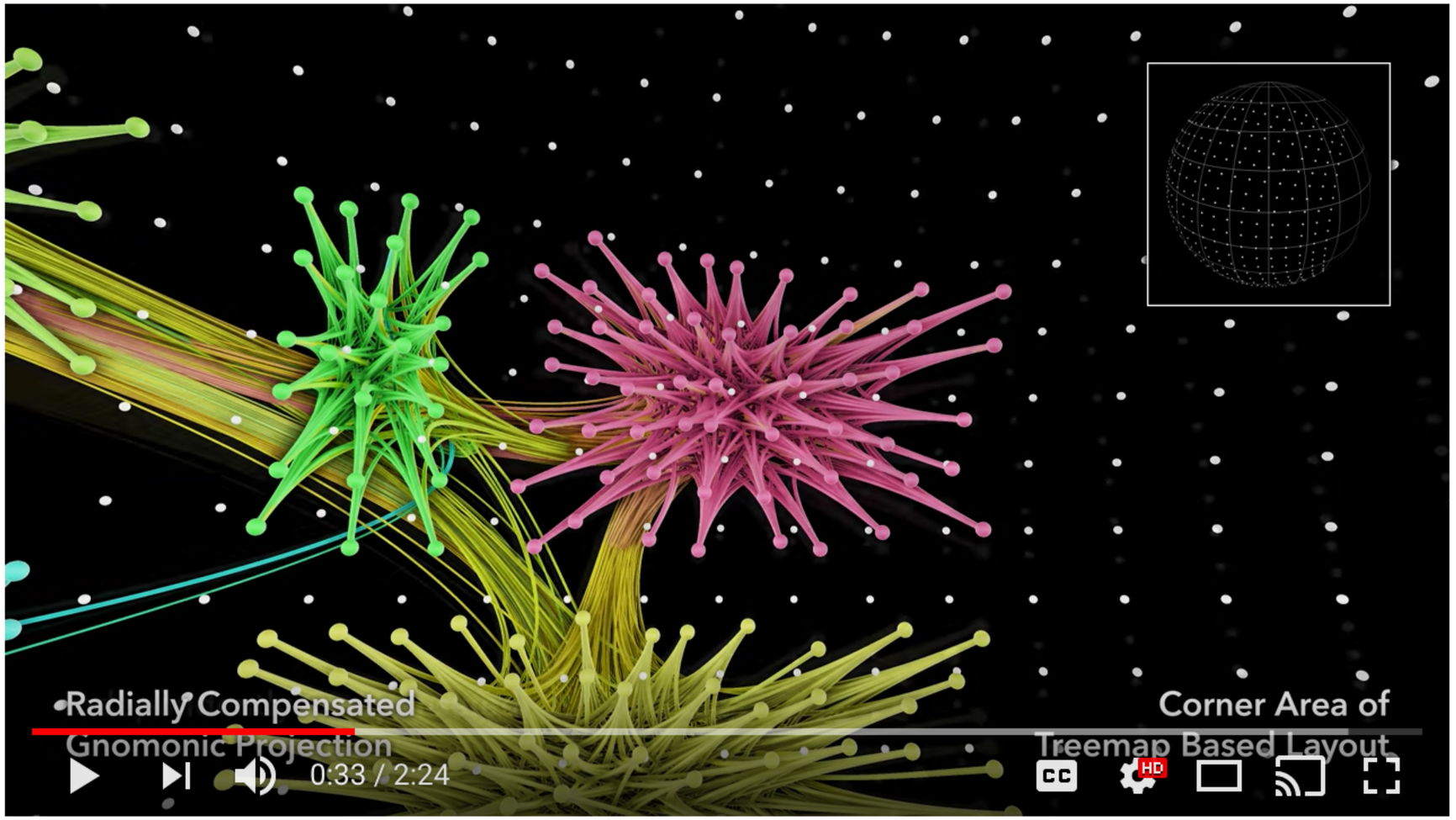


Fig. 1. The viewer is placed at the center of the sphere, on which the graph is laid out.

