# Advanced Data Visualization

## CS 6965

## Spring 2018


## Prof. Bei Wang Phillips

## University of Utah


Lecture 25

# Graph Layout
# Edge Bundling

NV

# Graph Layout: A Brief Overview

TarawnehKellerEbert2011

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

# 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

TarawnehKellerEbert2011

# 1

# Node-Link Layouts

Criteria and examples

# Challenge: directed graph layout

Two step approach:

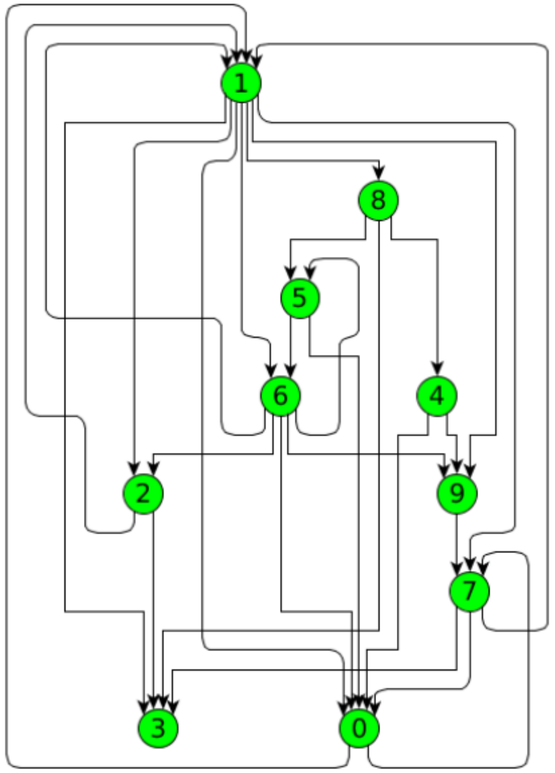
- First, layer the graph nodes: assign a layer for each node and placing the nodes into the corresponding layer.
- Second, reduce the edge-crossings and the node overlapping.

# L-Drawing of directed graphs

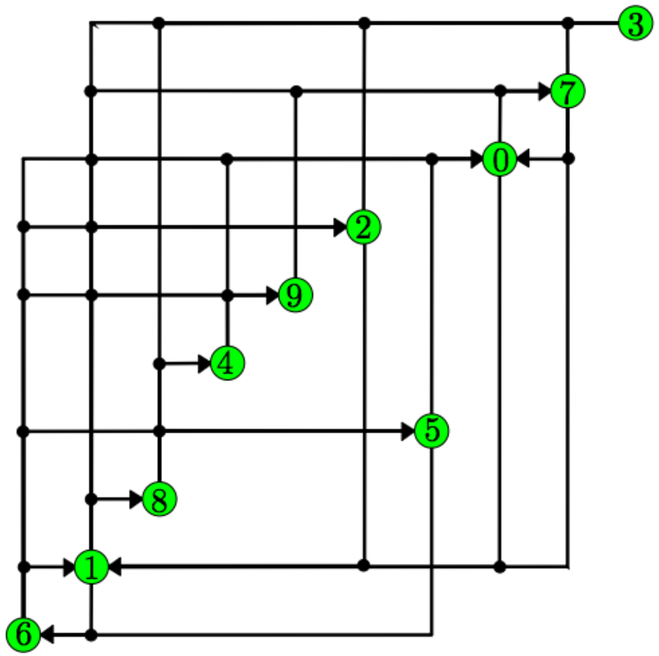
Combine Orthogonal Graph Drawing with matrix representation:

- 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

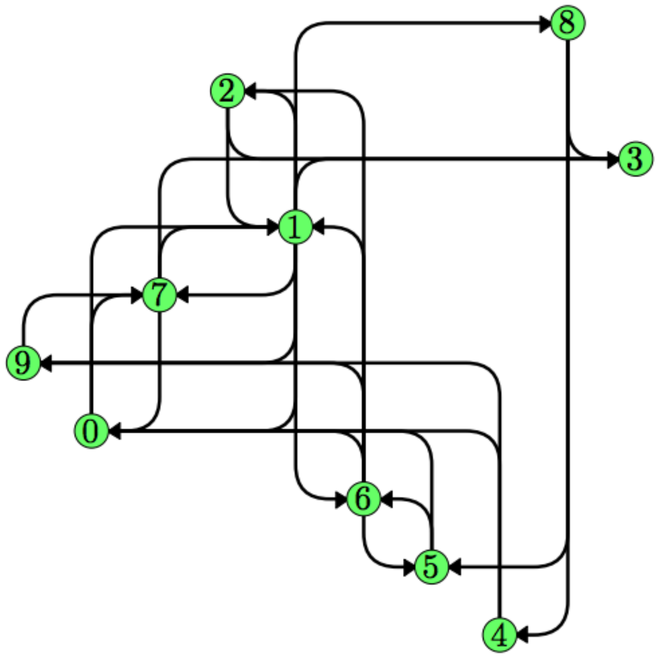
# L-Drawing of directed graphs




(a)




(b)



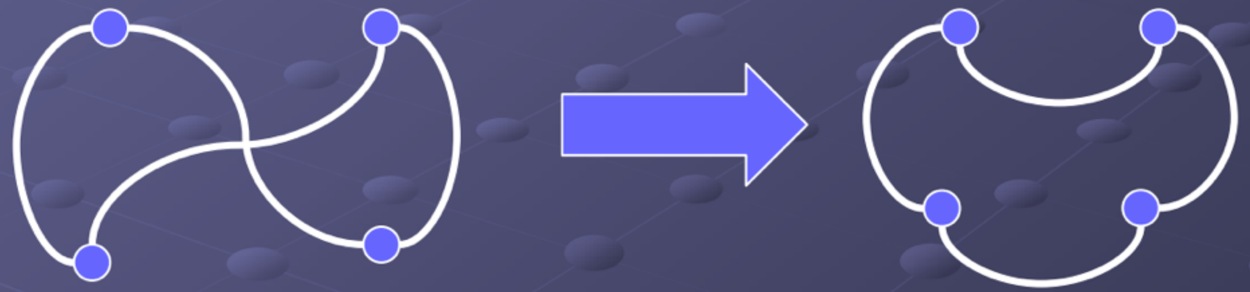

(c)

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

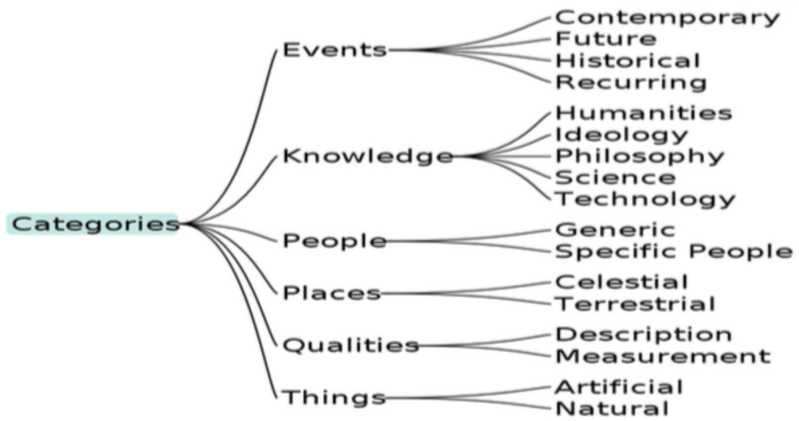
- A Graph G=(V,E) is a Planar Graph if it can be drawn in the plane with no edges crossing



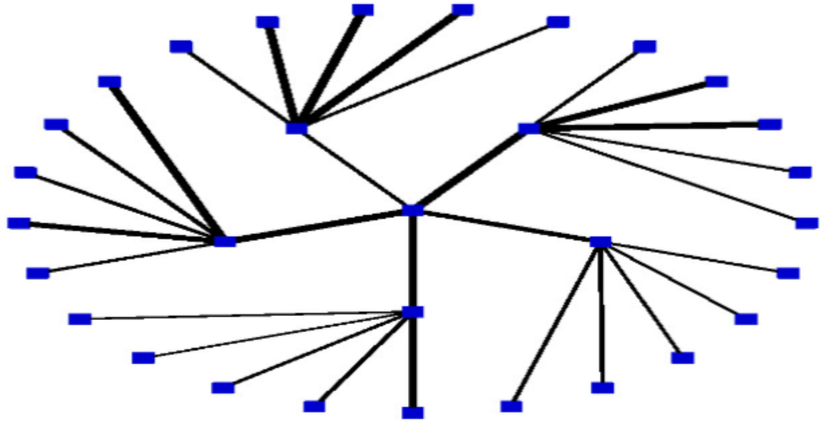
https://pdfs.semanticscholar.org/9c89/7e65499cc6caacabd8abab6071010b03248c.pdf
Slides by Jon Harris

