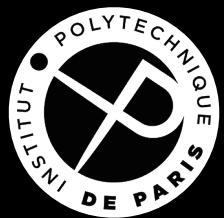


Graphs & Trees

James EAGAN



Includes content adapted
from John Stasko (Georgia Tech)



Updated : May 2020

1

Connections are everywhere

- Circle of friends
- SNCF train network
- ...

2

These connections form a graph

3

3

What is a graph?

- *vertices and edges*

a.k.a.

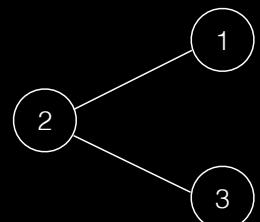
- *nodes and links*

	1	2	3
1	0	1	0
2	1	0	1
3	0	1	0

Adjacency matrix

1: 2
2: 1, 3
3: 2

Adjacency list

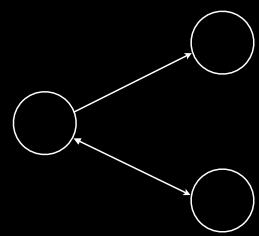


Drawing

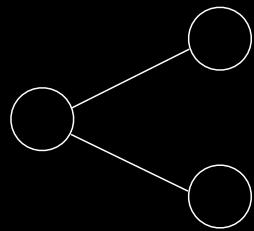
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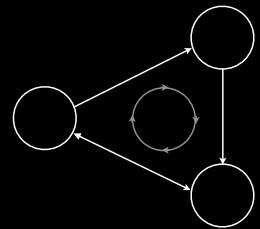


Directed

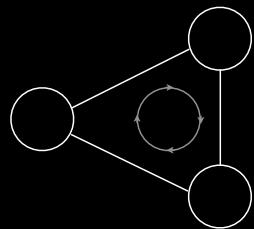


Undirected

6



Directed

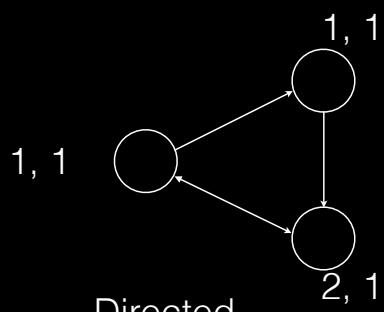


Undirected

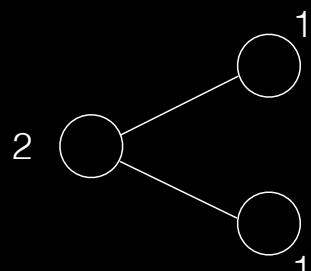
Cycles

7

7



Directed



Undirected

Degree

8

8



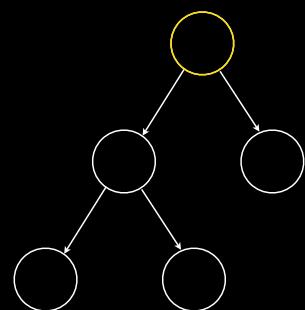
Directed

Undirected

Weights

9

9



Coming soon...

Trees

10

10

What can we model as a graph?

11

11

- European/Global Telephone system
- World Wide Web
- Retail distribution networks
- Software call graph
- Semantic map in an AI algorithm
- Social connectivity
- ...

12

12

Graphs are abstract mathematical objects

(But we want a concrete rendering.)

13

Scaling graph layout algorithms is hard

(Not just hard, but NP-hard.)

14

Users' focus frequently changes

(But small changes can have big effects on layout.)

15

Graph drawing community focuses just on layout

- www.cs.brown.edu/people/rt/papers/gd-tutorial/gd-constraints.pdf
- di Battista, Eades, Tamassia & Tollis, “Graph Drawing”, Prentice Hall, 1999

16

16

22nd International Symposium on Graph Drawing – Graph Drawing 2014
 lamut.informatik.uni-wuerzburg.de Lecteur

gd₁₄ Graph Drawing

24-26 September 2014, Würzburg, Germany

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Graph Drawing is concerned with the geometric representation of graphs and networks, and algorithmic methods for visualizing them. It is motivated by applications where it is crucial to visually analyze and interact with relational datasets. Examples of such application areas include social sciences, Internet and Web computing, information systems, computational biology, networking, VLSI circuit design, and software engineering.

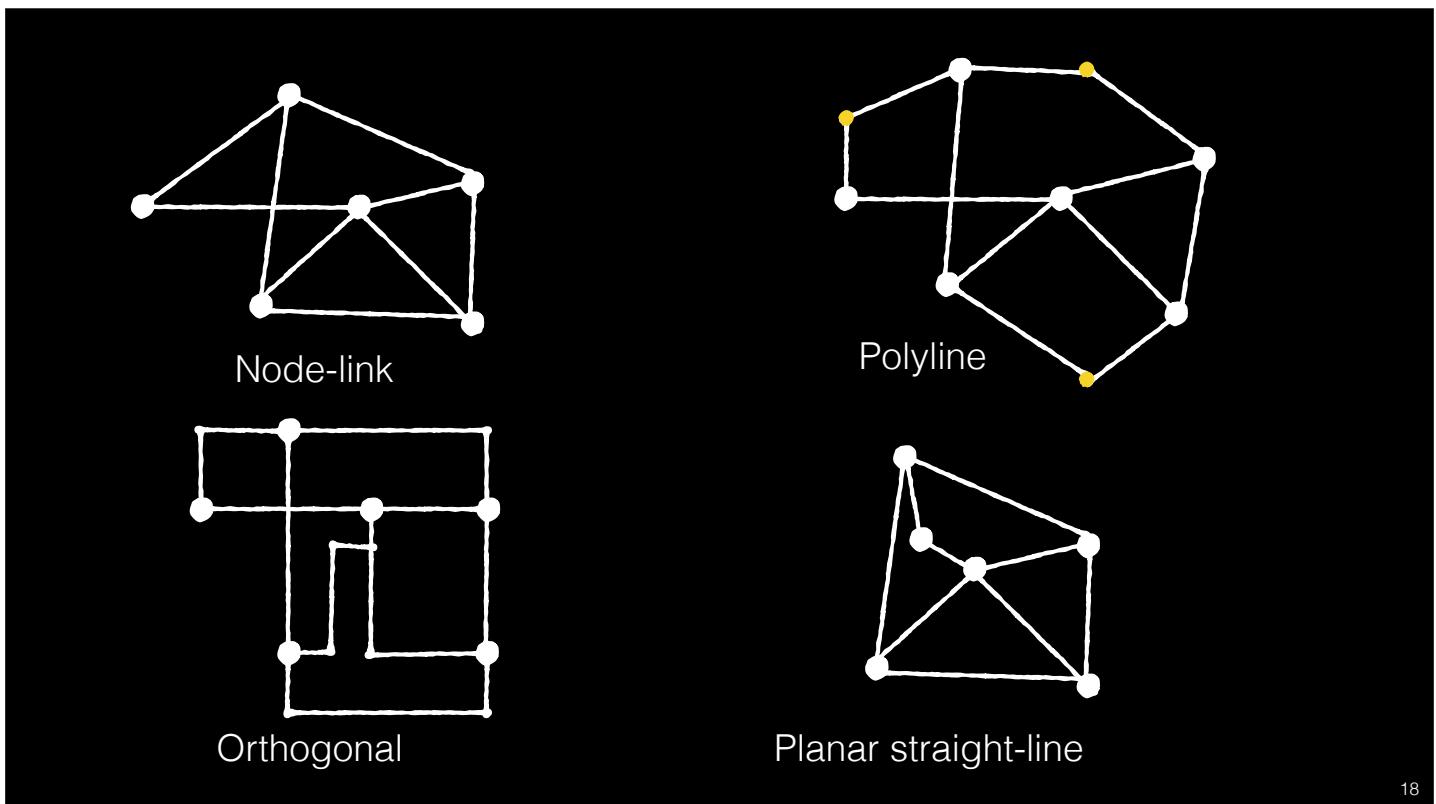
The **International Symposium** on Graph Drawing is the main annual event in this area. The symposium will be hosted by the University of Würzburg, September 24–26, 2014. Researchers and practitioners working on any aspect of graph drawing are invited to contribute papers and posters, and participate in the graph drawing contest. Each paper must be submitted explicitly to one of two distinct tracks. Papers submitted to one track will not compete with papers submitted to the other track.

Track 1: Combinatorial and algorithmic aspects
 This track is mainly devoted to fundamental graph drawing advances, such as combinatorial aspects and algorithm design. The range of topics for this track includes (but is not limited to) the following:
 • Design and analysis of graph drawing algorithms

Sponsors

17

17



18

18

Vertices can have various properties

(Shape, color, size, location, label, ...)

19

Edges, too

(Color, size, label, form, ...)

20

What factors make a graph drawing look good?

(Edge crossings, edge length, area, bends, ...)

21

Minimize number of edge crossings

(Ideally a planar layout.)

22

Minimize total edge length

(Toward a proper scale.)

23

Minimize area

(But still maintain inter-node spacing.)

24

Avoid long edges

(Minimize maximum edge length.)

25

Keep edge lengths uniform

(Minimize variance.)

26

Avoid bends

(Minimize orthogonal edges toward straight lines.)

27

Which of these matters?

- Purchase, Graph Drawing 1997
- Ware et al., Info Vis 1(2), 2002
- Ghoniem et al., Info Vis 4(2), 2005

28

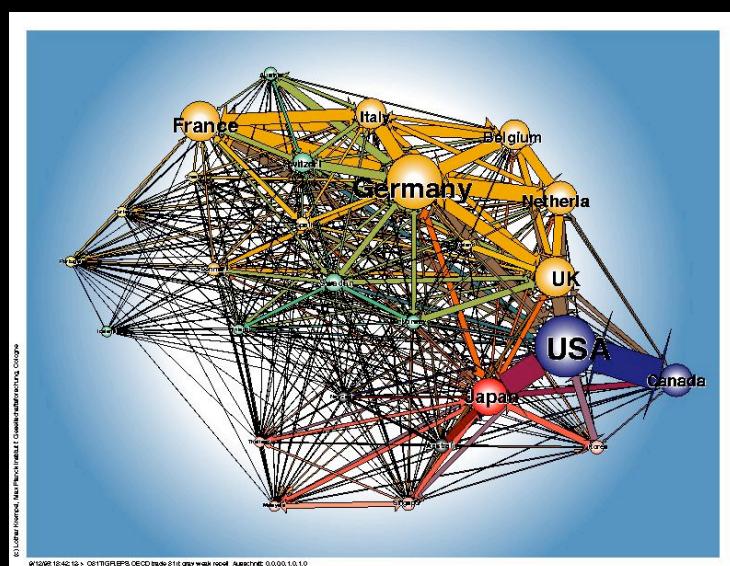
28

But how does it scale?

- Drawing might turn into a “ball of string.”
- Algorithm complexity is usually $\notin P$.