https://www.youtube.com/watch?v=LQYamaU8OvA

KwonMuelderLee2016

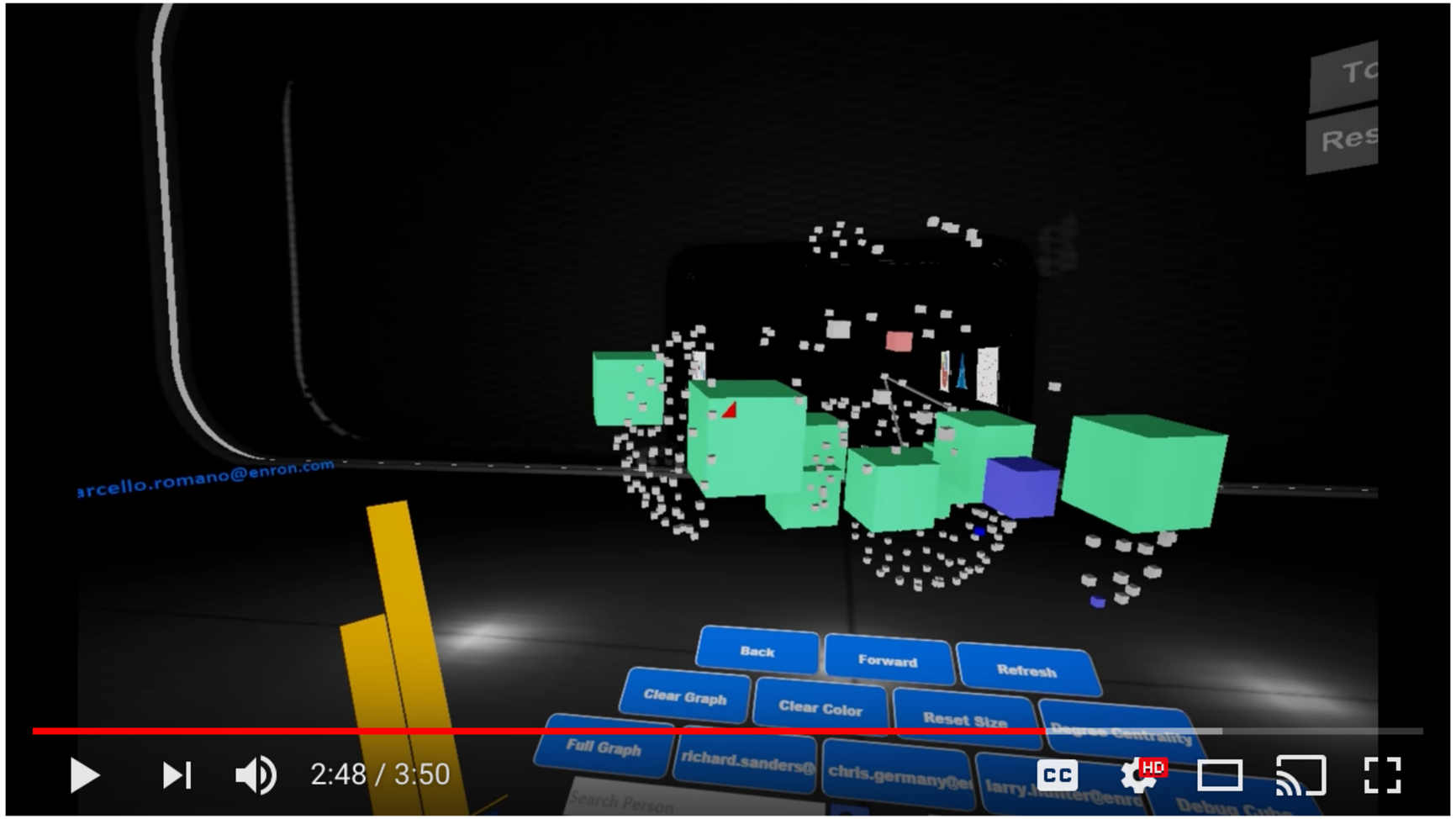
Immersive Graph Visualization



https://www.youtube.com/watch?v=LQYamaU8OvA

KwonMuelderLee2016

VR Graph Vis



https://www.youtube.com/watch?v=vsMTdd12NB0

5

Node and edge clustering (more on this later)

Interacting with Graph layout

General Interactions

- Selecting: highlight and process specific objects
- Abstracting/Elaborating: change the level of detail of the representation.
- Reconfiguring: change the layouts for the same representation.
- Encoding: switch between different layout methods.
- Exploring: change the view point of the graph layout, e.g. zooming and panning.
- Filtering: remove unnecessary detail, filter the nodes based on their attributes.
- Connecting: highlight the paths between relevant objects and the focus object.

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Zooming and Panning

- Panning: move the camera across the scene
- Zooming: switch between abstract and detailed views
  - Geometric zooming: adjusts the screen transformation, different level of magnification.
  - Semantic zooming: size of objects or displayed information may change when approaching a particular area of the graph.
  - Example: google earth
- Scale space diagram: combine geometric and semantic zooming