# 2
# Tree Layouts

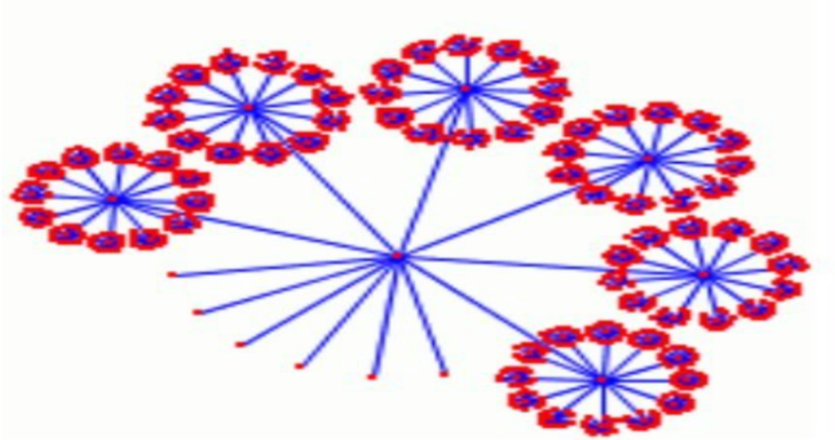
# Node-Link Tree Layout



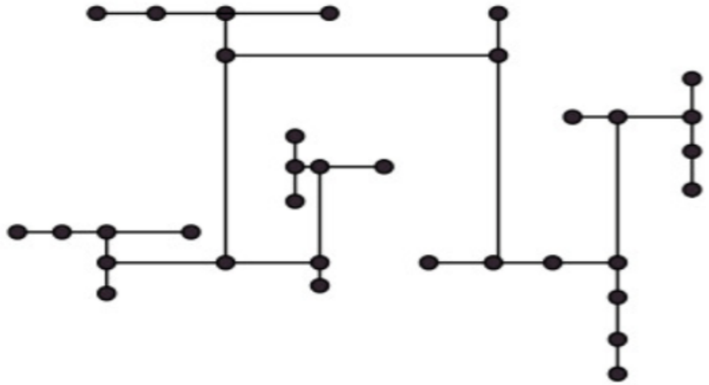

**(a)** Classical tree layout, produced with [19].



**(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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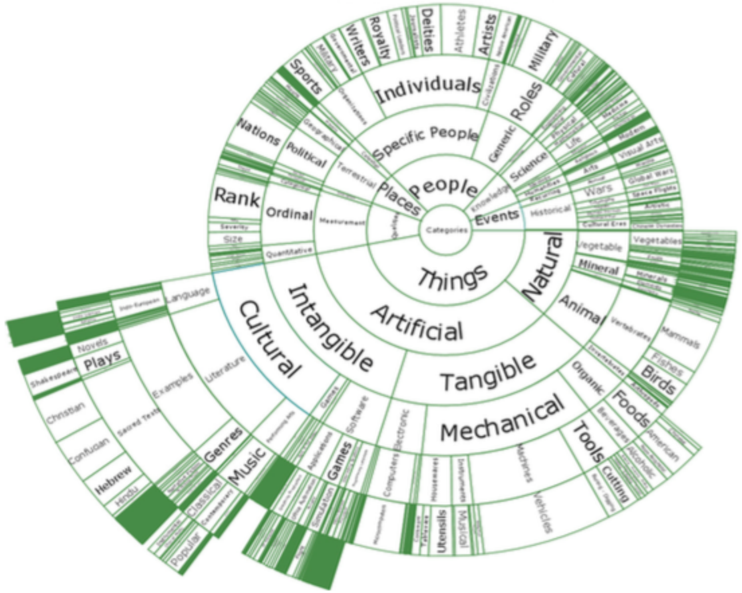
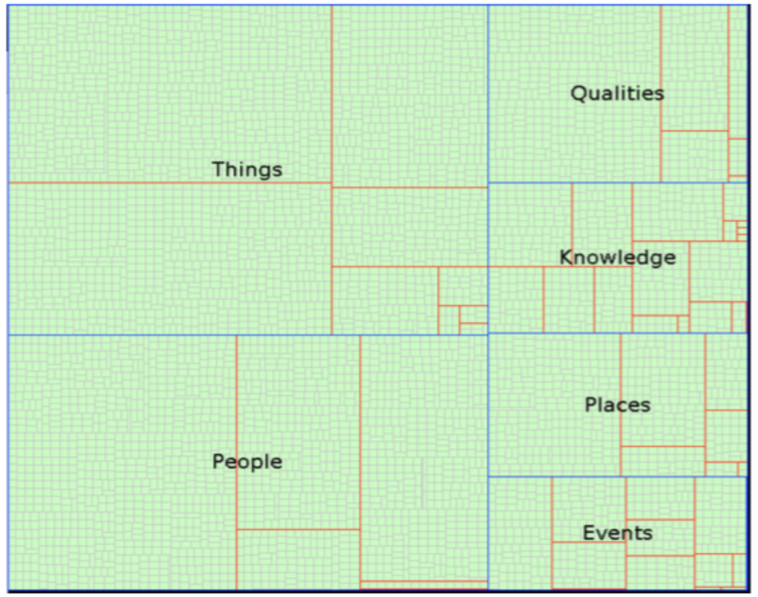
# Space-Filling




**(a)** SunBurst layout.




**(b)** TreeMap layout.

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

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# 3
# Matrix Visualization

# MatrixExplorer

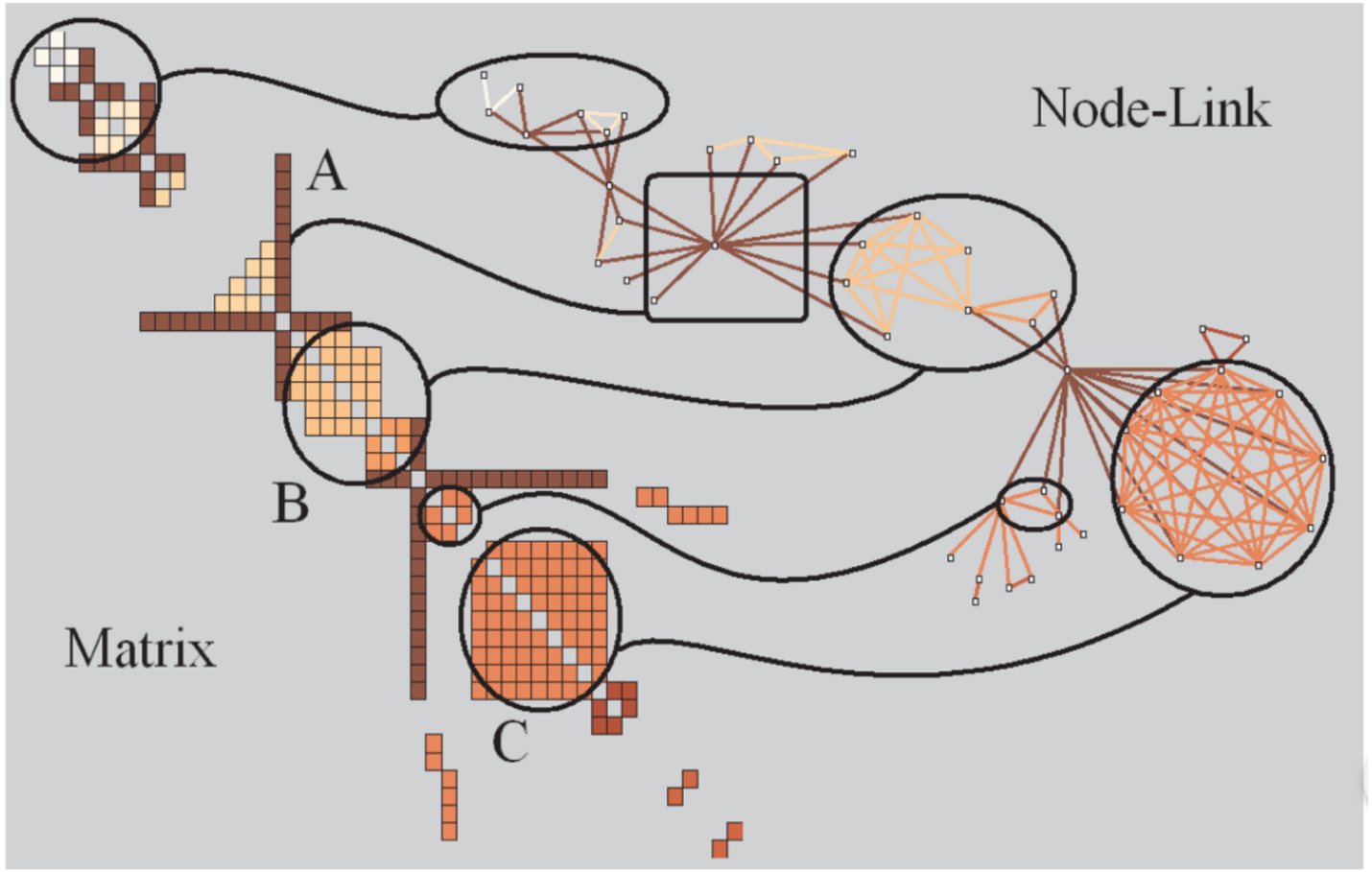



Fig. 3. Visual patterns in Matrix and Node-link representations of social networks. A represents an actor connecting several communities, B a community and C a clique (complete sub-graph).

HenryFekete2006

# 4

# 3D Layout

# TreeCube

Extension from TreeGraph

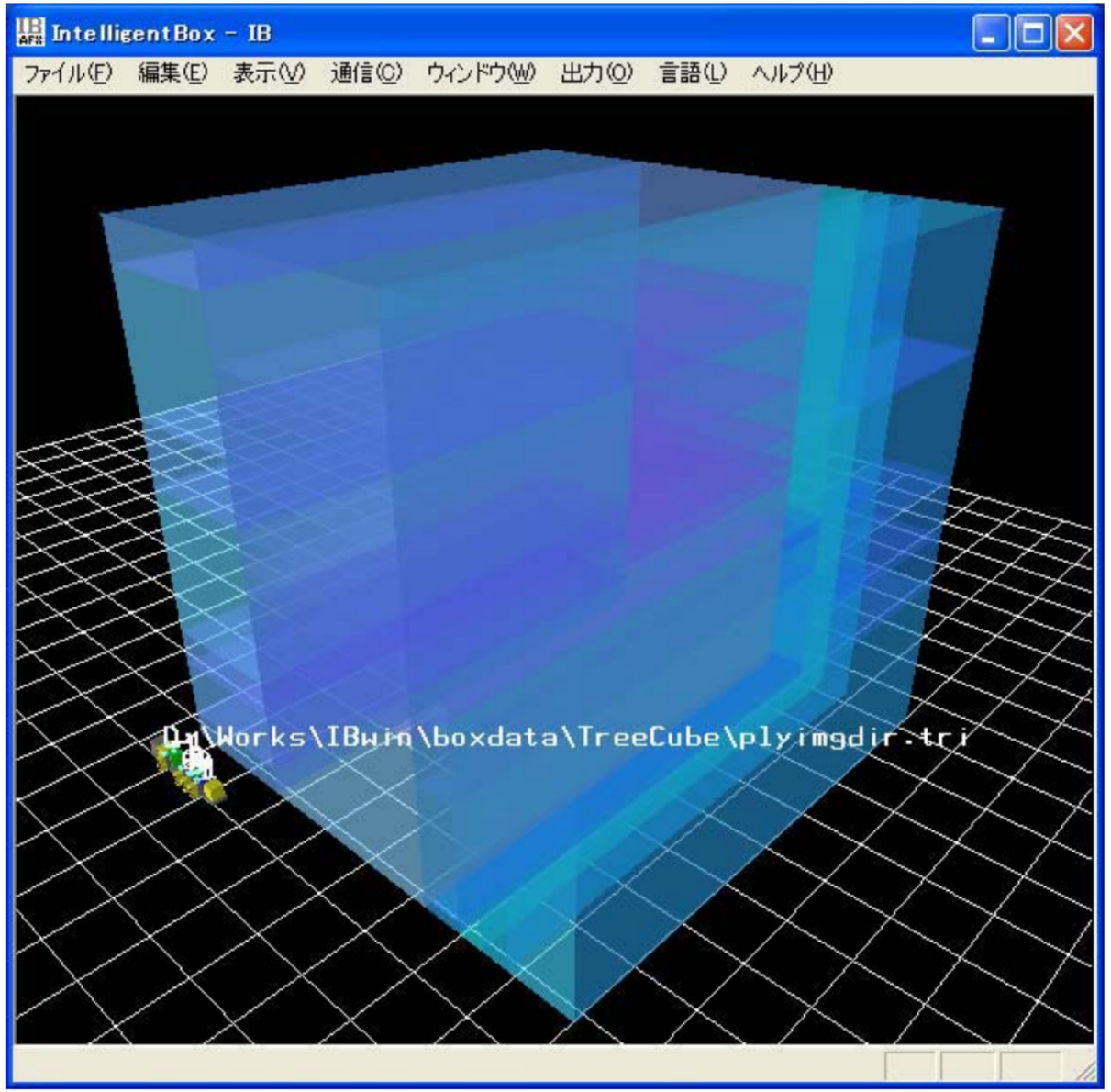



Fig. 2: Layout example of hierarchical information by the slice-and-dice treecube algorithm.

TanakaOkadaNiijima2003

# True Cube

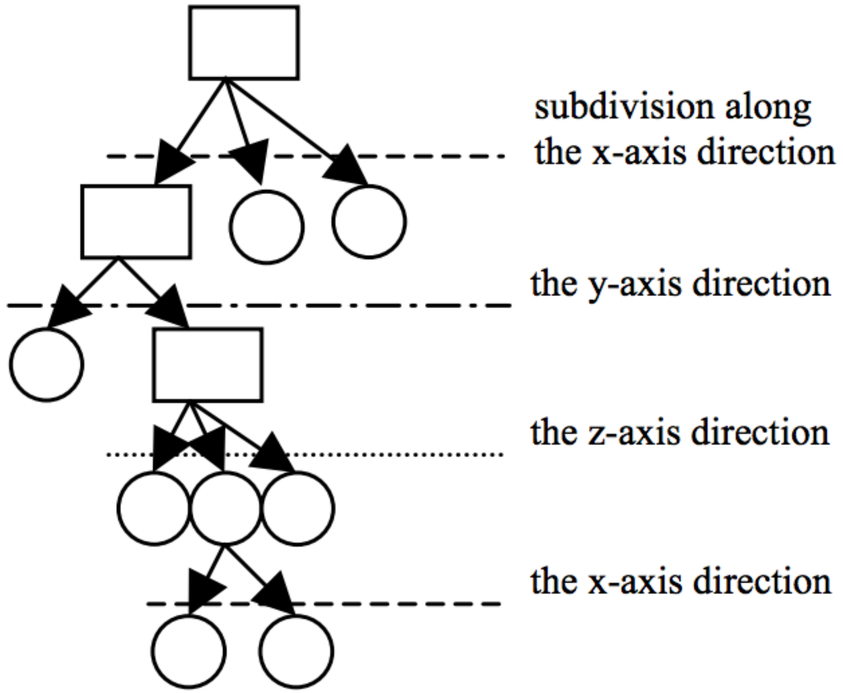



Fig. 1(a): Hierarchical information and the direction of the subdivision operation in its each level.