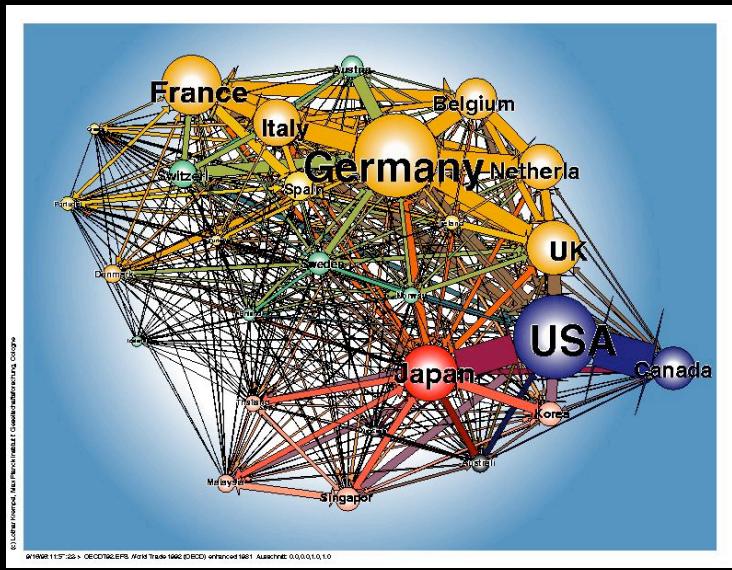
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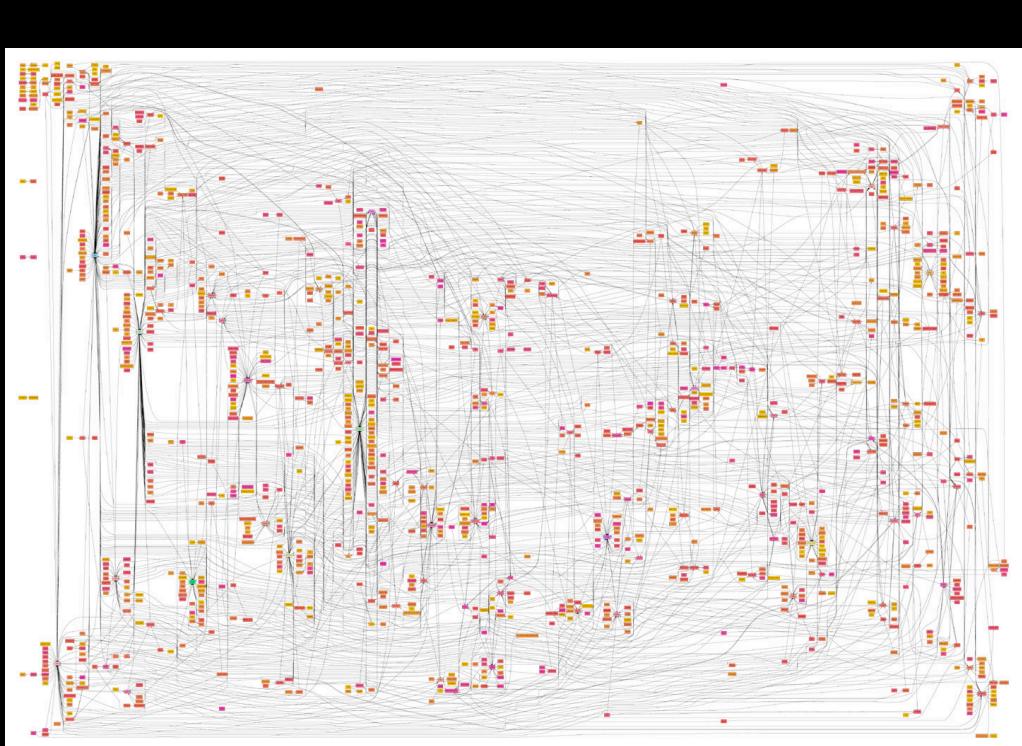
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[Charles Isbell, Cobot]

32

32

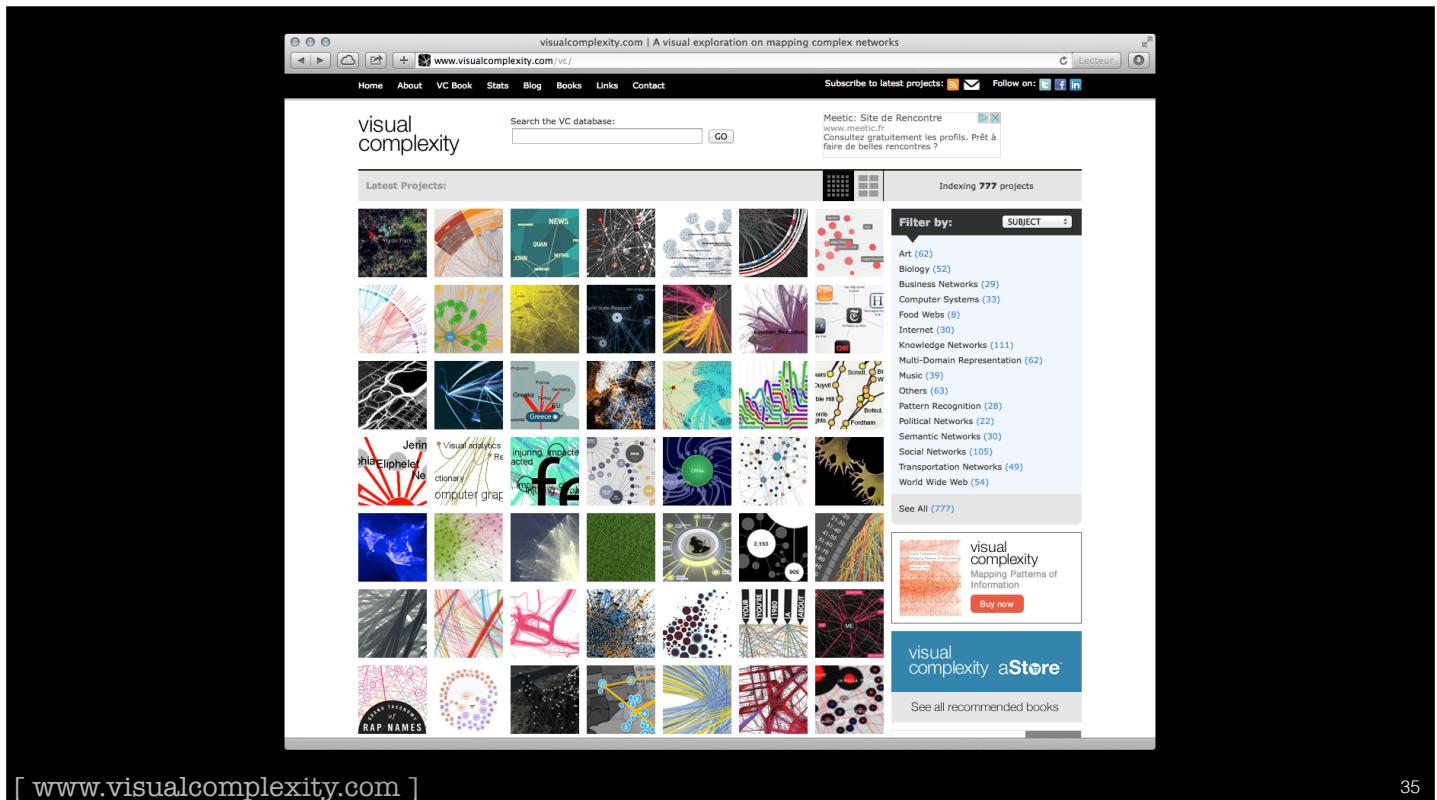
Clustering can sometimes help

Aggregate highly connected subgraphs.

33

34

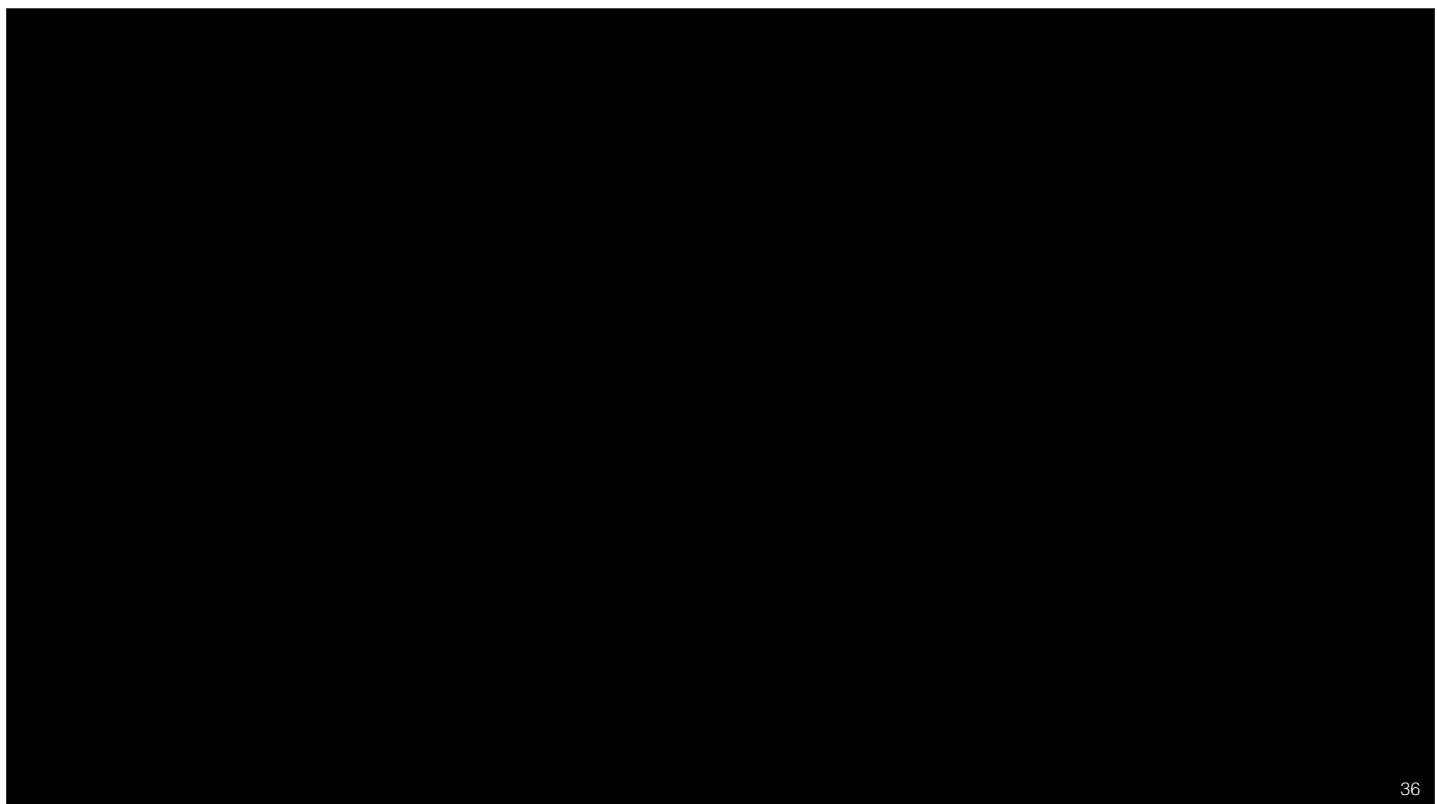
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[www.visualcomplexity.com]