Scale Space Diagram

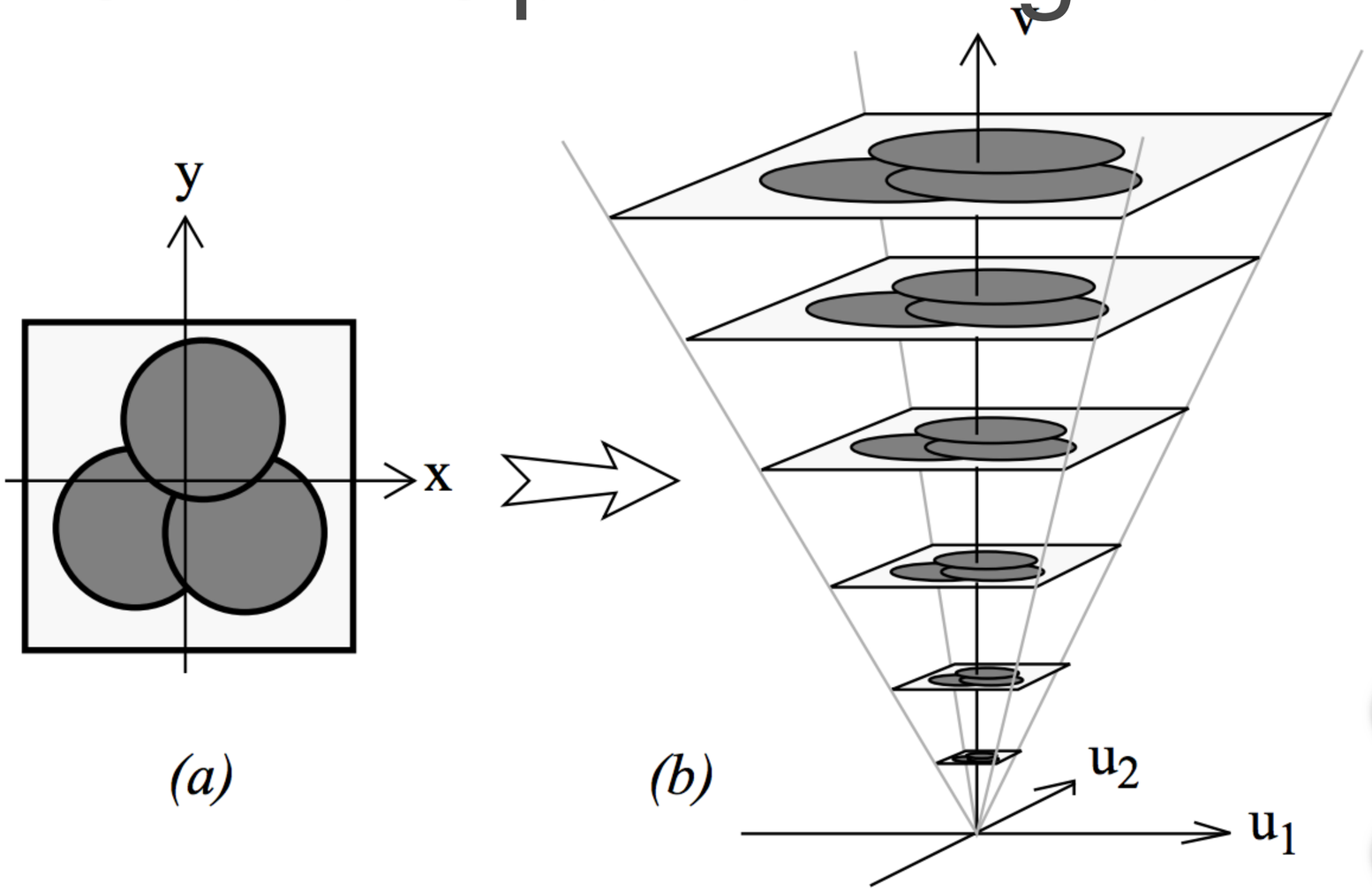

Figure 1. *The basic construction of a Space-Scale diagram from a 2D picture.*

FurnasBederson1995

Focus+Context

- Avoid losing context when zooming into given data
- See the primary object in a detailed view (focus) together with an overview of all the surrounding information (context)
- For example: fish-eye
  - The area of interest becomes larger while at the same time the other regions of the layout are successively shown with less detail.