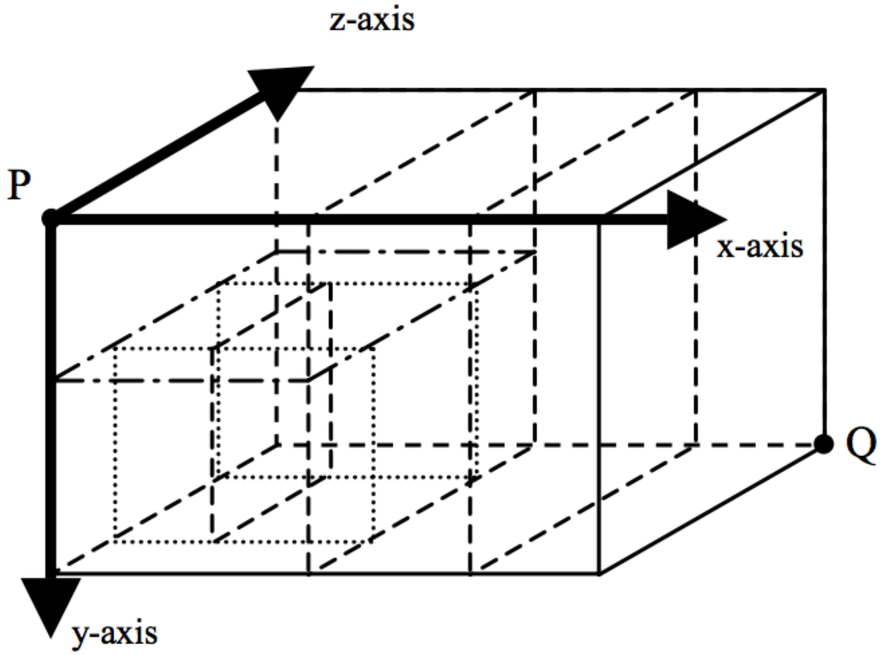
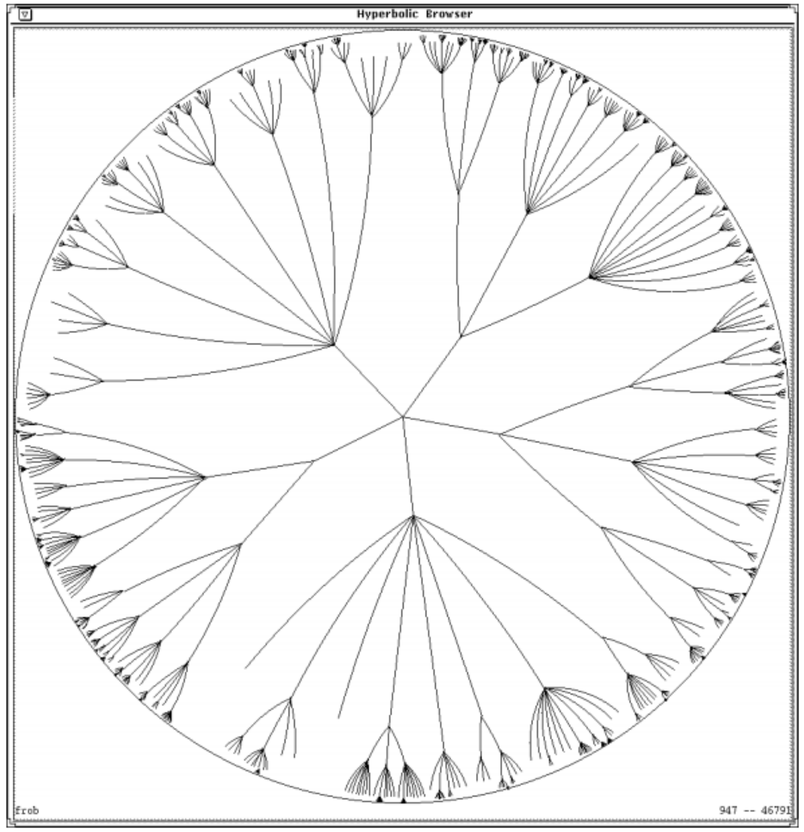
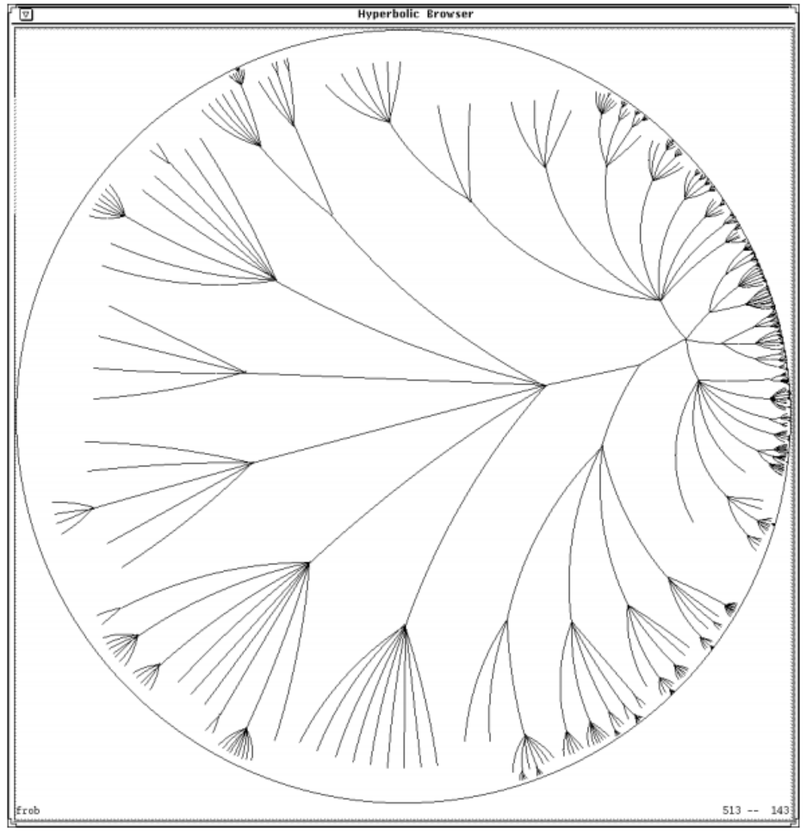



Fig. 1(b): Slice-and-dice treecube layout of the hierarchical information shown in Fig. 1(a).