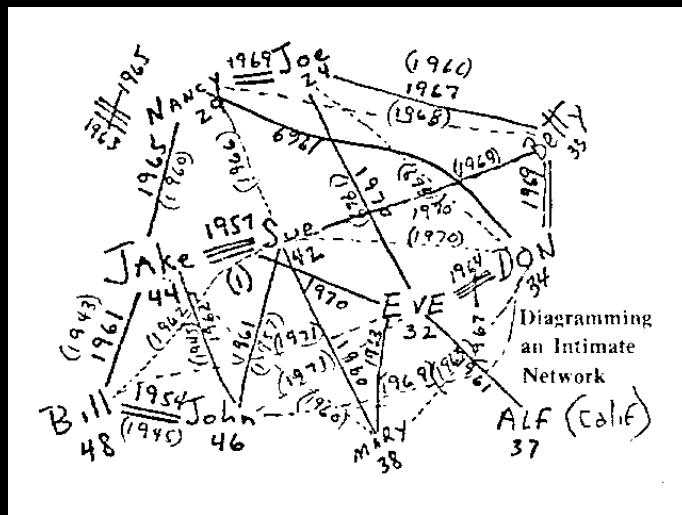
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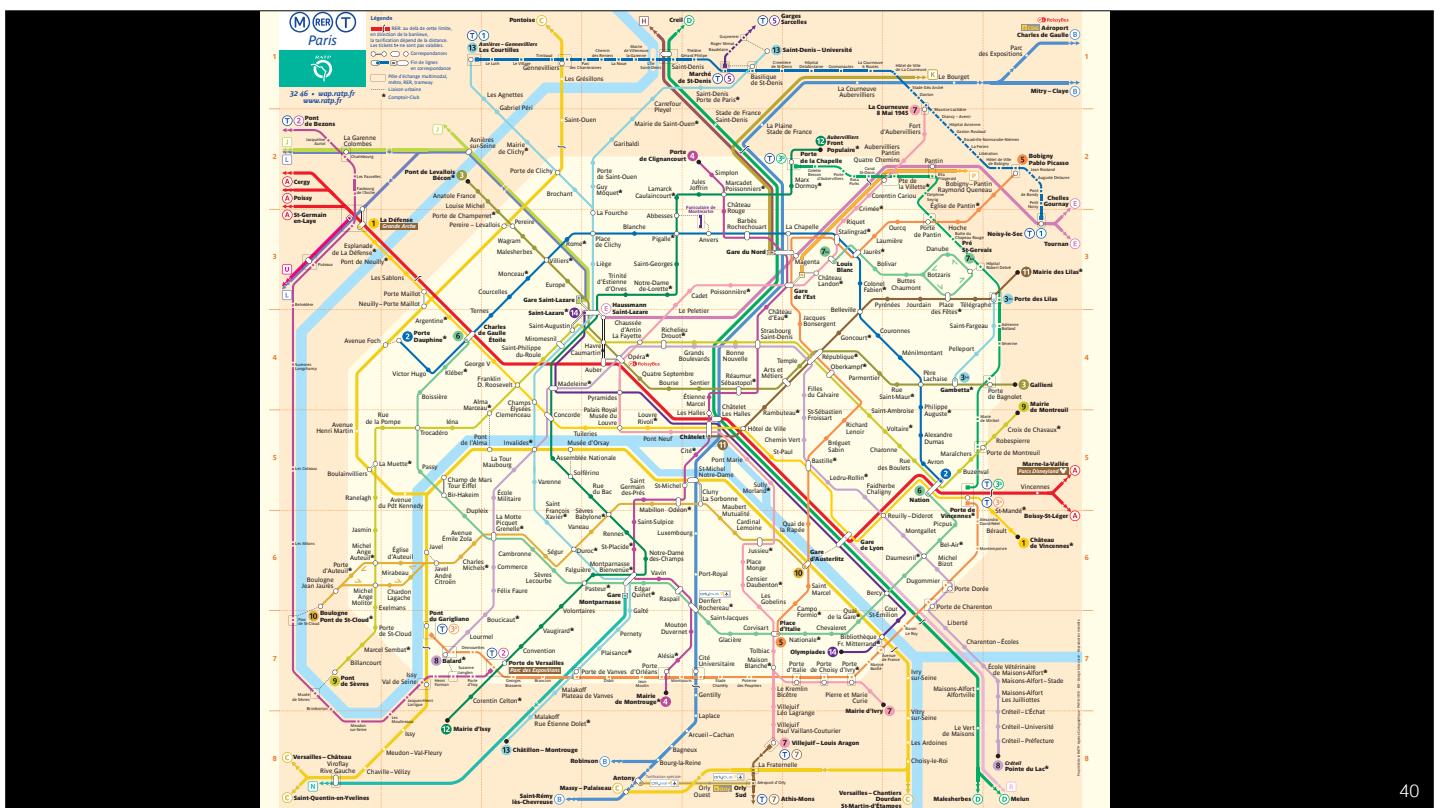
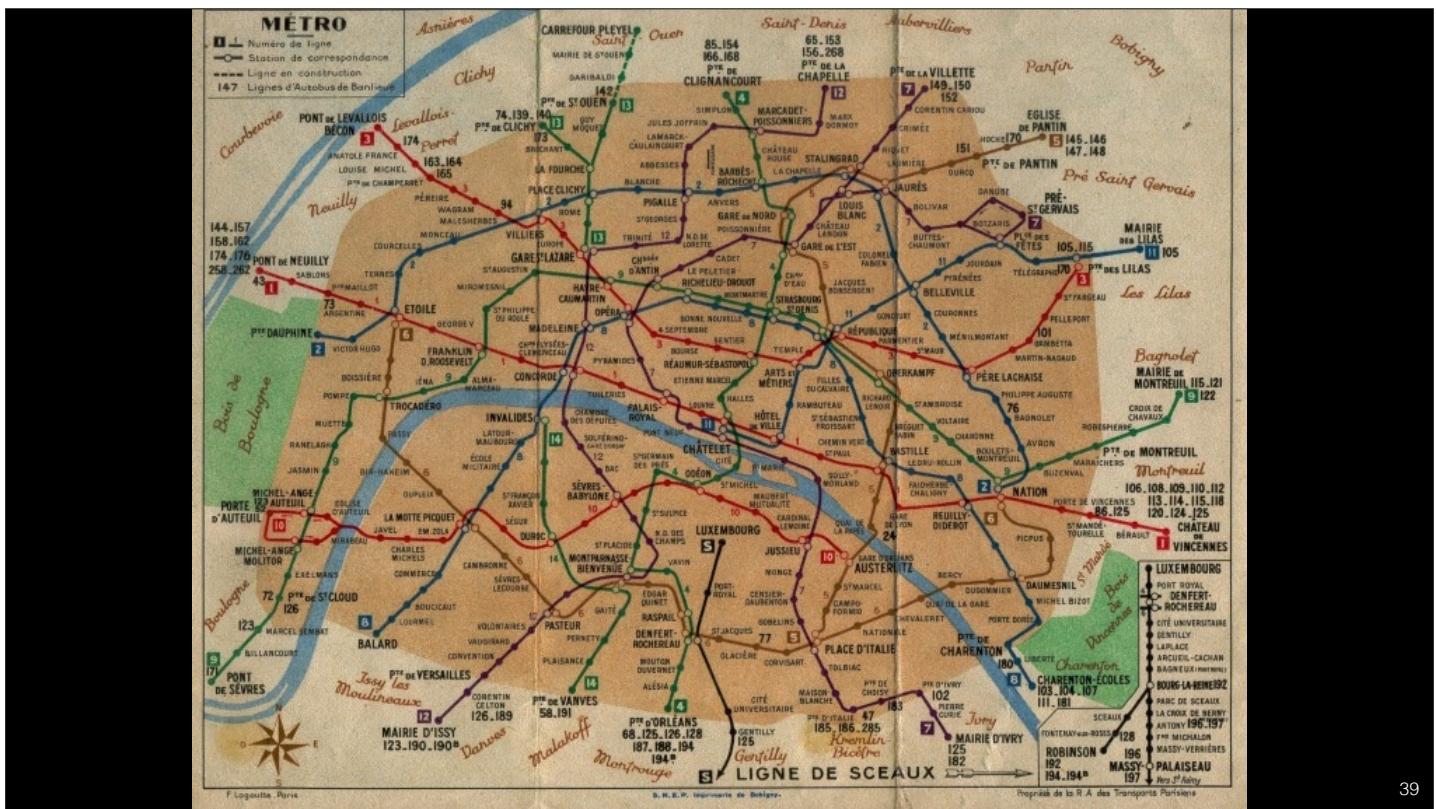


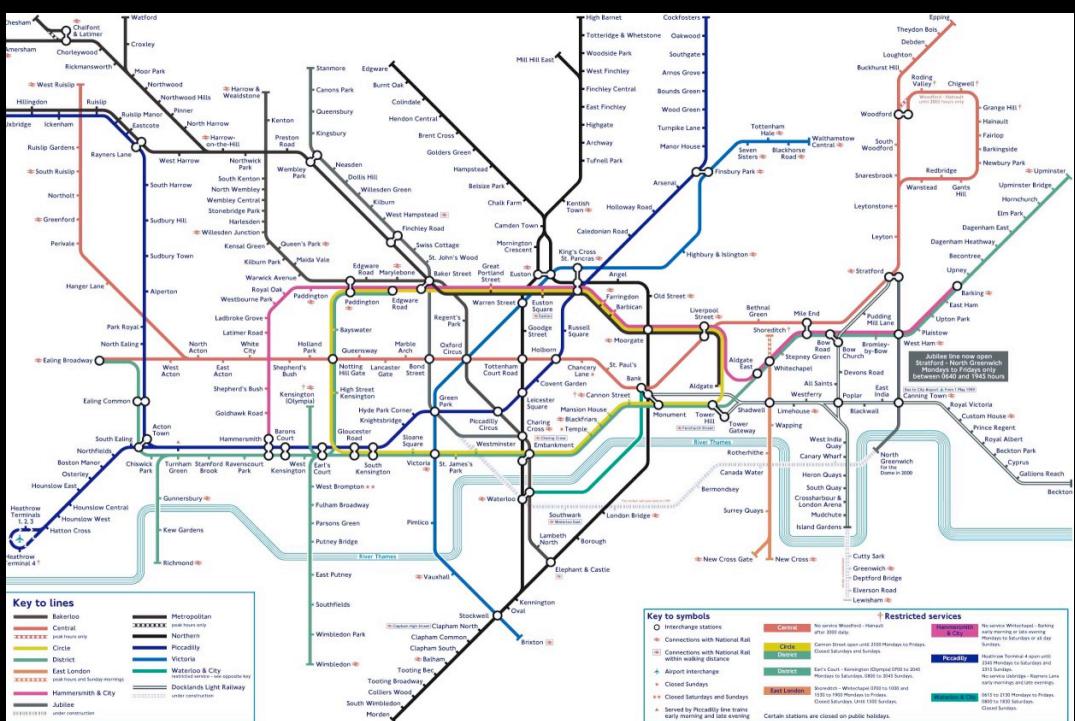
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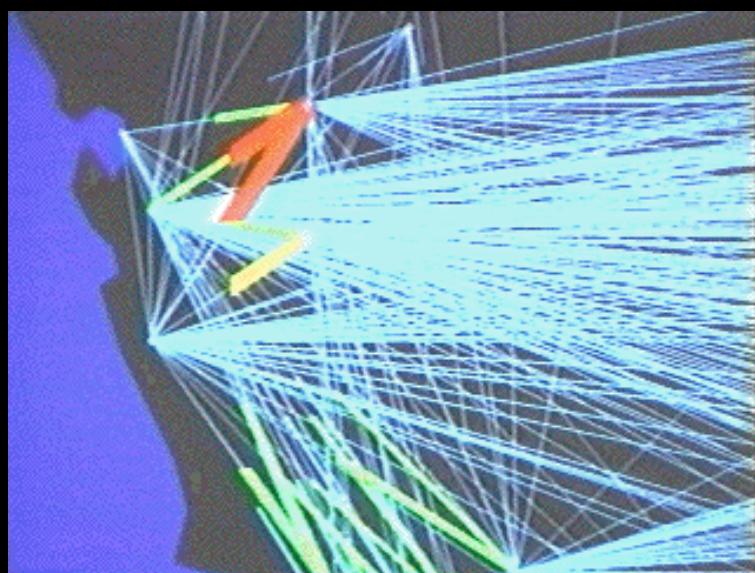