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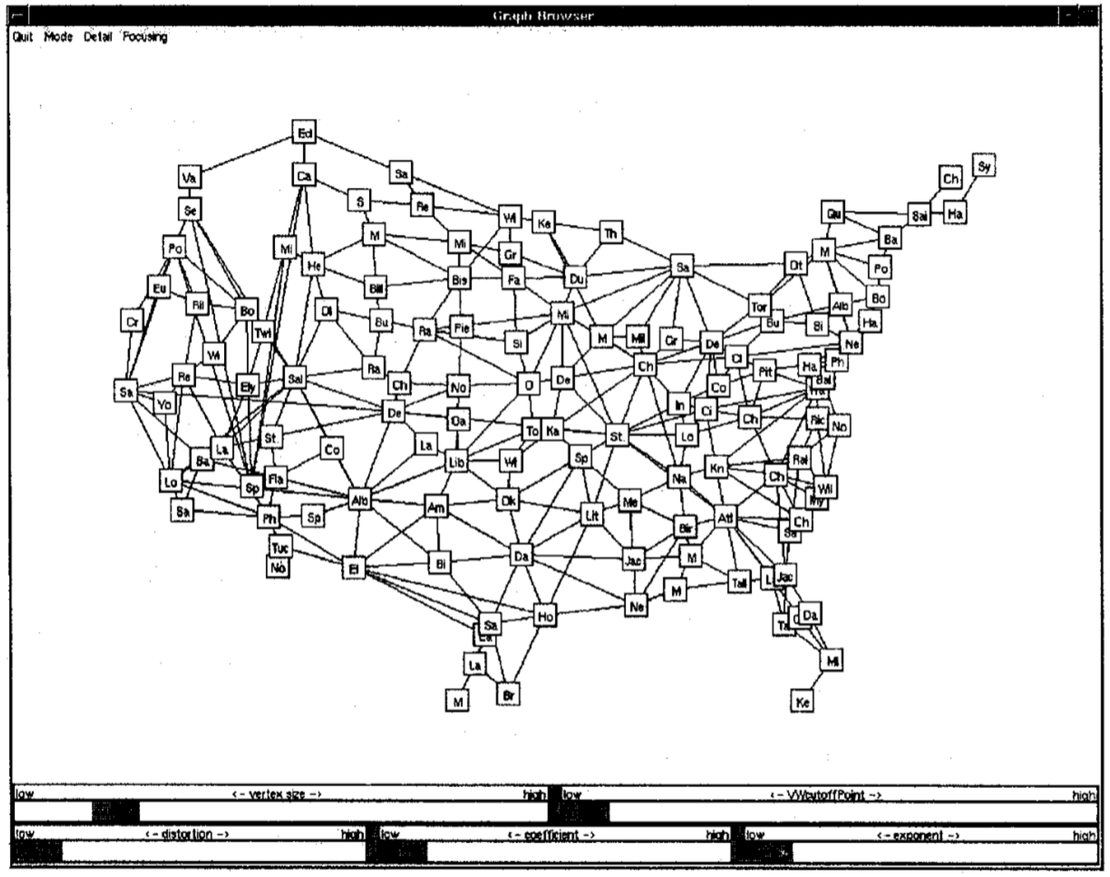
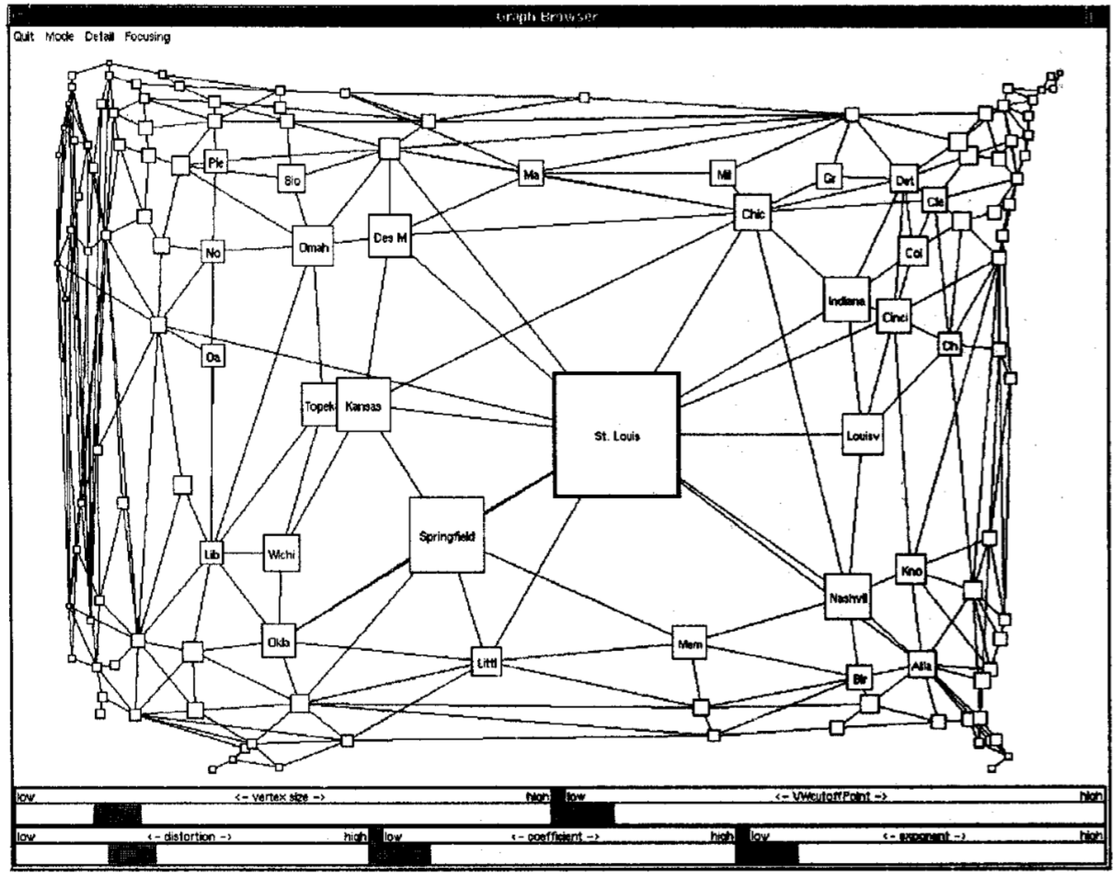
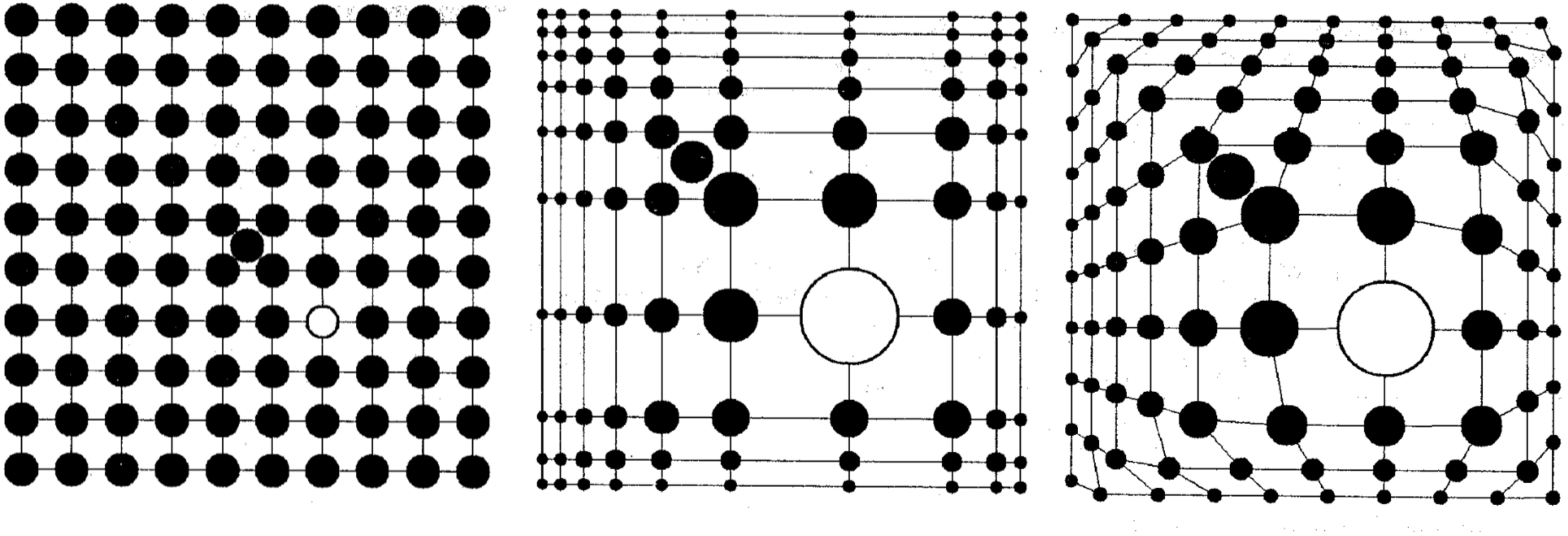
Fish-Eye