TanakaOkadaNiijima2003

# Hyperbolic graph layout

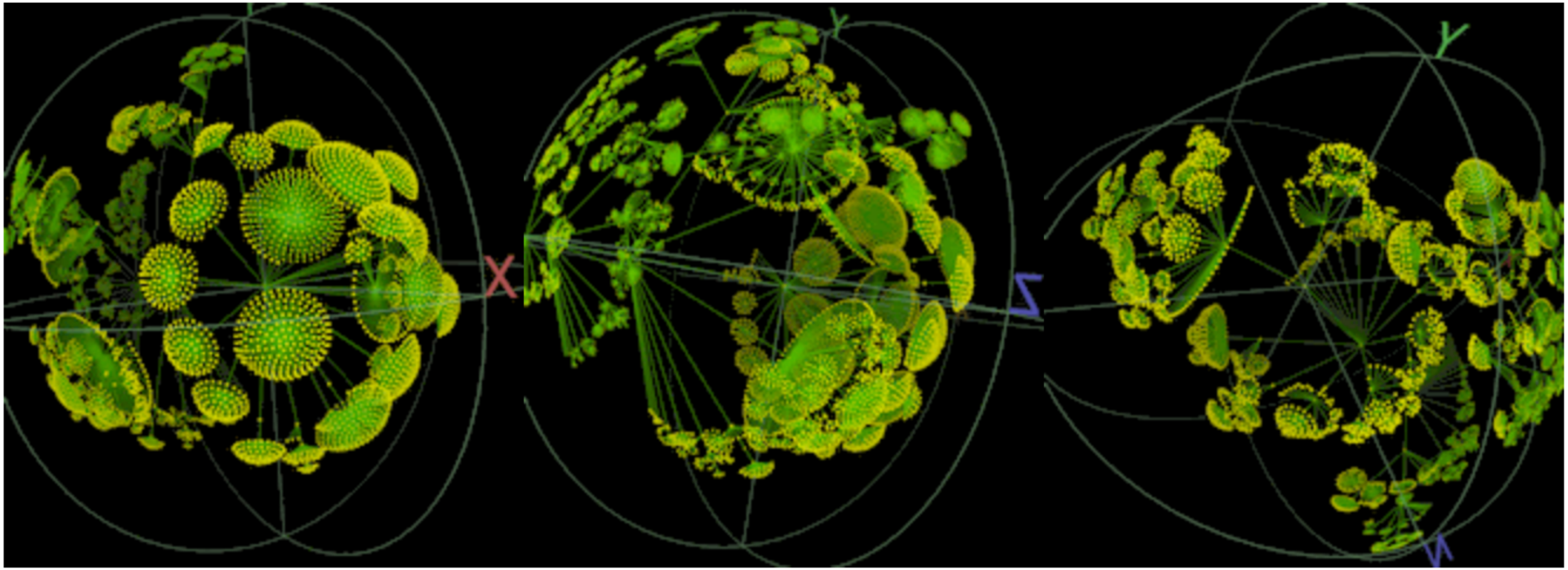



LampingRaoPirolli1995

# (3D) Hyperbolic graph layout

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




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

# Immersive Graph Visualization

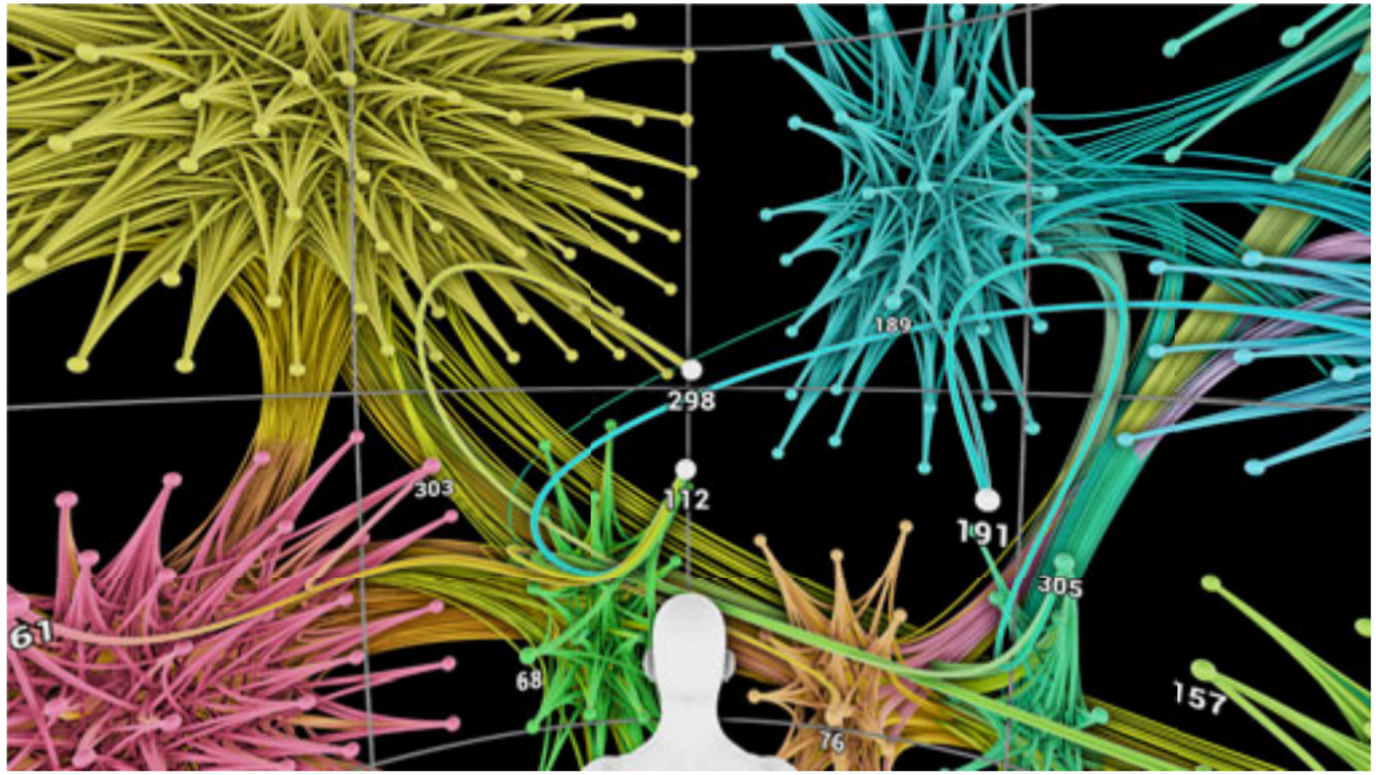
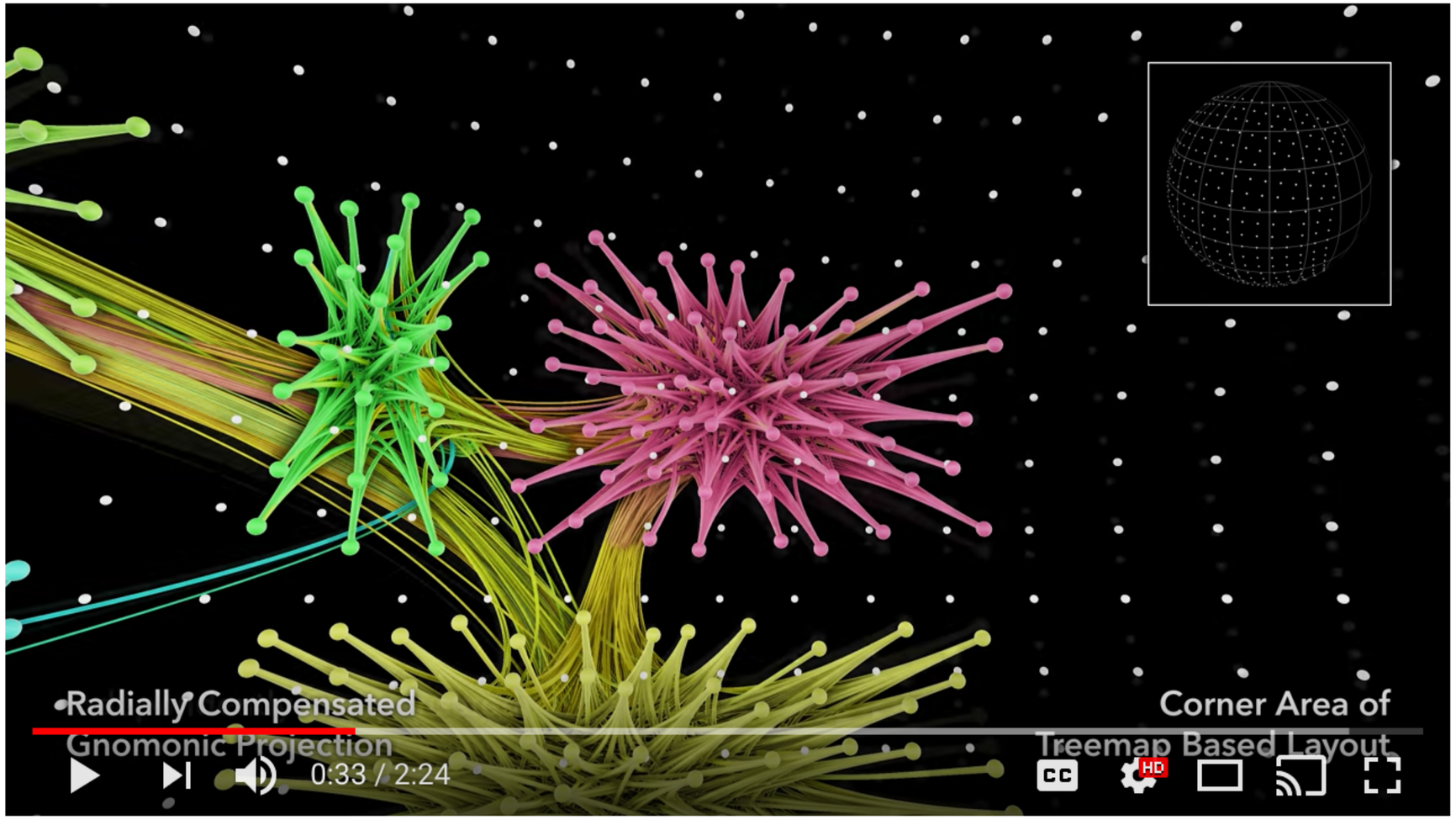



Fig. 1. The viewer is placed at the center of the sphere, on which the graph is laid out.