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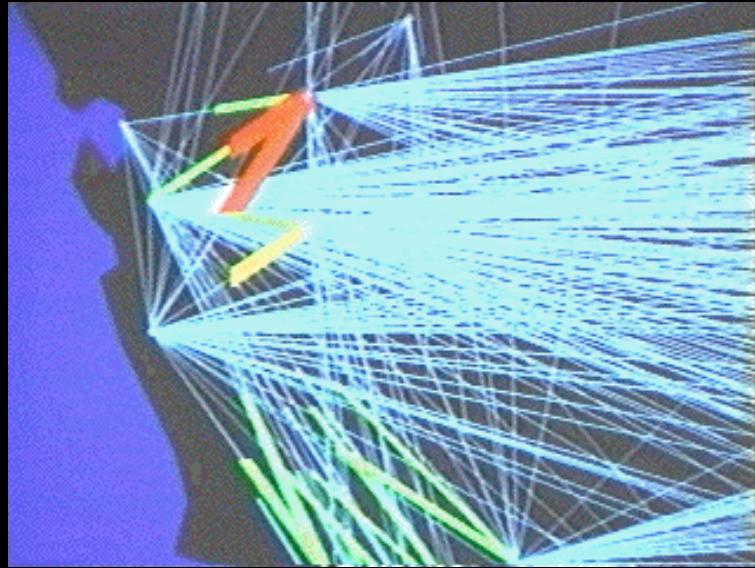
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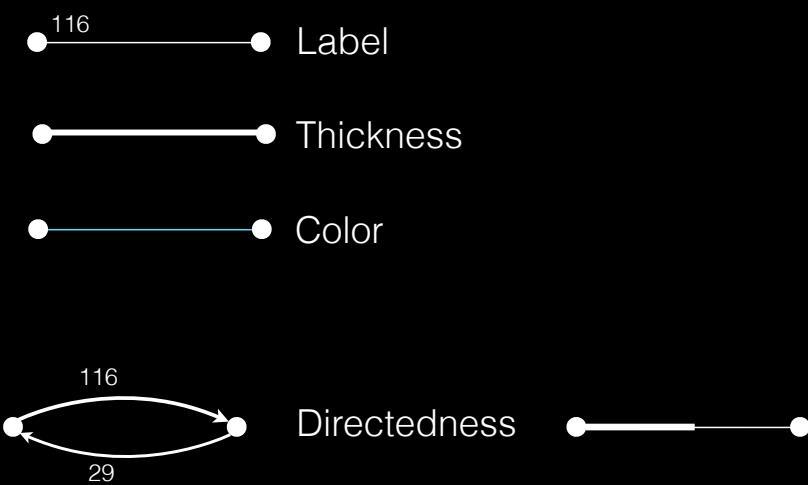


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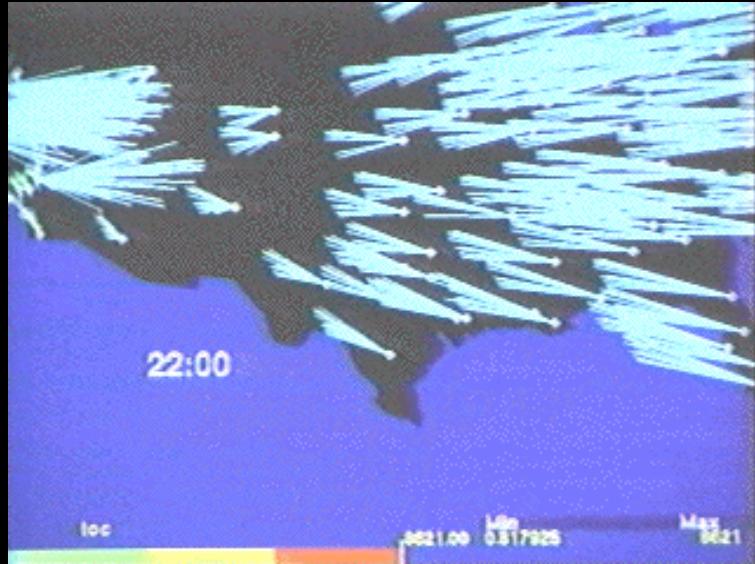
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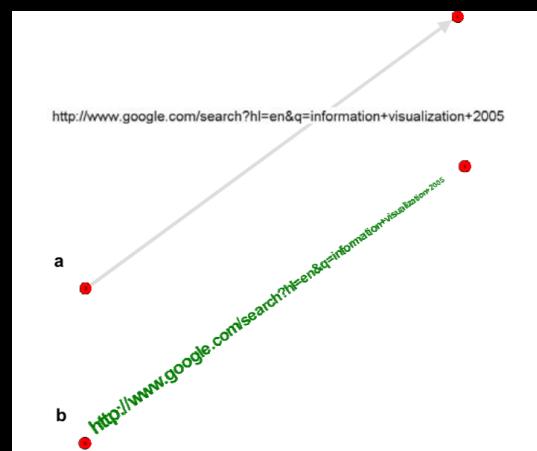


47

47

Graphs with long edge labels

- Where to put the label?
- NP-hard
- Idea: draw label as edge

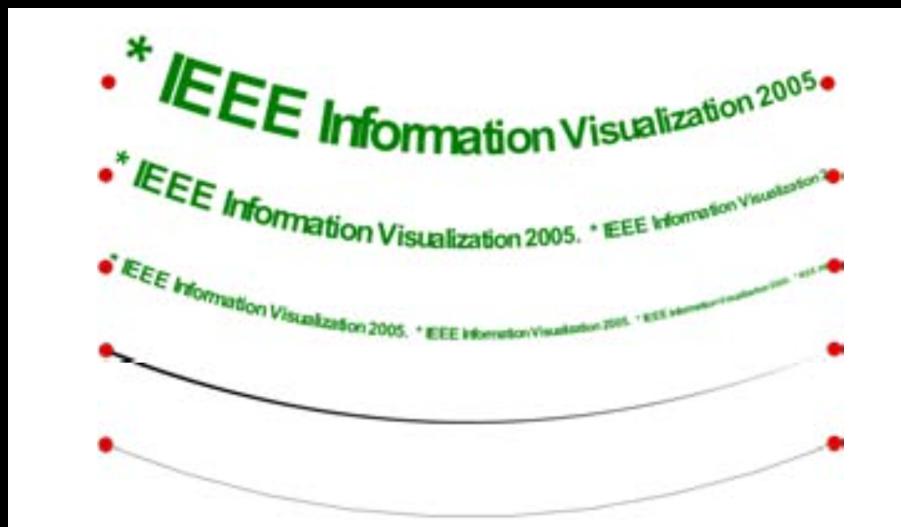


[Wong, Mackey, Perrine, Eagan, Foote & Thomas, InfoVis '05]

48

48

Multiple scales



[Wong, Mackey, Perrine, Eagan, Foote & Thomas, InfoVis '05]

49

49

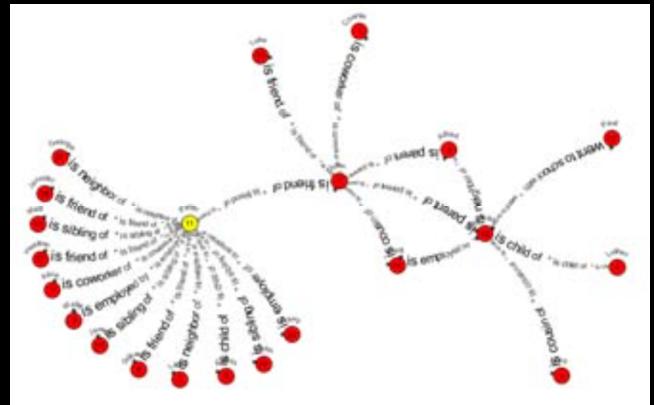
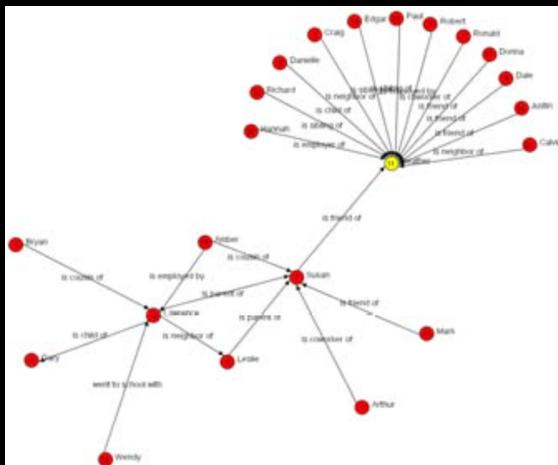
Directed edges



[Wong, Mackey, Perrine, Eagan, Foote & Thomas, InfoVis '05]