SarkarBrown1992

Fish-Eye



Introducing distortion to graphs

SarkarBrown1992

Fish-Eye

Figure 6: Outline of the United States

Figure 7: A cartesian transformation of Figure 6. The focus is at the point where Missouri, Kentucky, and Tennessee meet.

Figure 8: A polar transformation of Figure 6. The focus is at the point where Missouri, Kentucky, and Tennessee meet.

SarkarBrown1992

Topological Fish-Eye View

- Precompute a hierarchy of coarsened graphs that are combined on-the-fly into renderings
- Rendering's level of detail is dependent on distance from one or more foci.
- Geometric distortion yields constant information density displays from these renderings

GansnerKorenNorth2005

Topological Fish-Eye View

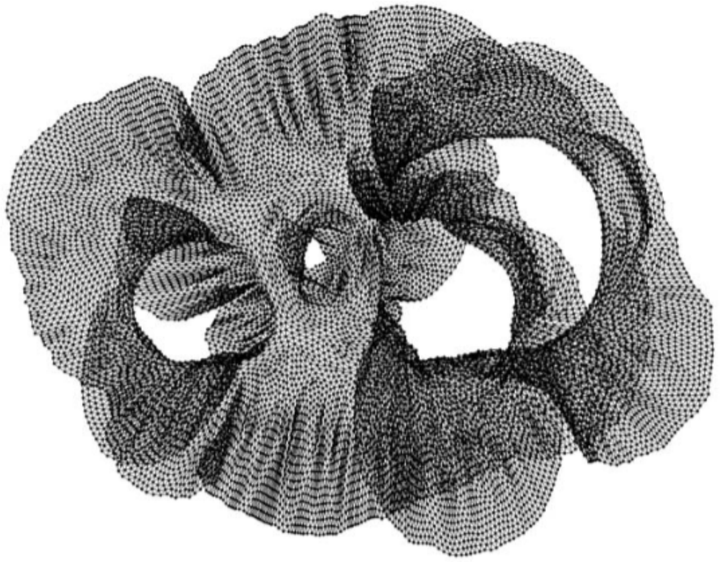


Fig. 1. The 4elt graph, $|\mathrm{V}| = 15,606$, $|\mathrm{E}| = 45,878$.