KwonMuelderLee2016

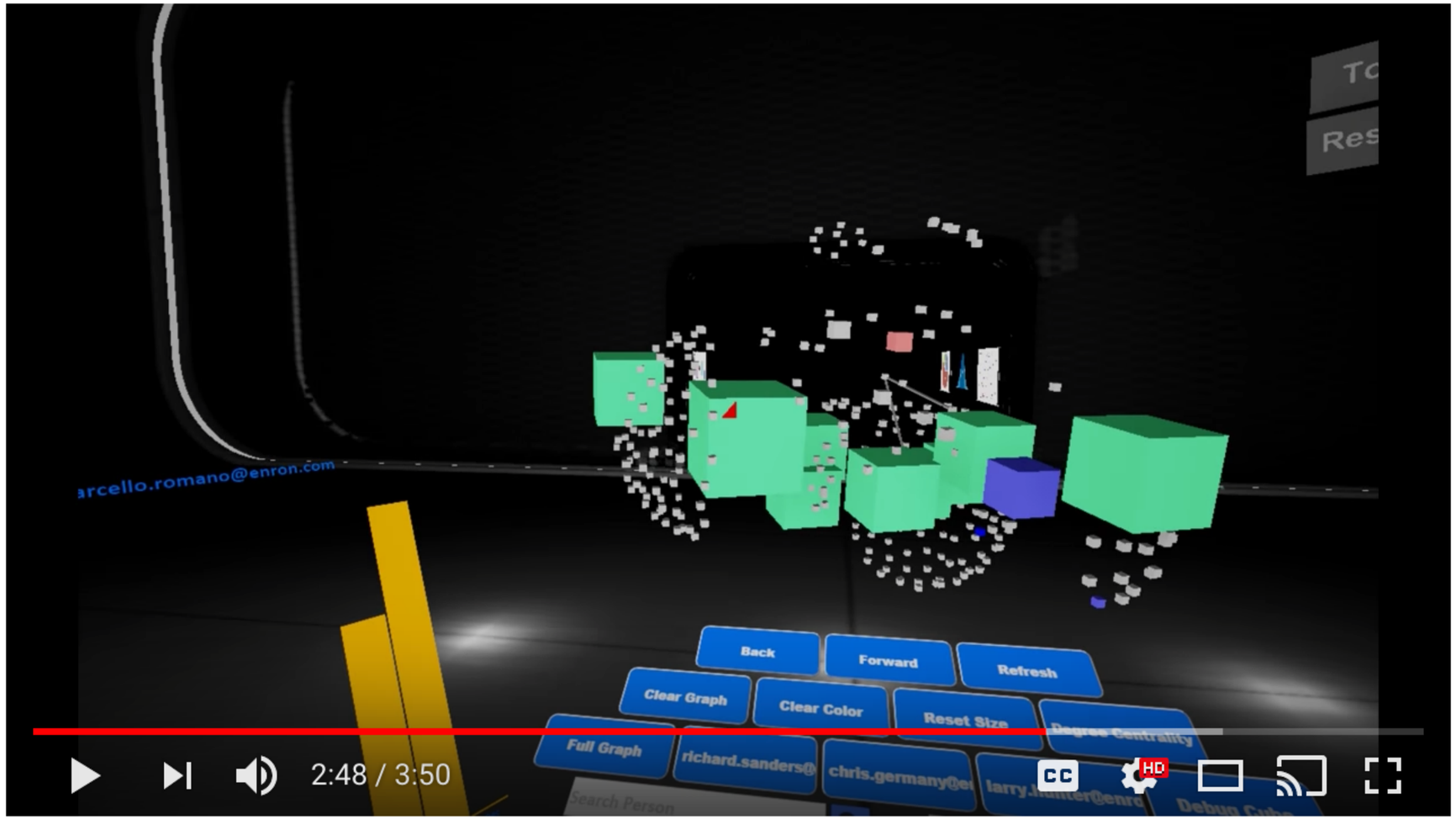
# Immersive Graph Visualization




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

KwonMuelderLee2016

# VR Graph Vis




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

# 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.

TarawnehKellerEbert2011

# 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

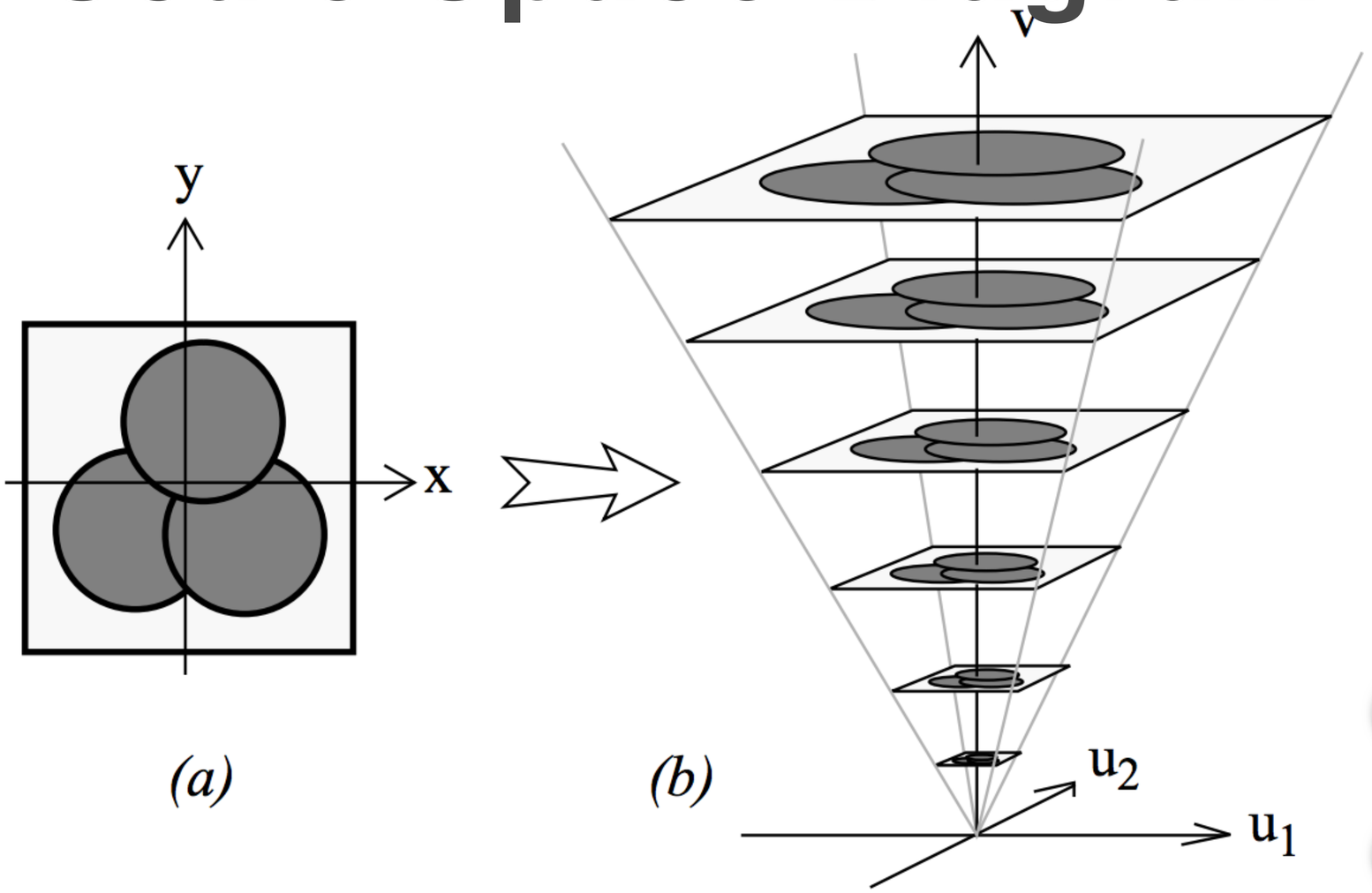



**Figure 1**. *The basic construction of a Space-Scale diagram from a 2D picture.*

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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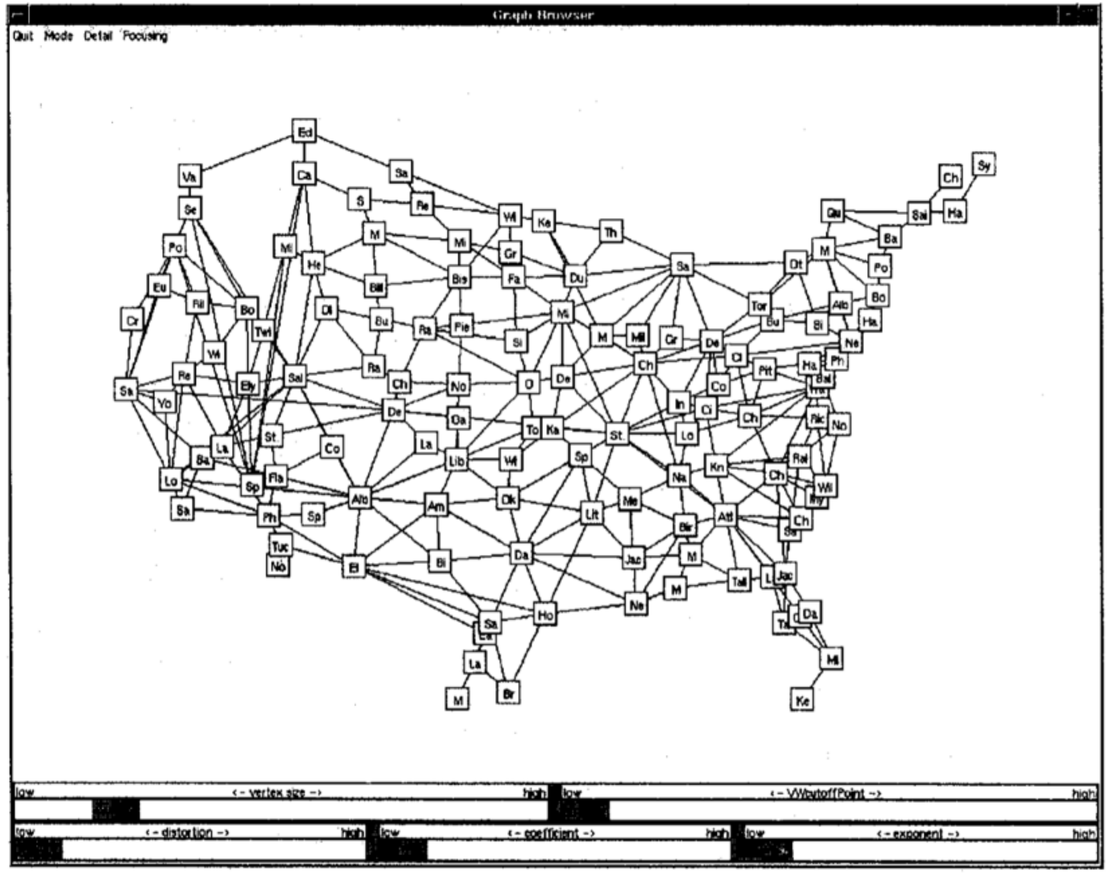
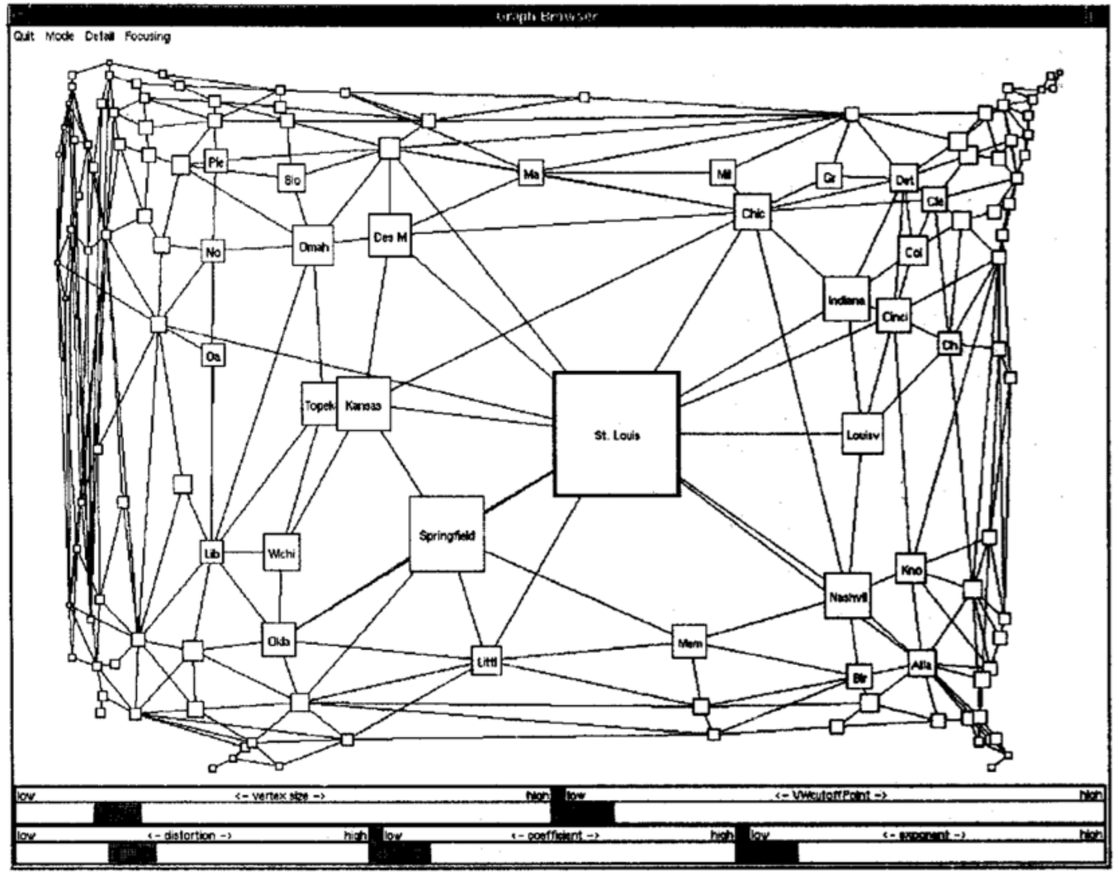
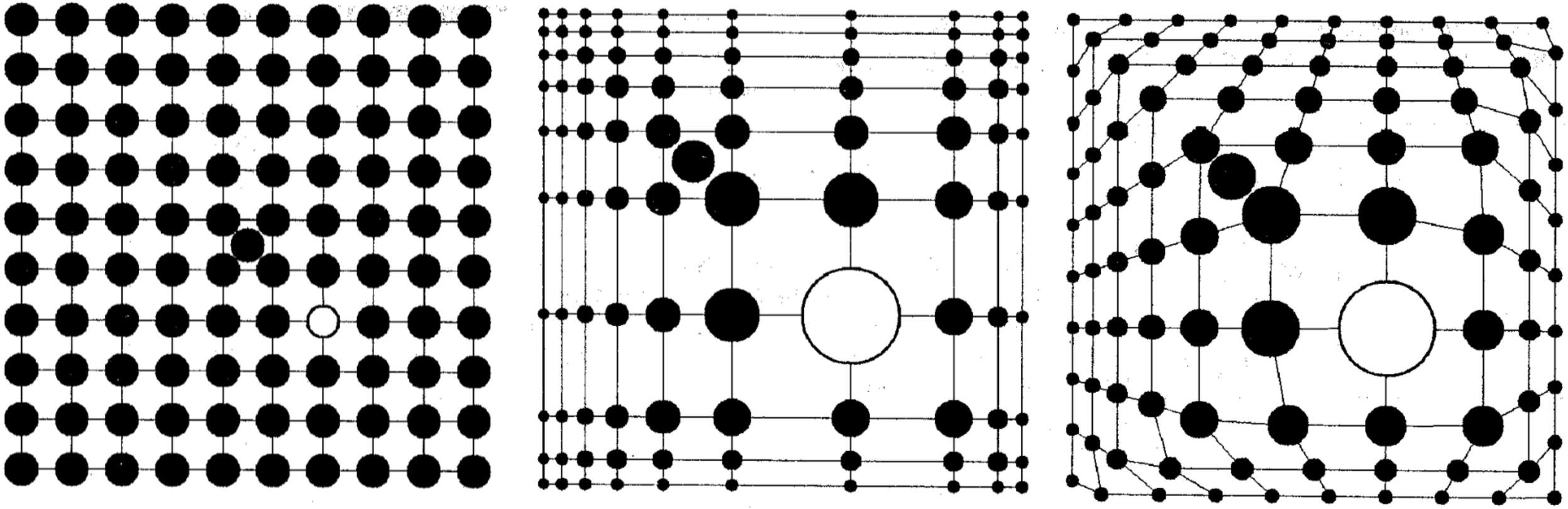
# Fish-Eye




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

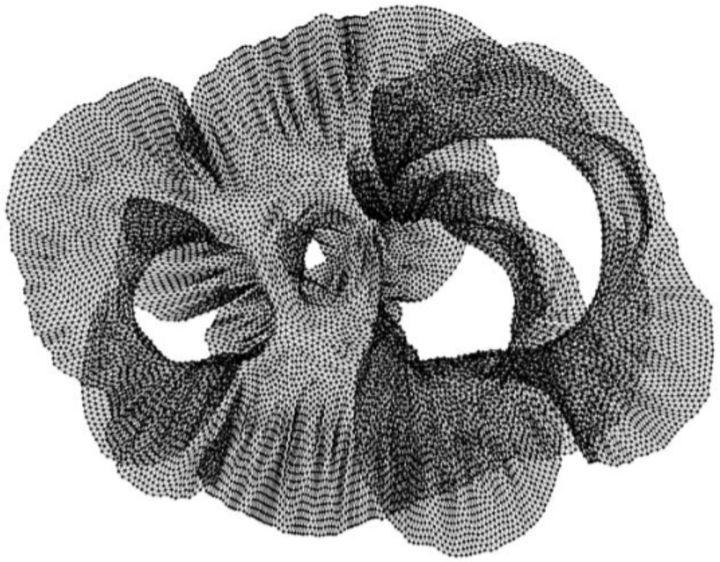


Fig. 1. The 4elt graph, $|\mathrm{V}| = 15,606$, $|\mathrm{E}| = 45,878$.