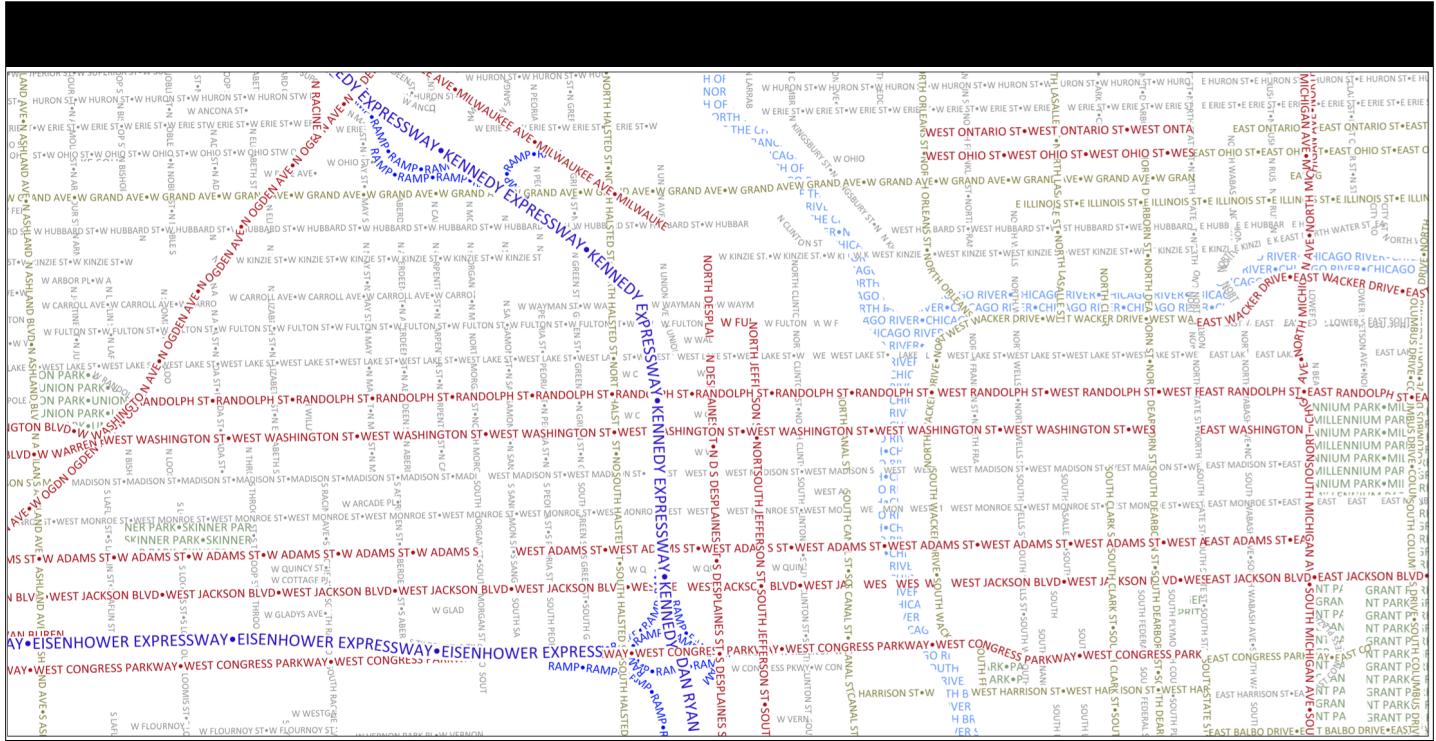
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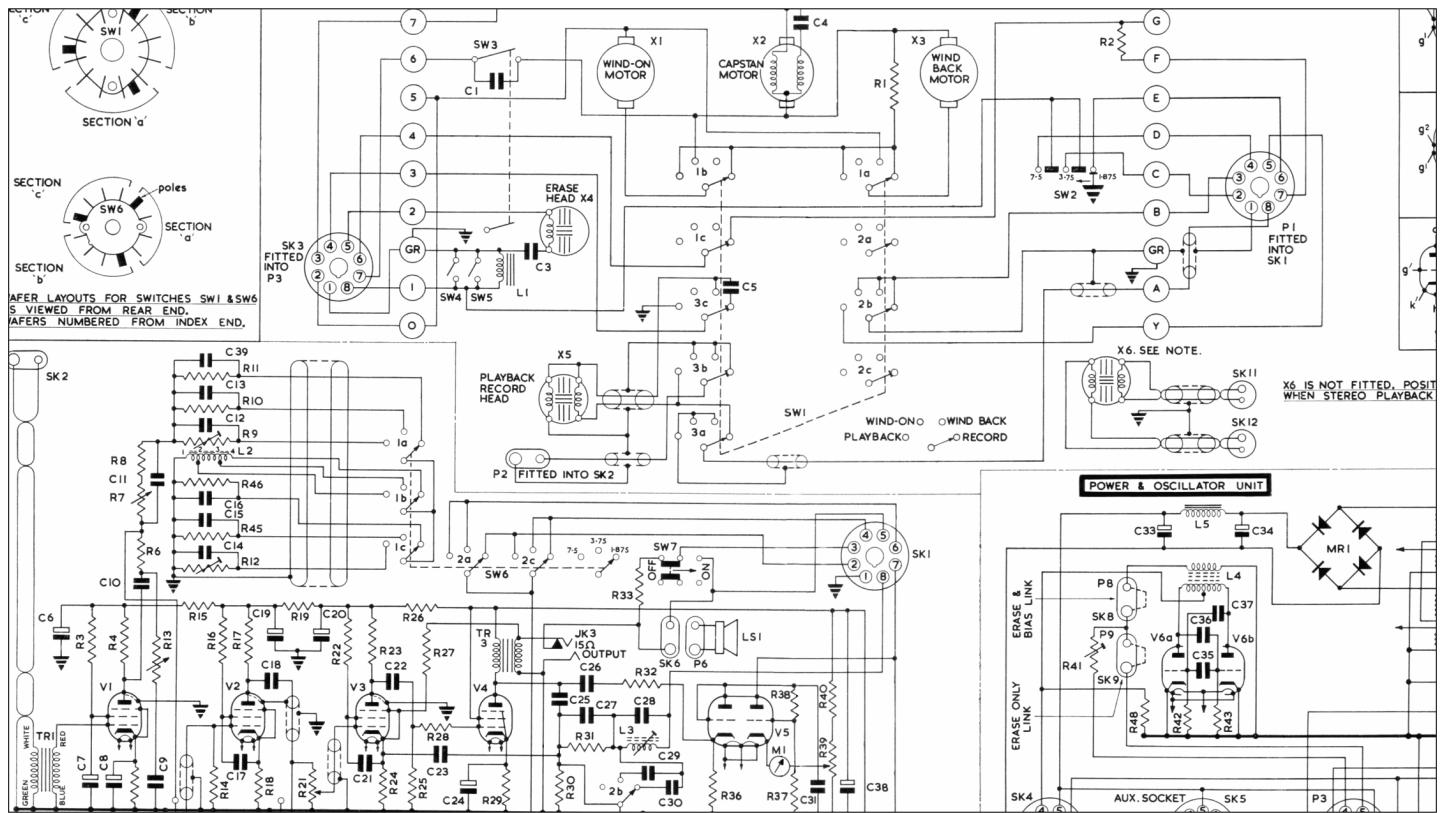
[Wong, Mackey, Perrine, Eagan, Foote & Thomas, InfoVis '05]

51

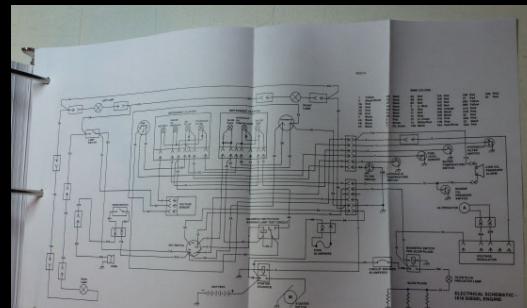
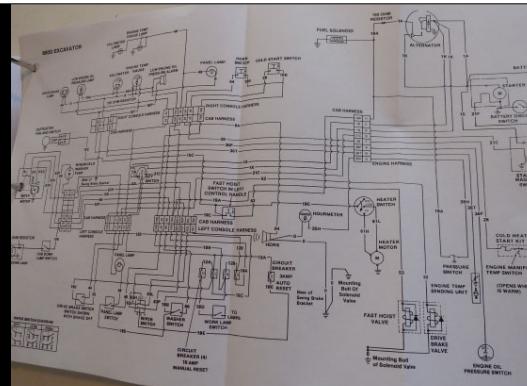


[Afzal et al., InfoVis '12]