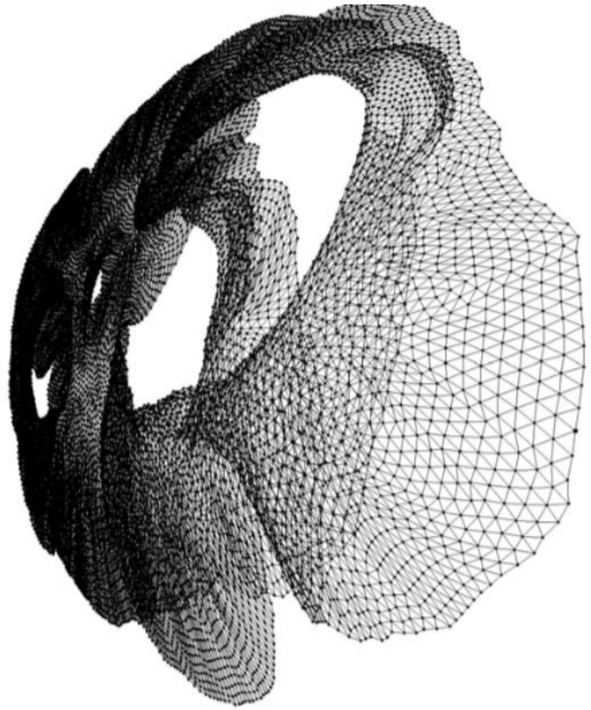
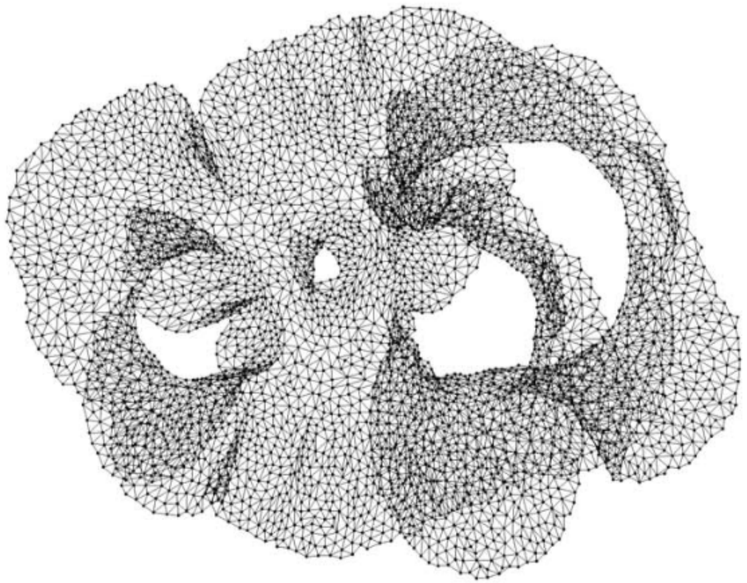


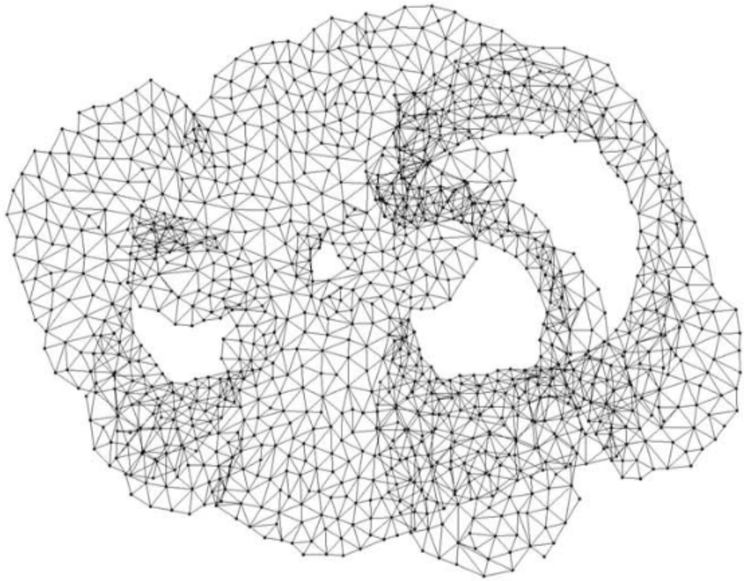
Fig. 2. A fisheye view of the 4elt graph focused on the right-hand portion.