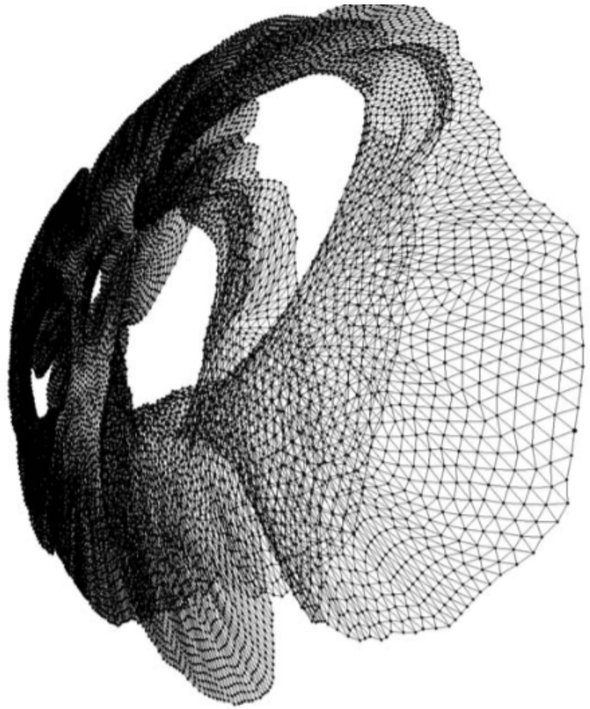
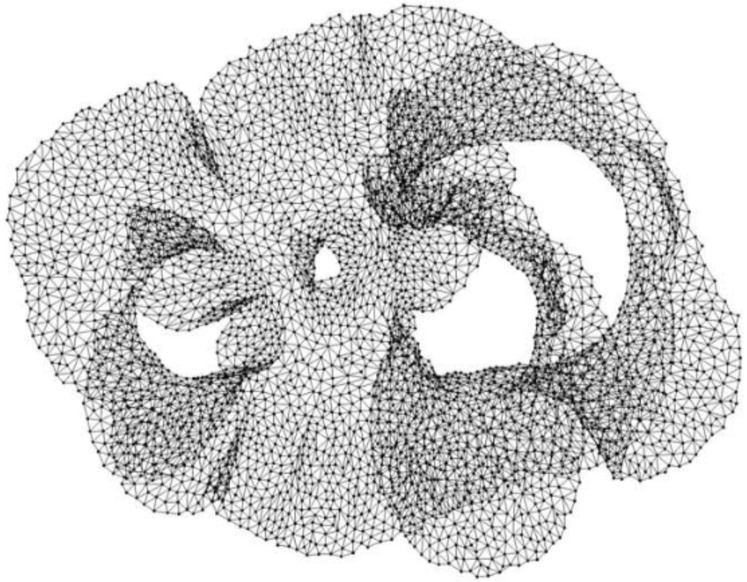


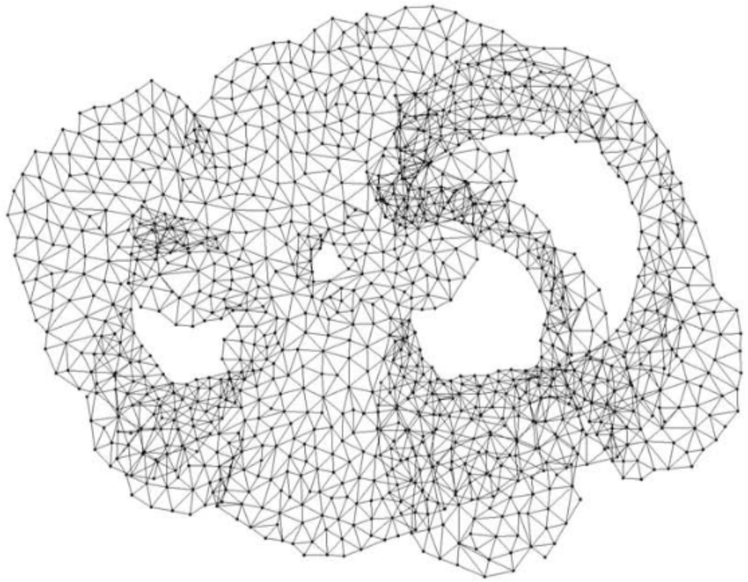
Fig. 2. A fisheye view of the 4elt graph focused on the right-hand portion.

GansnerKorenNorth2005

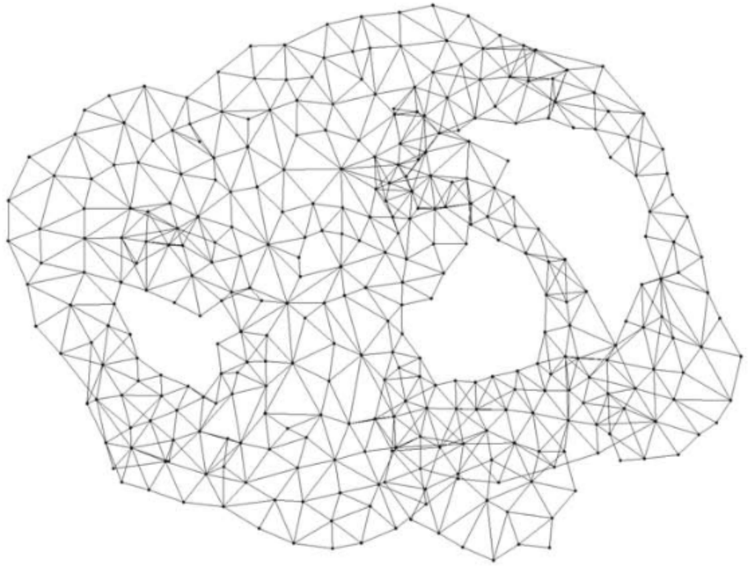
# Topological Fish-Eye View



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

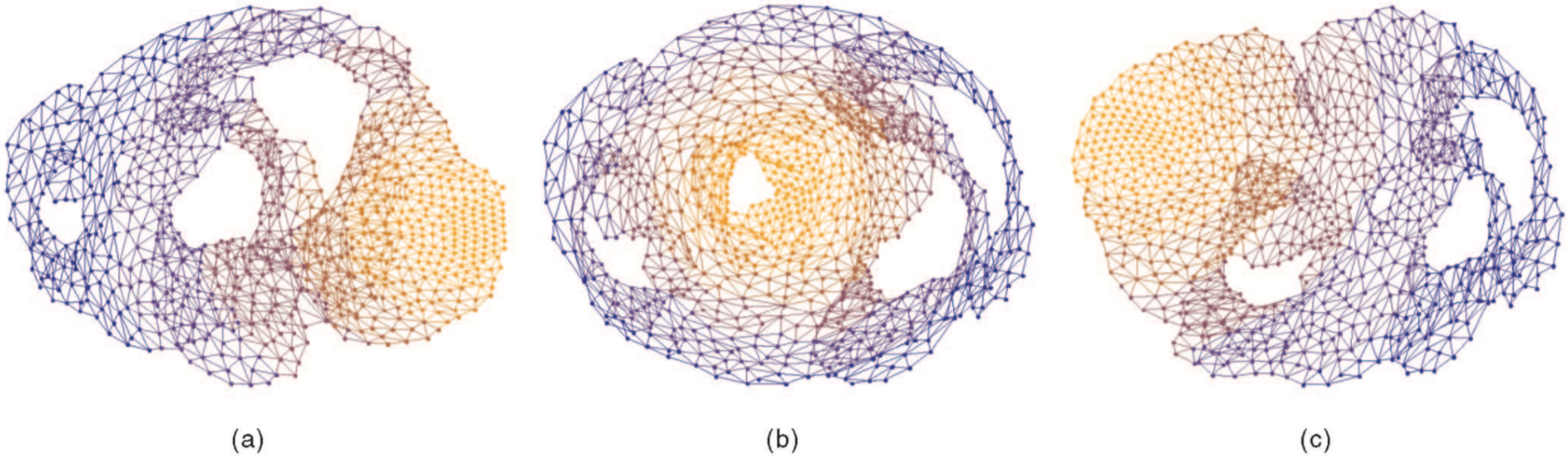
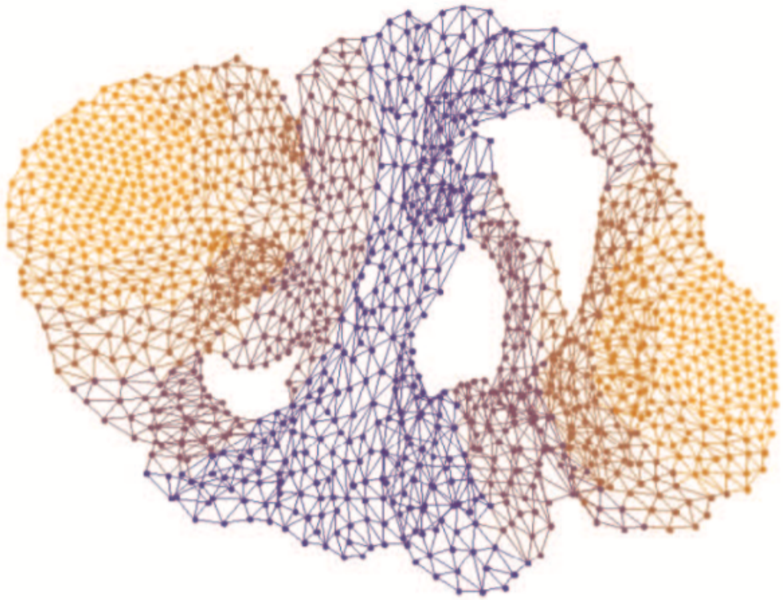


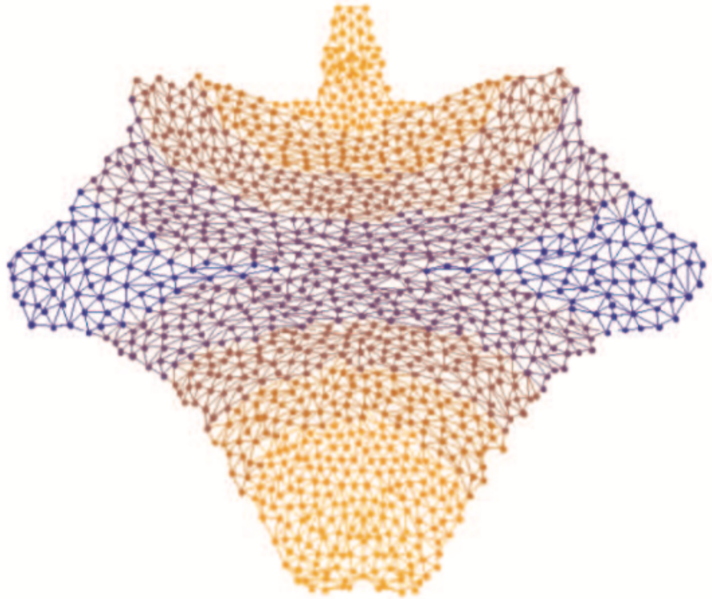

Fig. 4. Topological fisheye views of the 4elt graph. Views are based on “hybrid graphs” formed by superposition of several approximations of the graph. Levels are colored orange-to-blue, where the focus area from the finest graph is in orange. The figure shows three examples, focusing on (a) the right-hand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

GansnerKorenNorth2005

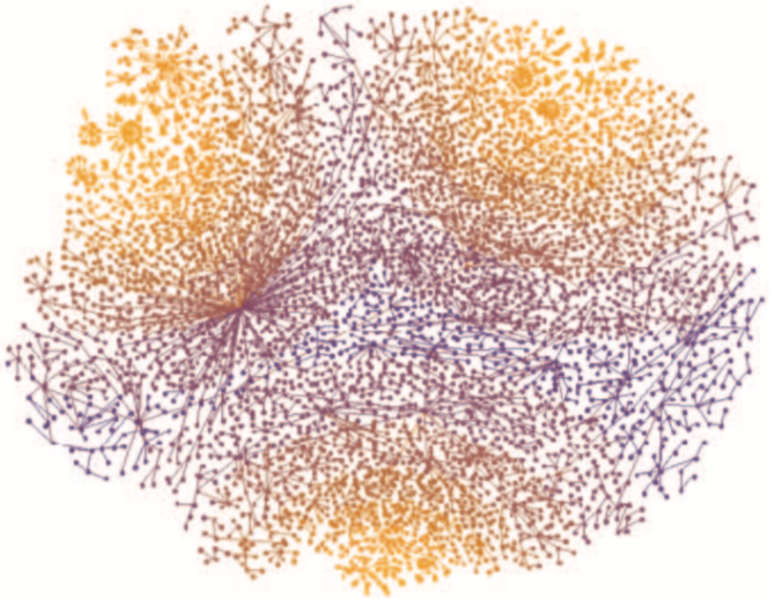
# Topological Fish-Eye View



4elt graph (2 foci)



Crack graph (2 foci)



Internet graph (3 foci)

Fig. 17. Viewing graphs with multiple foci.