52



53

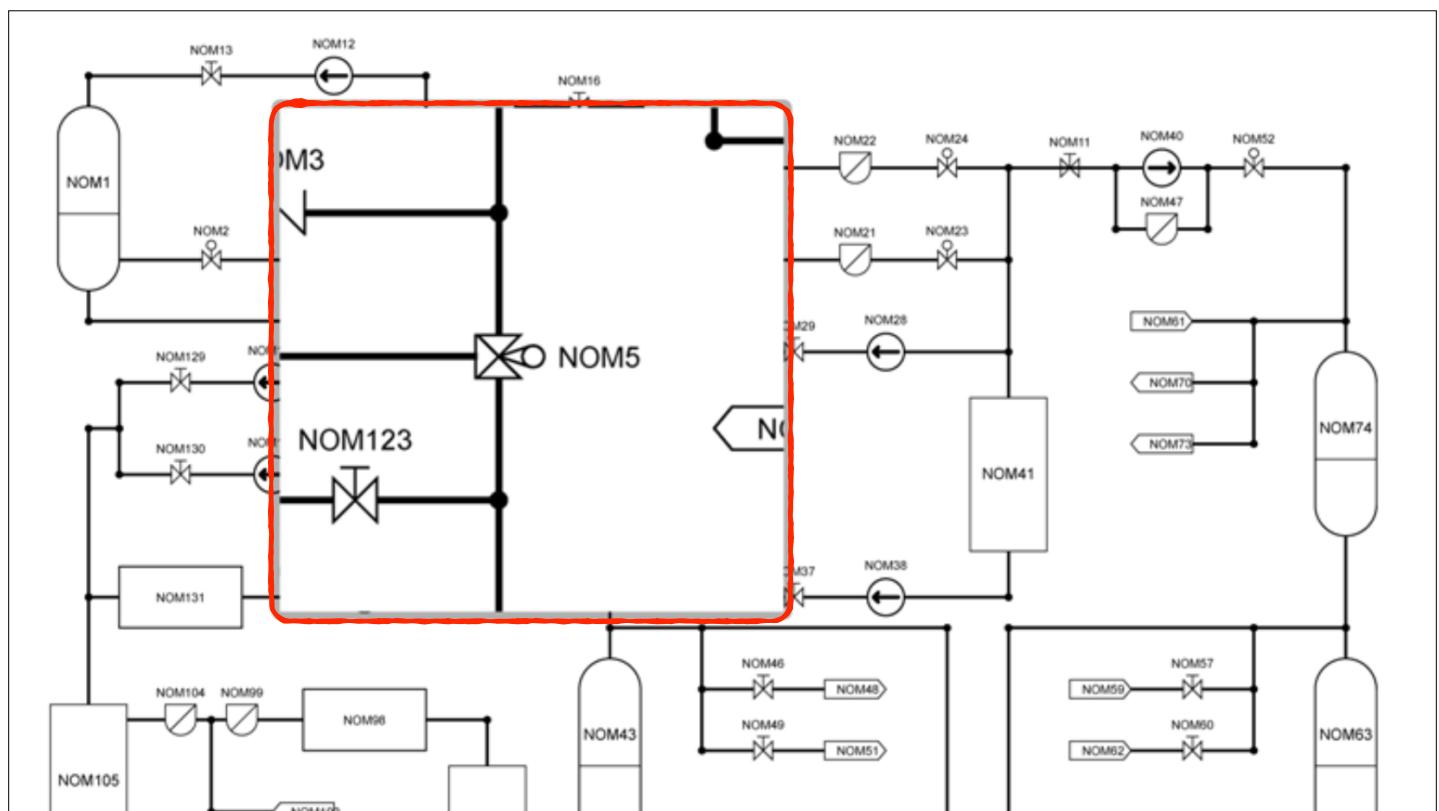


54

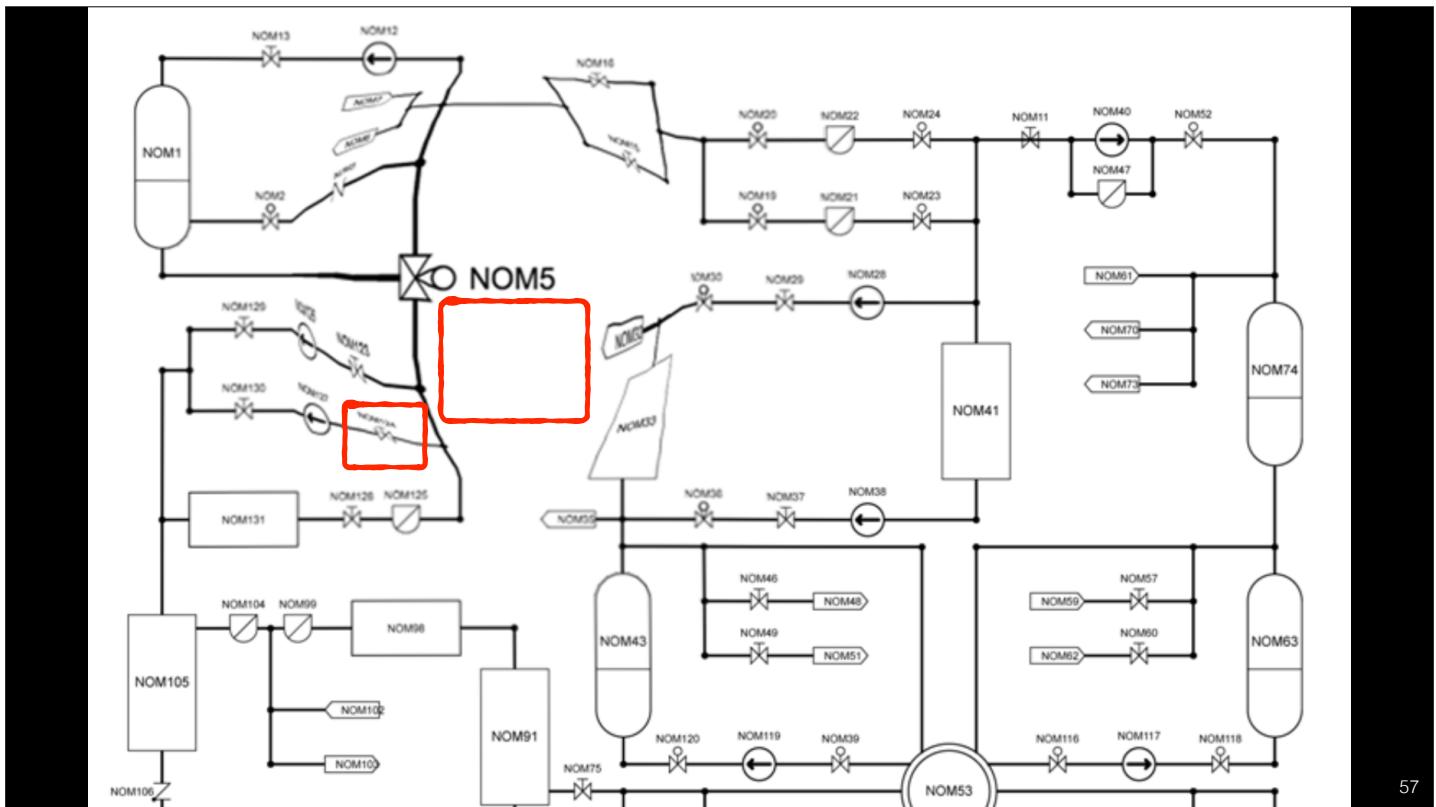
Focus + Context

55

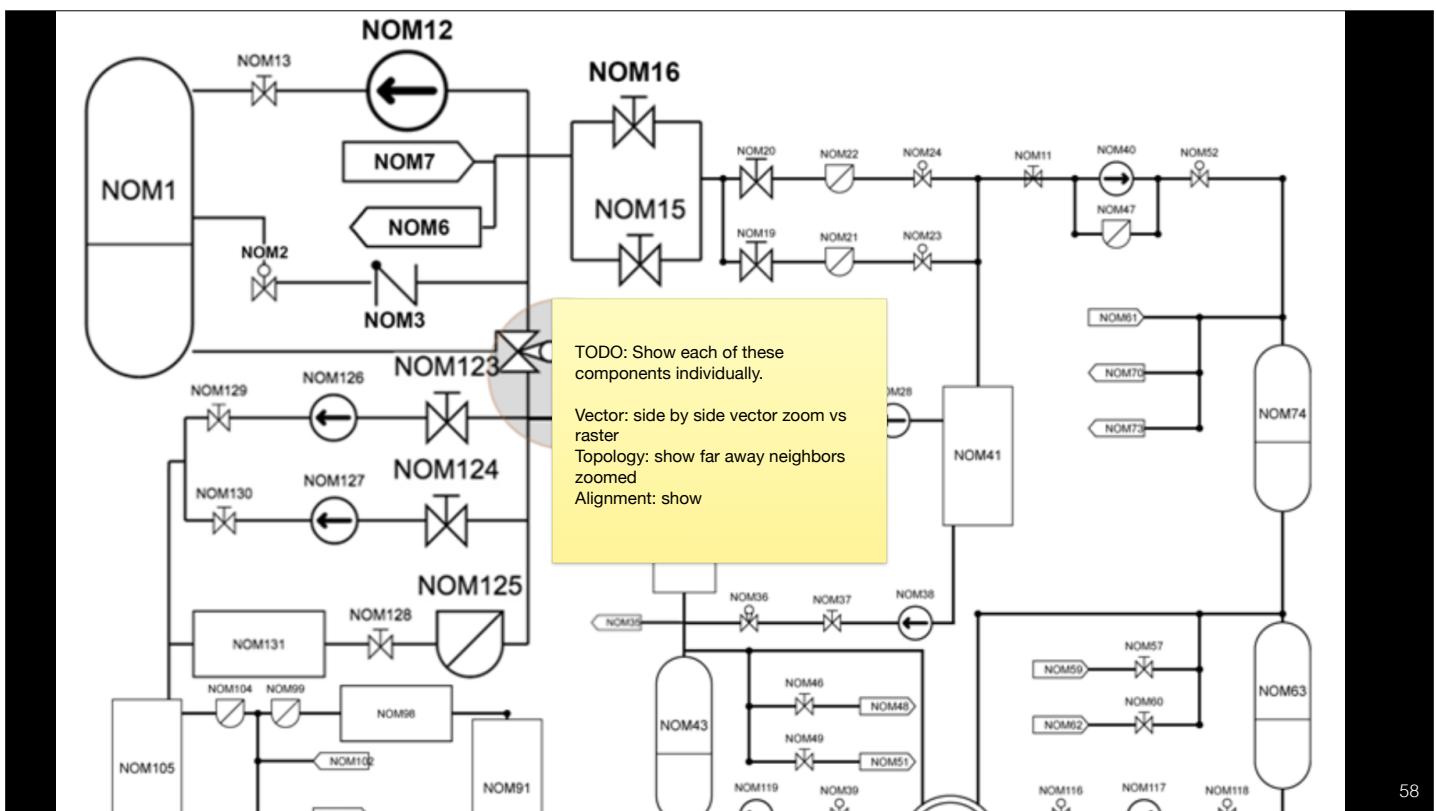
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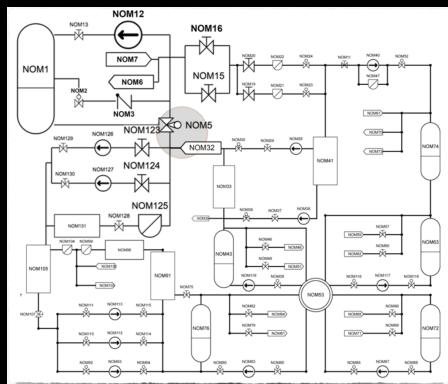


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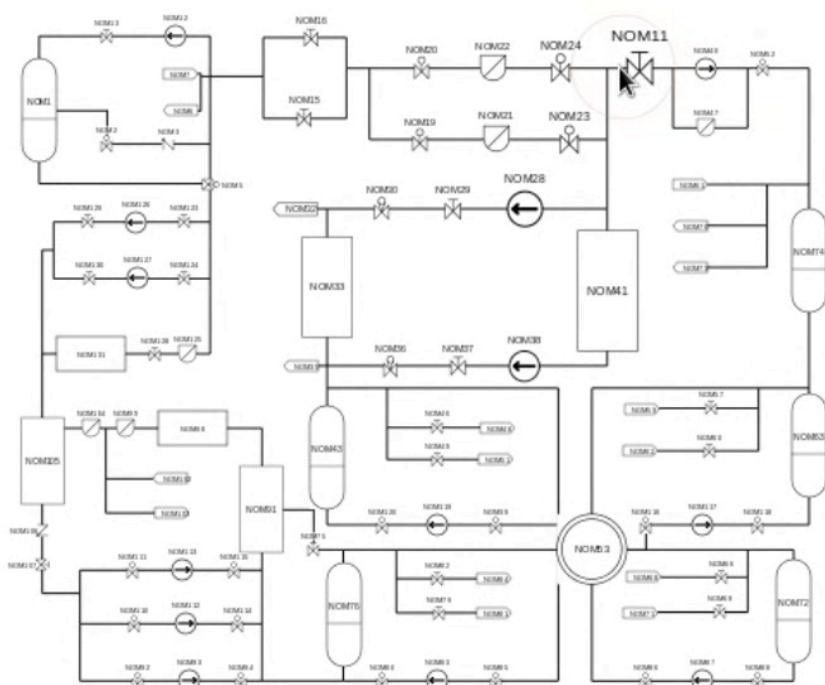
58

SchemeLens



59

59



Schemelens

60

What is a graph?

- *vertices and edges*

a.k.a.