GansnerKorenNorth2005

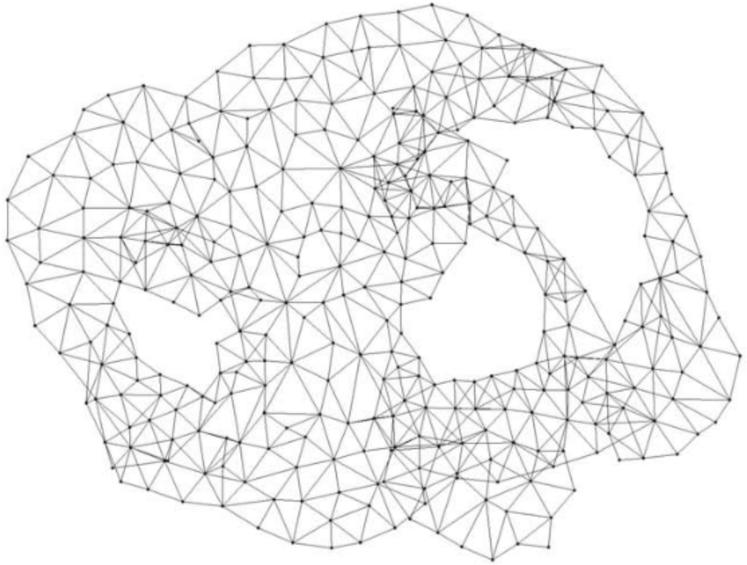
Topological Fish-Eye View



4394-node approximation



1223-node approximation



341-node approximation

Fig. 3. Approximating the 4elt graph at three different scales of decreasing size and accuracy.

GansnerKorenNorth2005

Topological Fish-Eye View

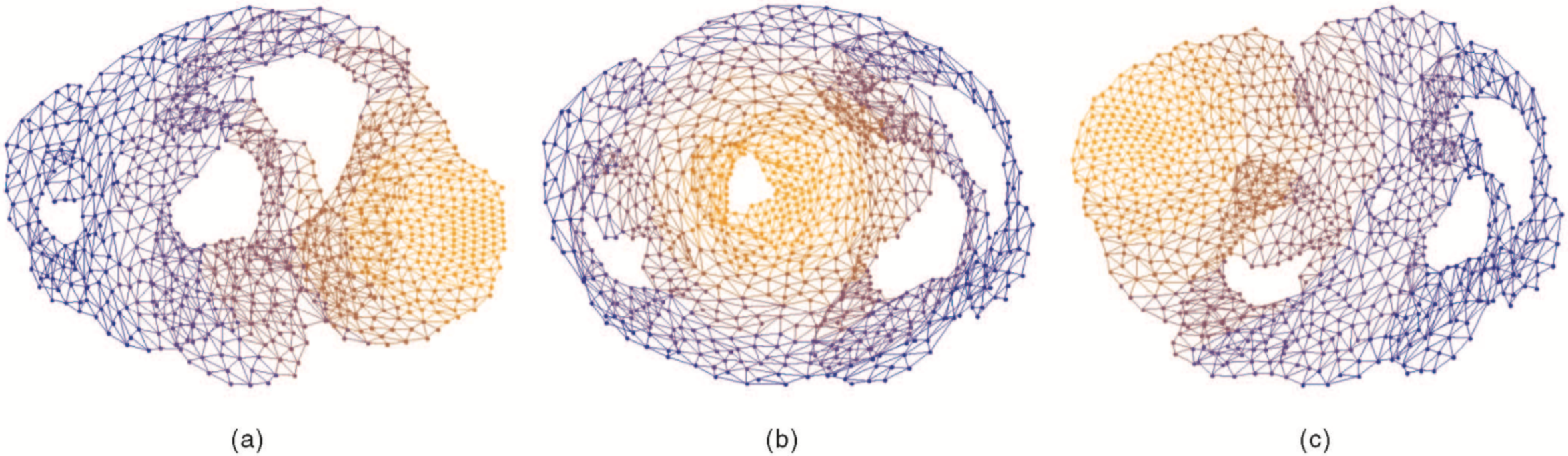
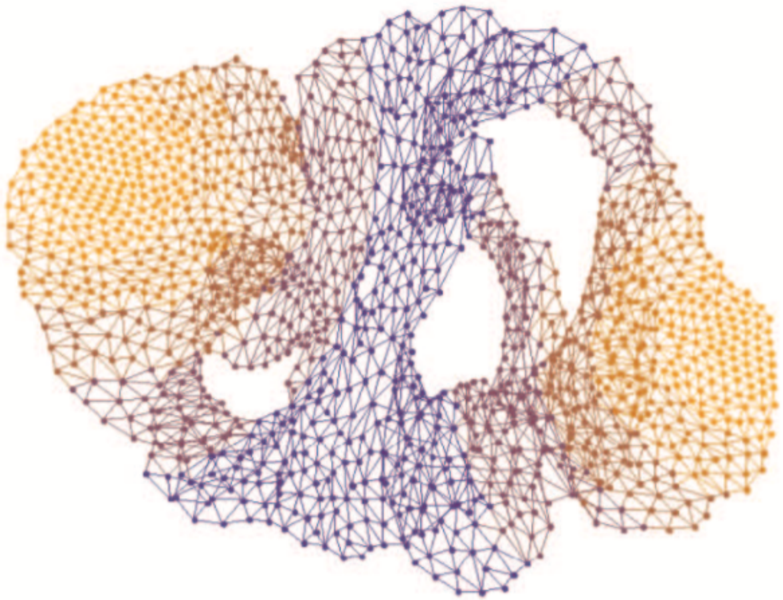