GansnerKorenNorth2005

# 5

# Node and edge clustering

# Edge Bundling

Survey: ZhouXuYuan2013

Survey: http://www.chaofz.me/asset/file/Edge%20Bundling%20Survey.pdf [Zhou2017]

# Edge Bundling Classification

- Hierarchical Edge Bundling
- Flow Map
- Geometry-based
- Force-directed
- Image-based
- Skeleton-based

[Zhou2017]

# *Hierarchical Edge Bundling*

# Hierarchical Edge Bundling

- Starting from tree visualization…

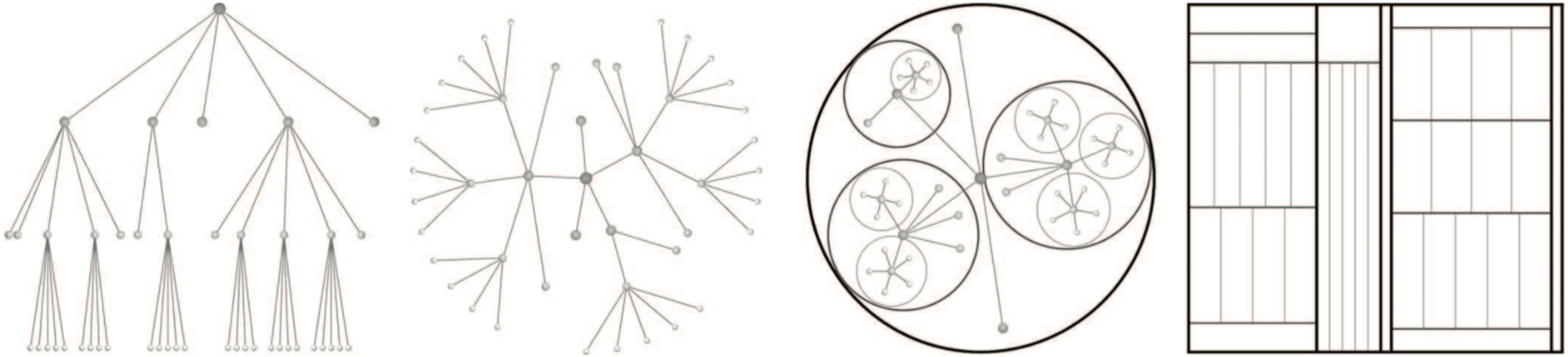


Fig. 1. Common tree visualization techniques. From left-to-right: rooted tree, radial tree, balloon tree, and treemap layout.

Holten2006

# Hierarchical Edge Bundling

- Bundling adjacent edges using hierarchical relations

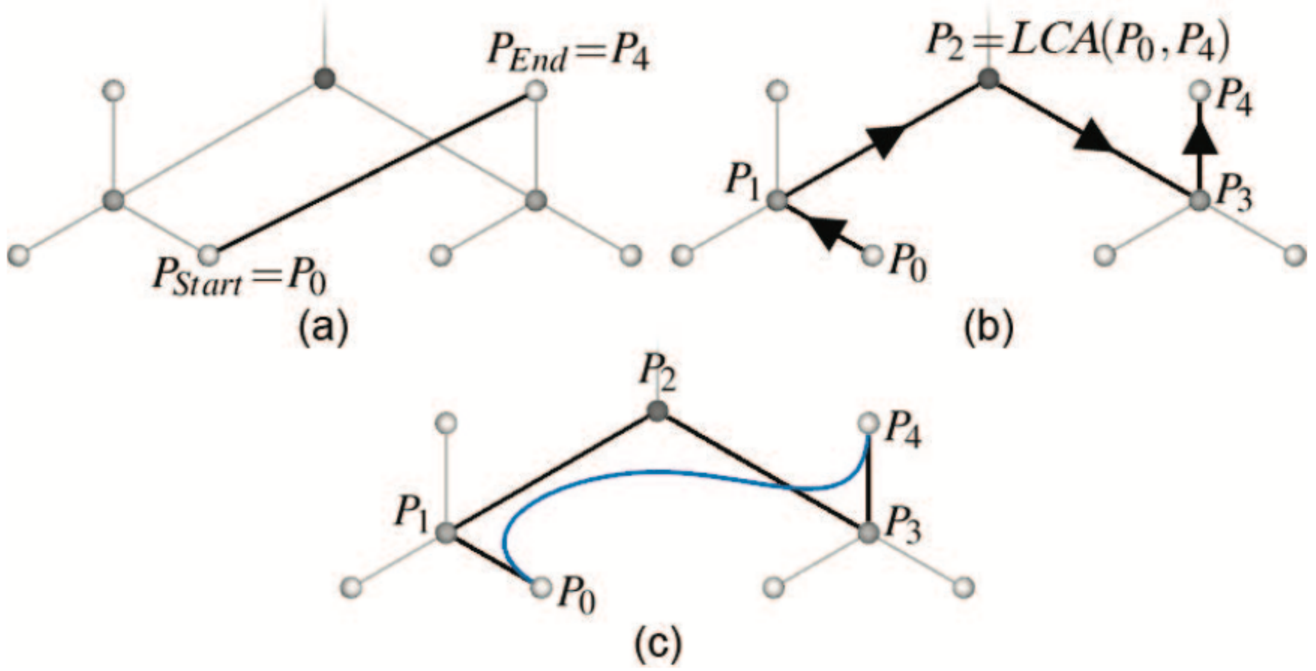
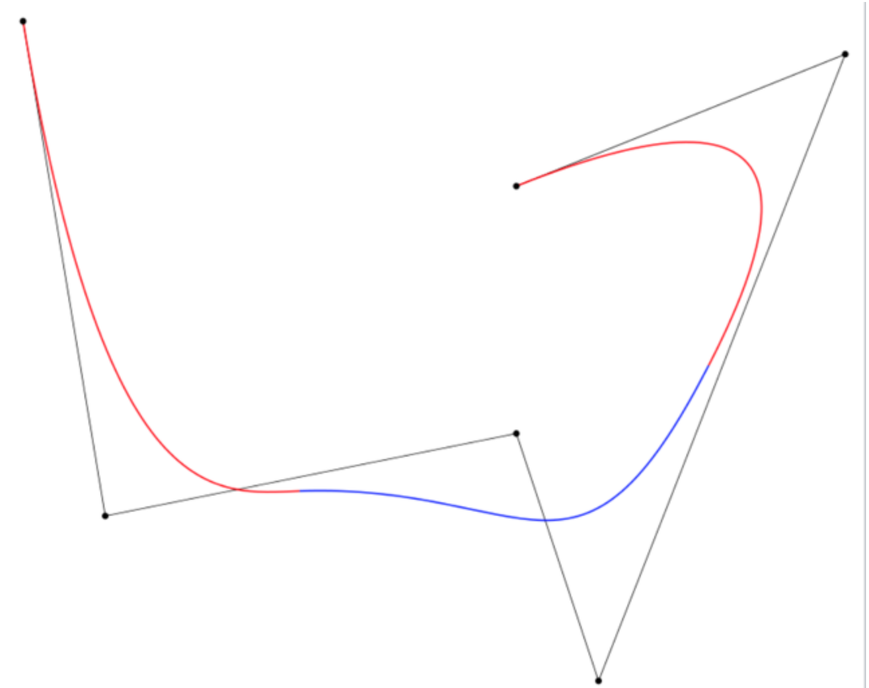



Fig. 3. Bundling adjacency edges by using the available hierarchy. (a) Straight line connection between $P_0$ and $P_4$; (b) path along the hierarchy between $P_0$ and $P_4$; (c) spline curve depicting the connection between $P_0$ and $P_4$ by using the path from (b) as the control polygon.