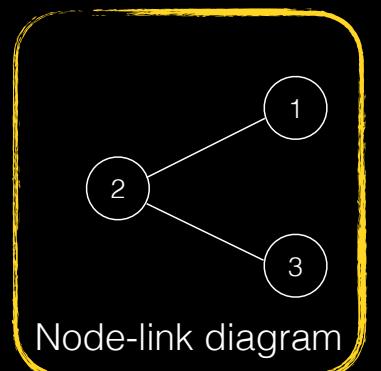
- *nodes and links*

	1	2	3
1	0	1	0
2	1	0	1
3	0	1	0

Adjacency matrix

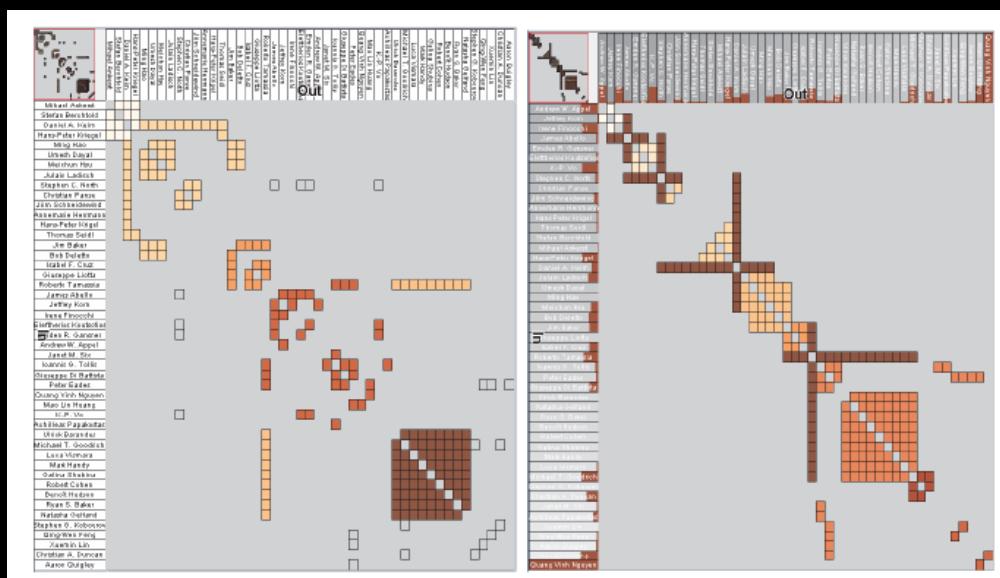
1: 2
2: 1, 3
3: 2

Adjacency list



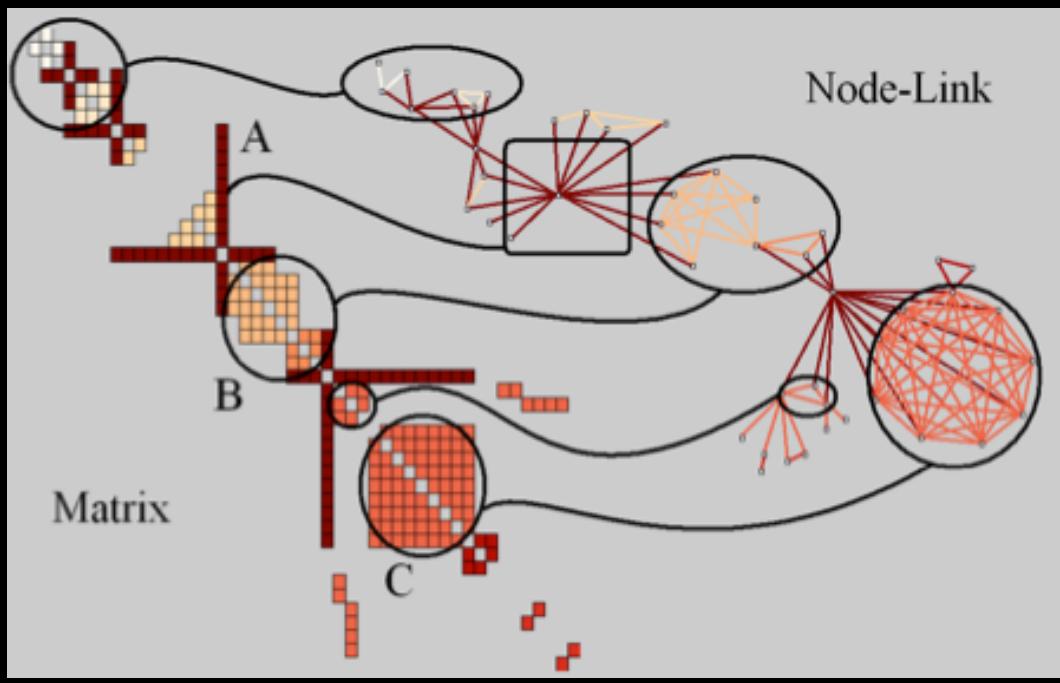
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63

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64

64

More useful resources

- Network visualization: www.caida.org/projects/internetatlas/viz/
- Graph layout: www.csi.uottawa.ca/ordal/papers/sander/main.html

65

65

Trees

66

66

What is a hierarchy?

- Data repository in which cases are related to subcases.

67

67

Where do we see hierarchies in the world?

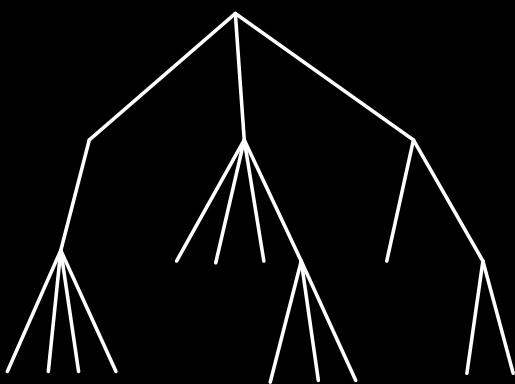
- Family histories
- File systems on computers
- Organization charts
- Animal kingdom (phylum, genus, etc.)
- OO software class structures
- ...

68

68

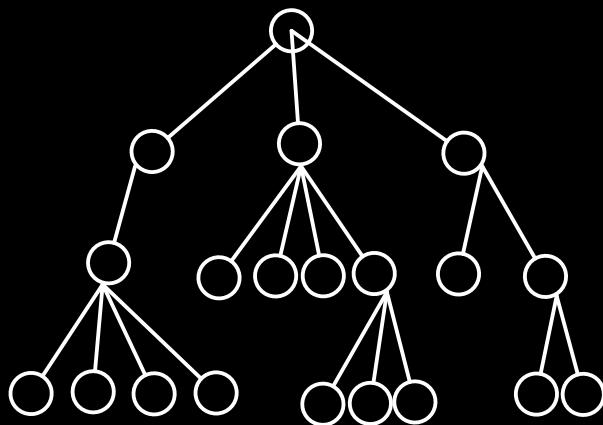
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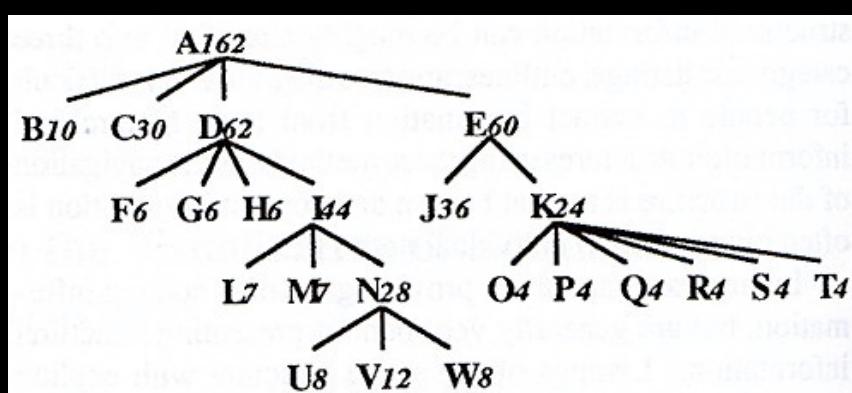
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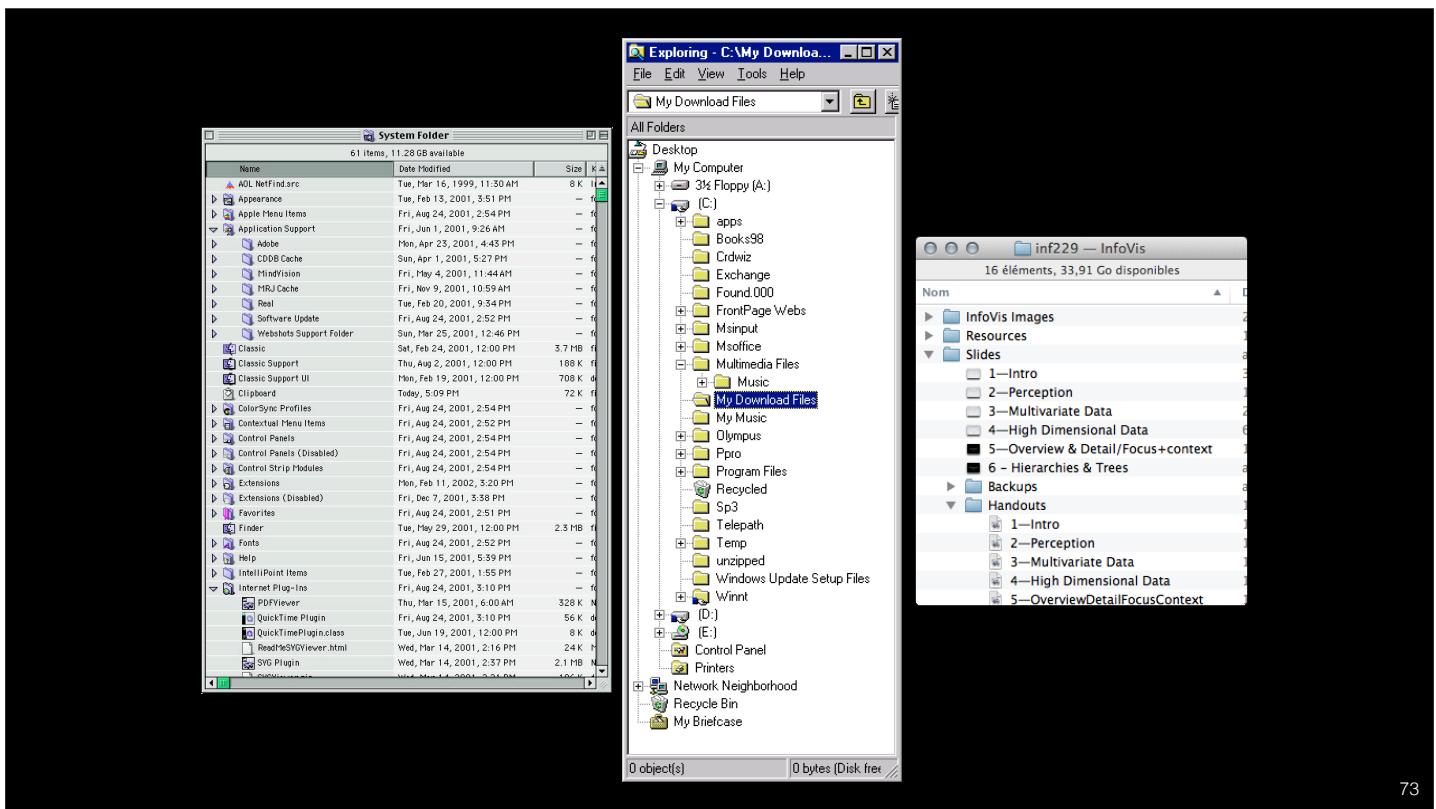
71