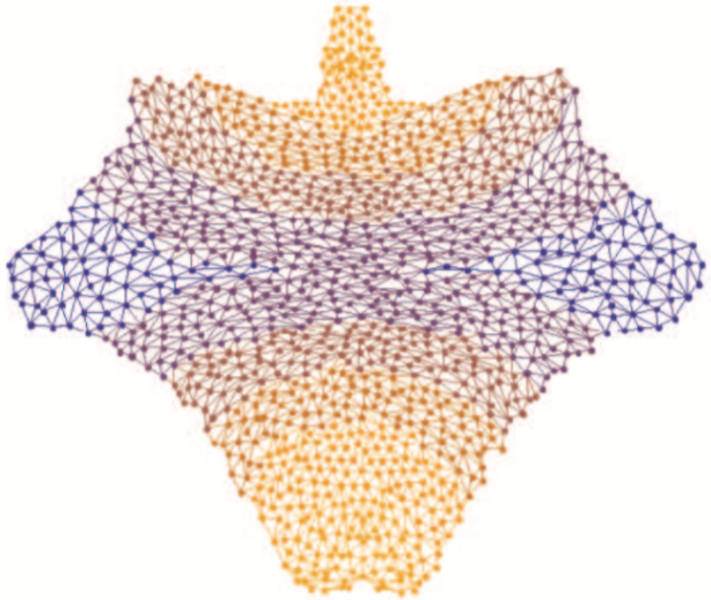
Fig. 4. Topological fisheye views of the 4elt graph. Views are based on “hybrid graphs” formed by superposition of several approximations of the graph. Levels are colored orange-to-blue, where the focus area from the finest graph is in orange. The figure shows three examples, focusing on (a) the right-hand side, (b) the small central hole, and (c) the left-hand side.

GansnerKorenNorth2005

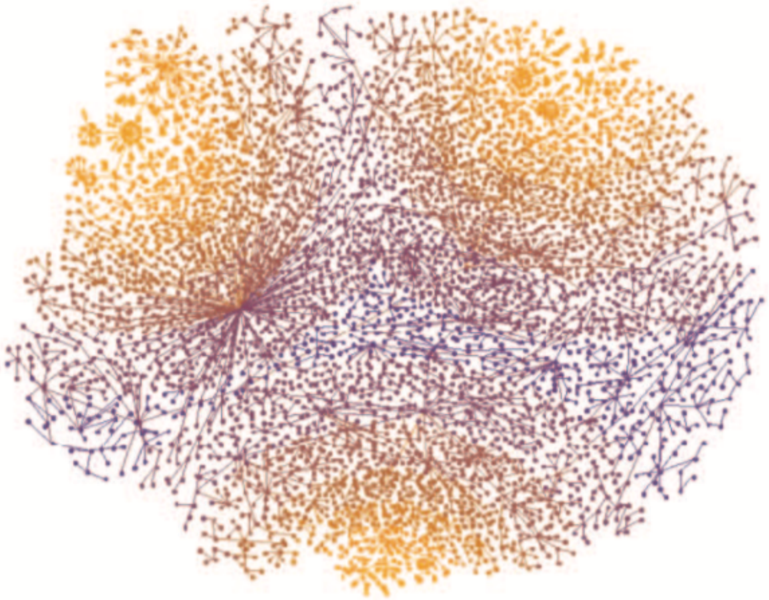
Topological Fish-Eye View



4elt graph (2 foci)



Crack graph (2 foci)



Internet graph (3 foci)

Fig. 17. Viewing graphs with multiple foci.

GansnerKorenNorth2005

Thanks!

Any questions?

You can find me at: beiwang@sci.utah.edu

CREDITS

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- Presentation template designed by Slidesmash
- Photographs by unsplash.com and pexels.com
- Vector Icons by Matthew Skiles

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http://www.1001fonts.com/oswald-font.html

https://www.fontsquirrel.com/fonts/open-sans

Colors used