Holten2006

# Spline Models



B-spline with control points/control polygon, and marked component curves

Piecewise cubic B-spline

https://en.wikipedia.org/wiki/B-spline

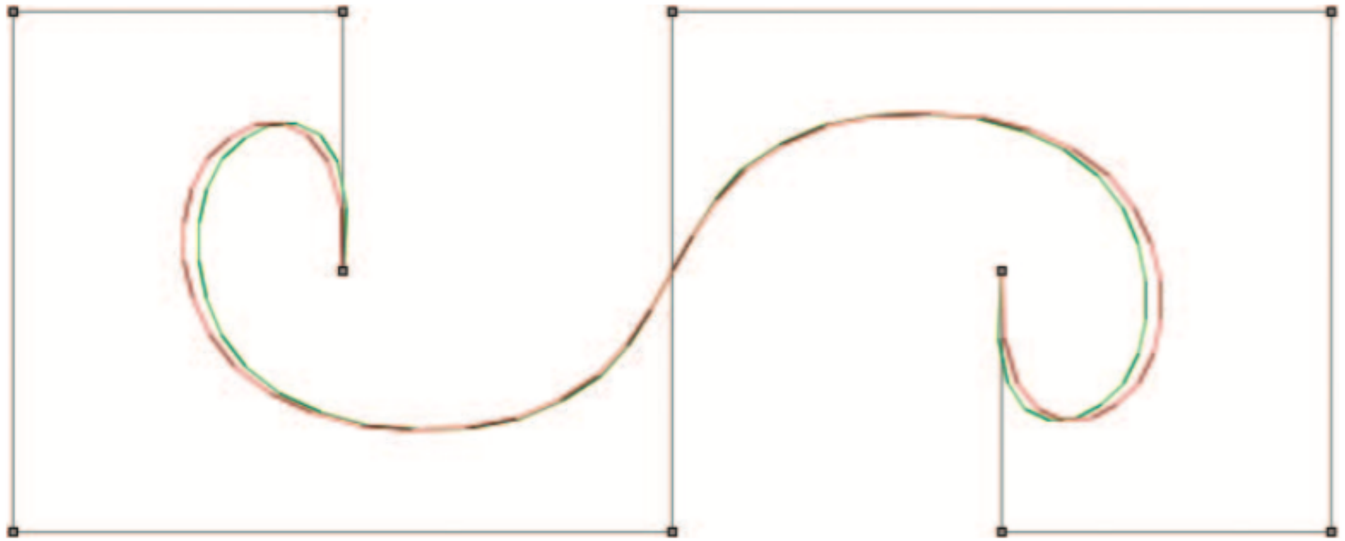
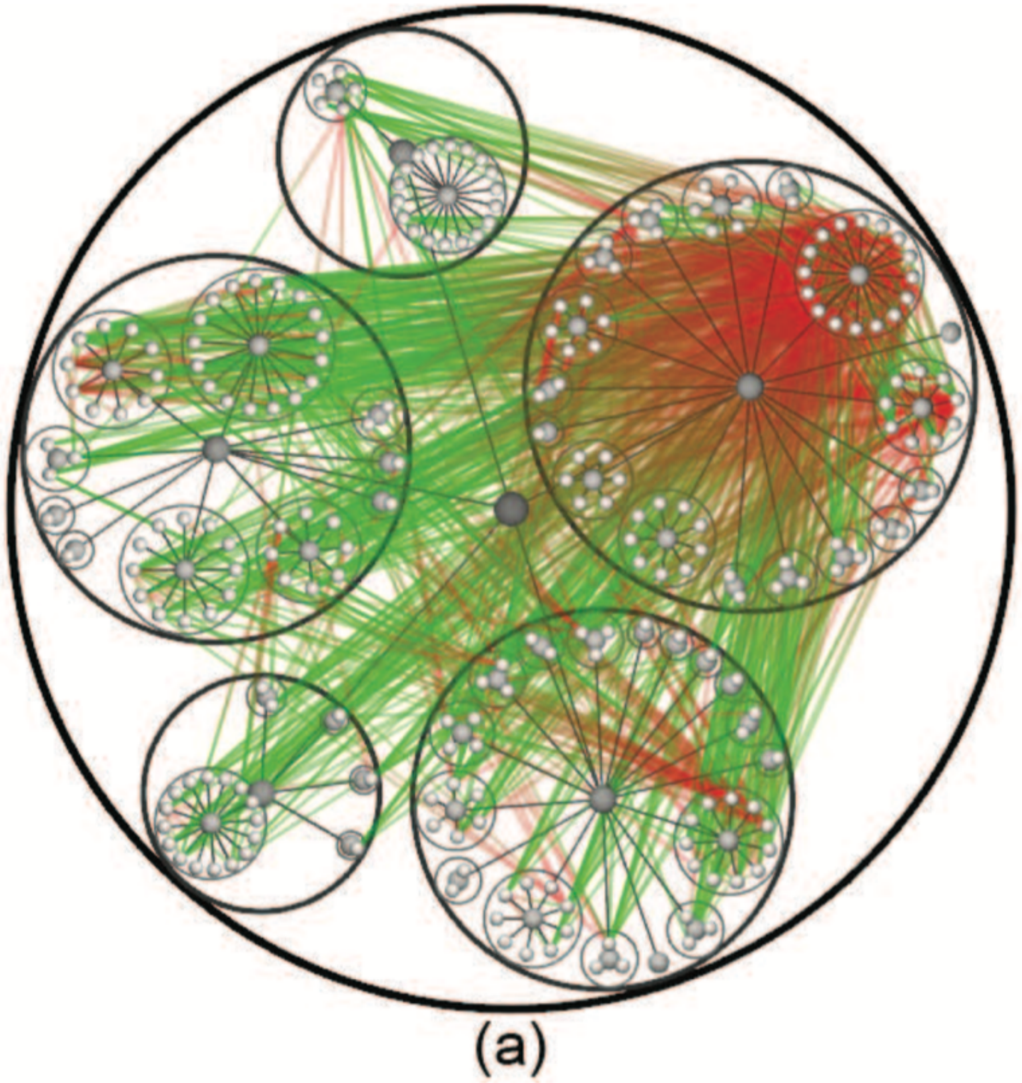
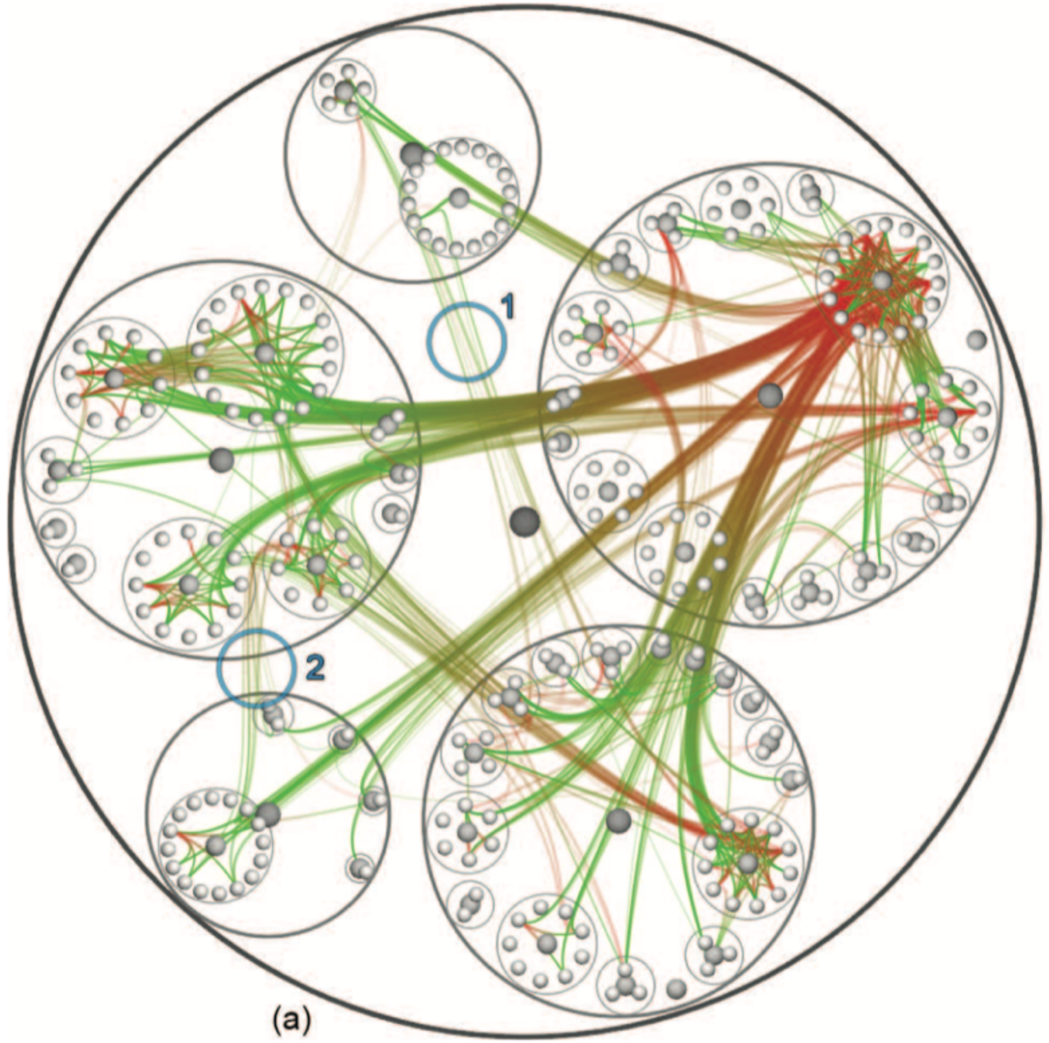


Fig. 5. Spline curve straightening by means of control polygon straightening (green) and spline point straightening (red) yield somewhat different results, but these differences are minimal from a visual point of view.

Holten2006

# Hierarchical Edge Bundling




Holten2006

# Bundling Strength

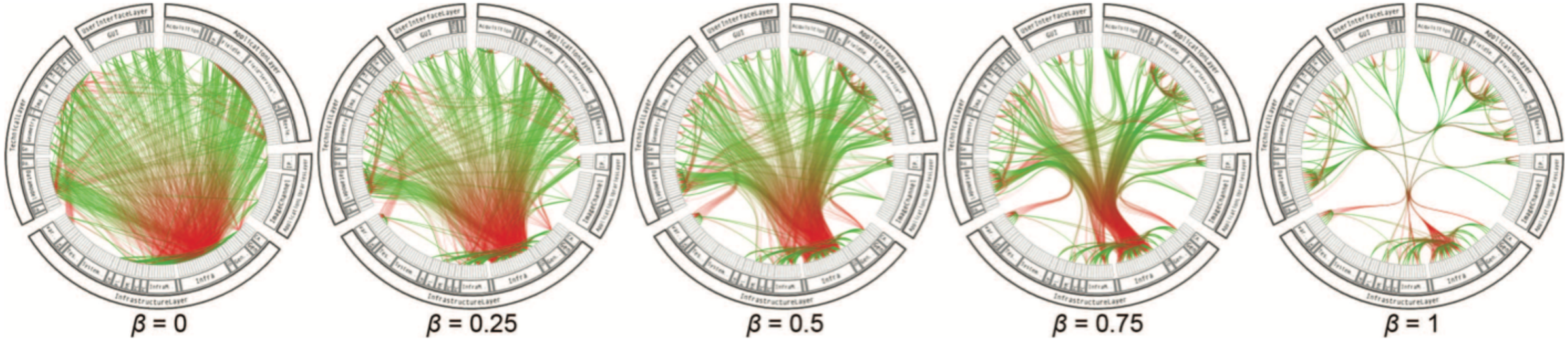



Fig. 14. Using the bundling strength $\beta$ to provide a trade-off between low-level and high-level views of the adjacency relations. The value of $\beta$ increases from left-to-right; low values mainly provide low-level, node-to-node connectivity information, whereas high values provide high-level information as well by implicit visualization of adjacency edges between parent nodes that are the result of explicit adjacency edges between their respective child nodes.

Holten2006

# *Flow Map Layout*

# Flow map layout

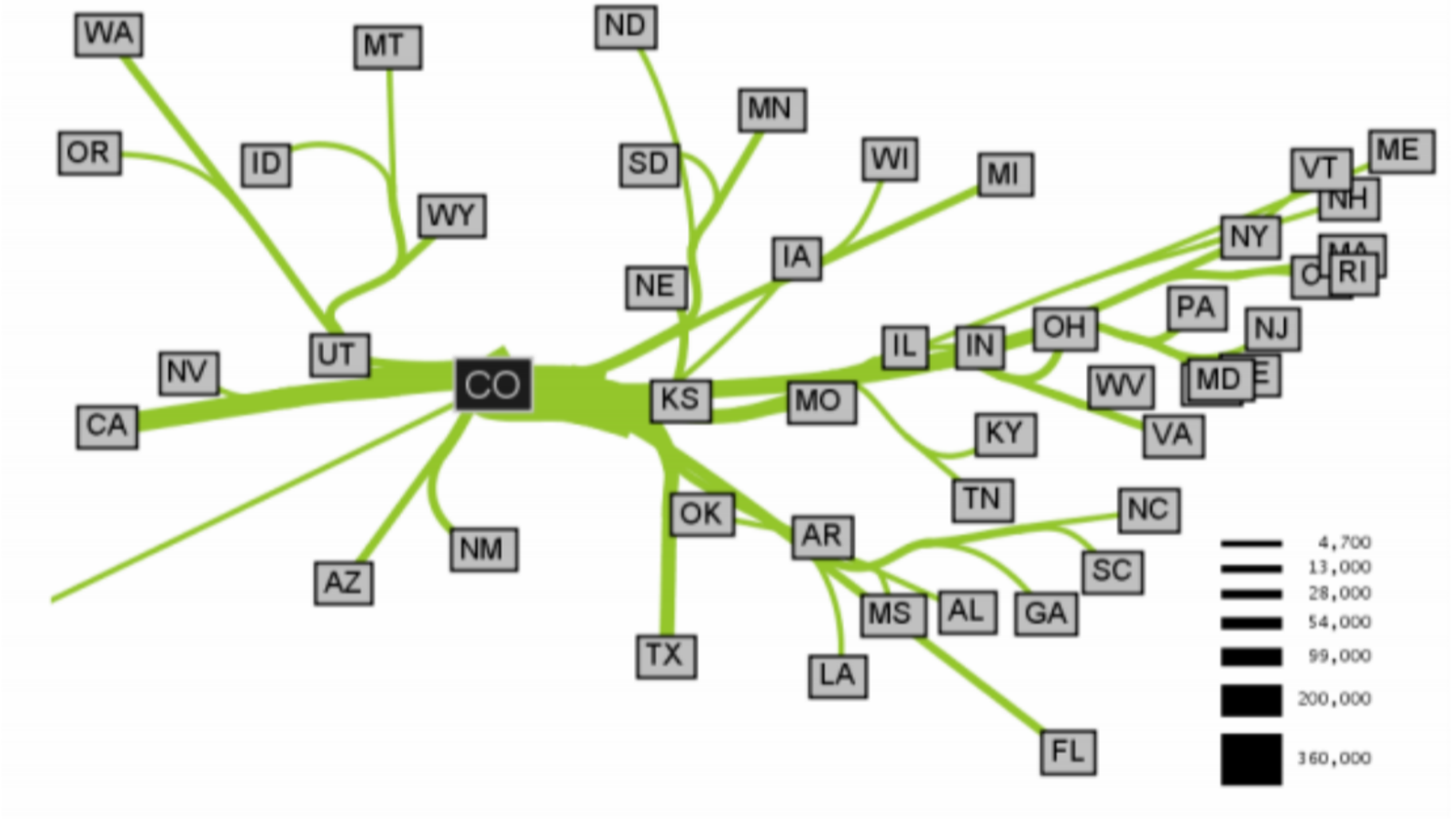



*Fig. 1: Outgoing migration map from Colorado from 1995-2000, generated by Phan et al.'s algorithm*

[Zhou2017]

# Flow map layout

*Fig. 2: Flow layout of embodied CO2 to the United Kingdom generated by Verbeek et al.'s techniques*

[Zhou2017]

# *Coming up: Force-directed, geometry-based, Image-based Edge bundling*

# Thanks!

Any questions?

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

# CREDITS

Special thanks to all people who made and share these awesome resources for free:

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

# Presentation Design

This presentation uses the following typographies and colors:

## Free Fonts used:

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

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

## Colors used