[Johnson & Schneiderman, 1991]

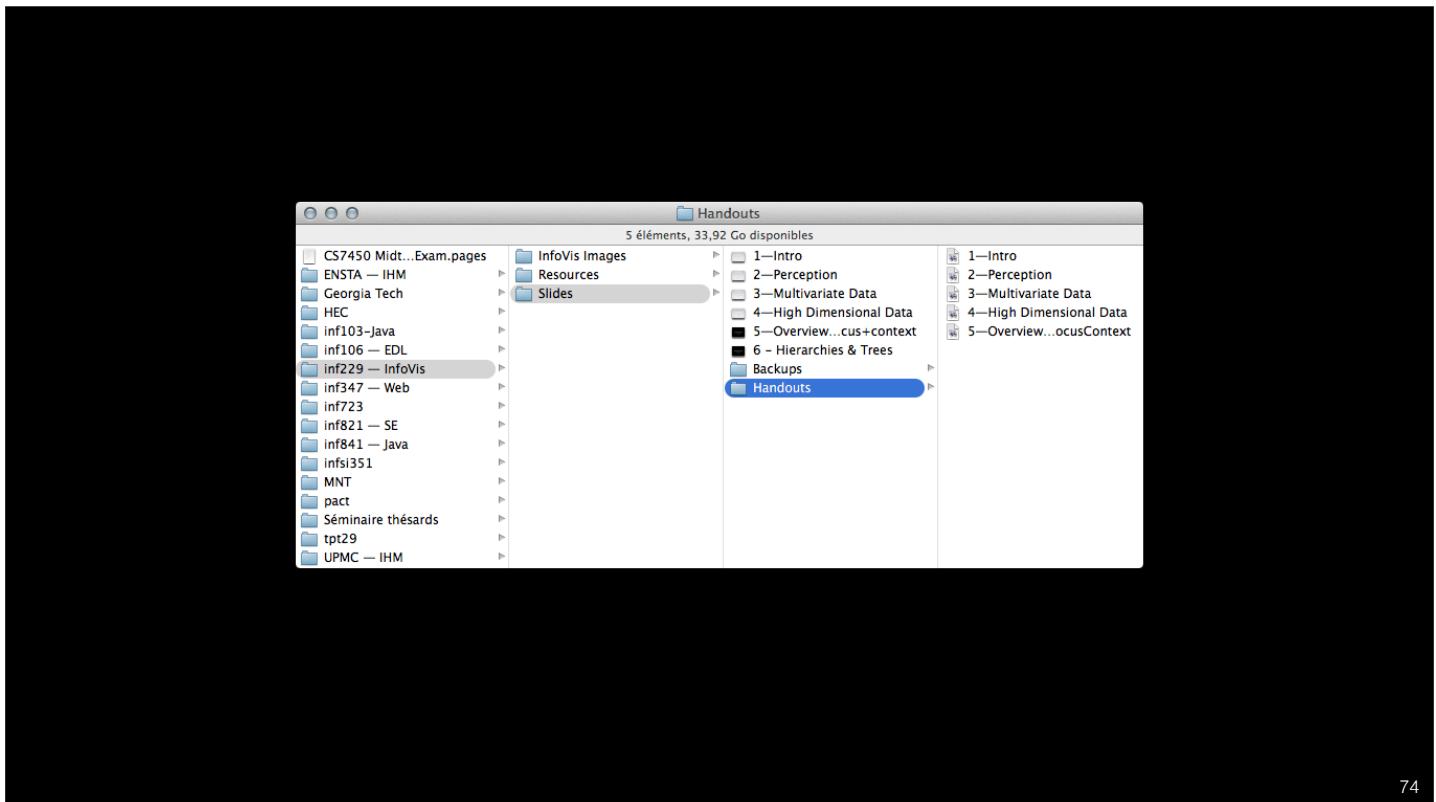
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72



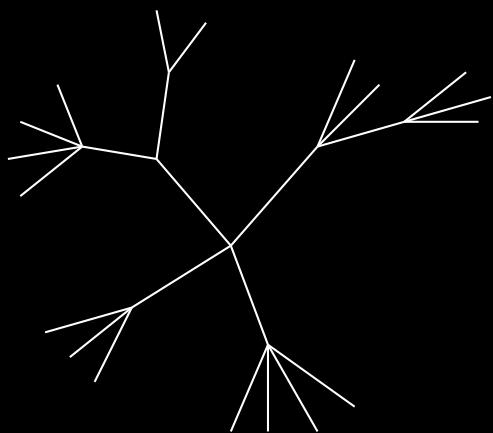
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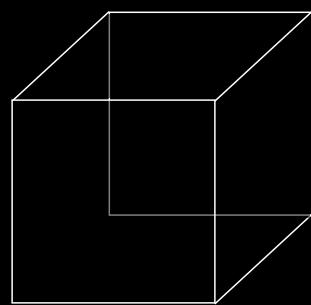
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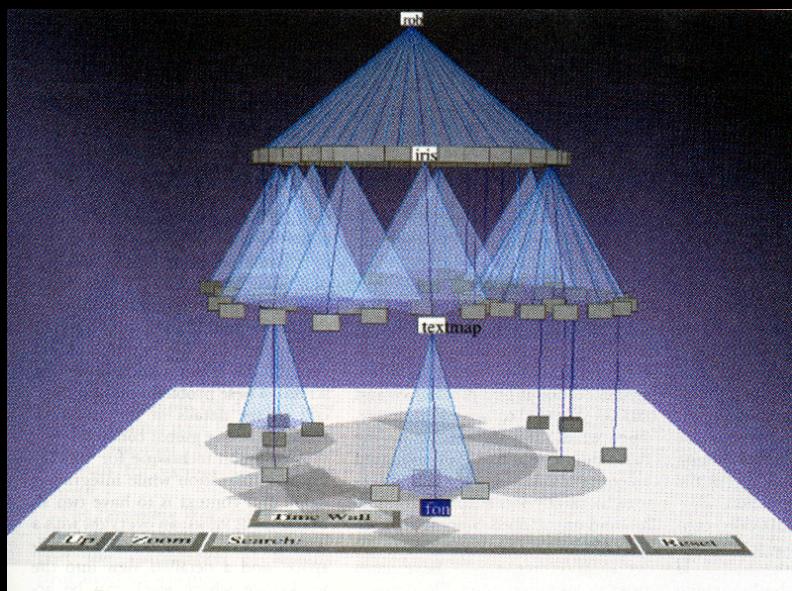
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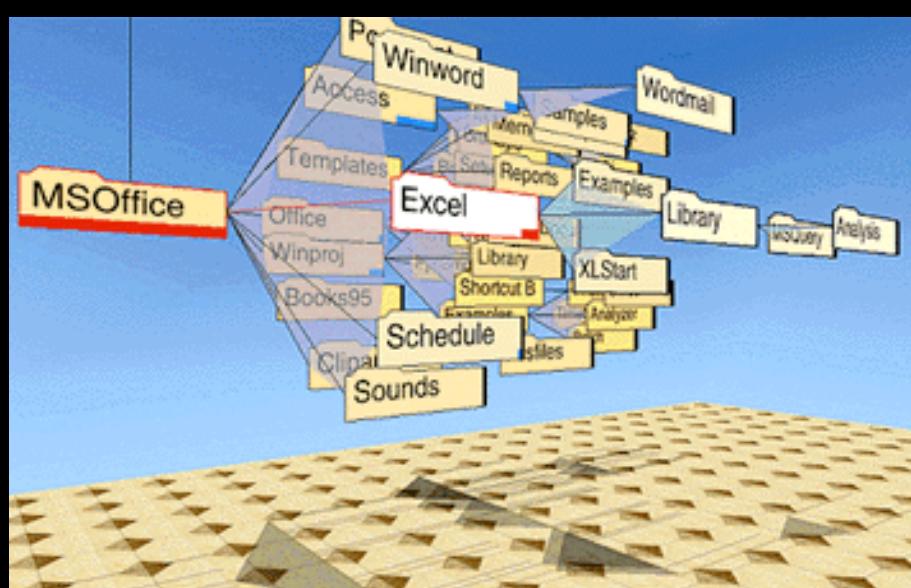
76



[Robertson, Mackinlay & Card, CHI 1991]

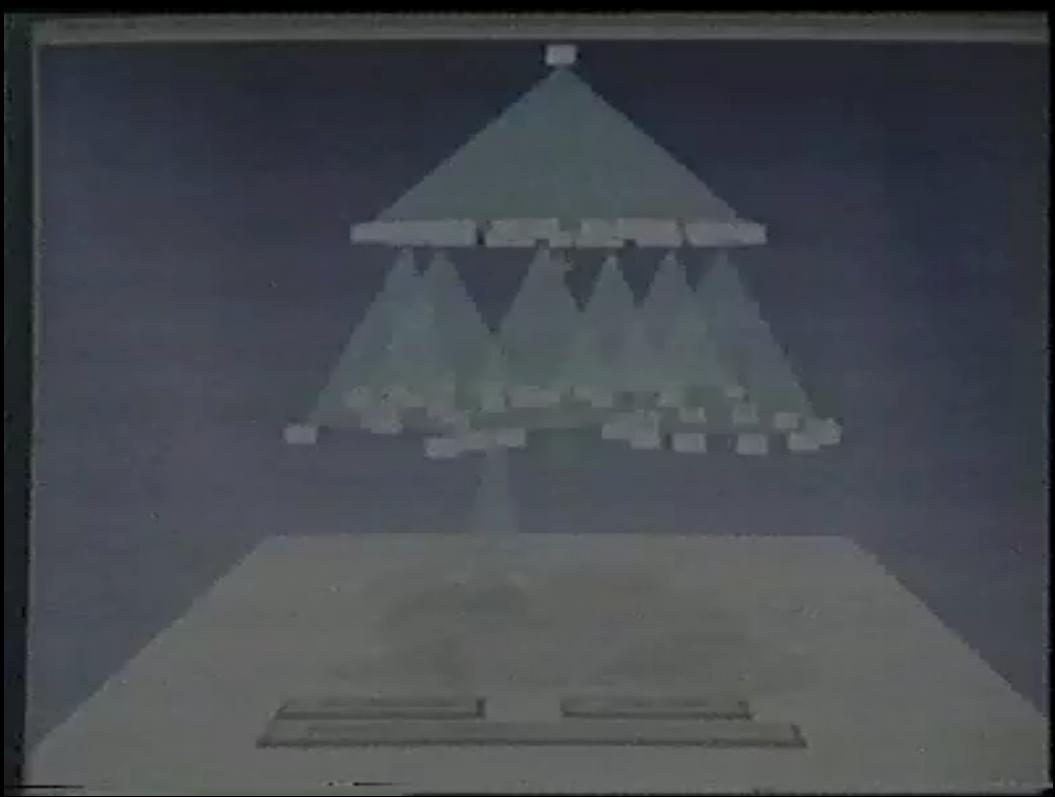
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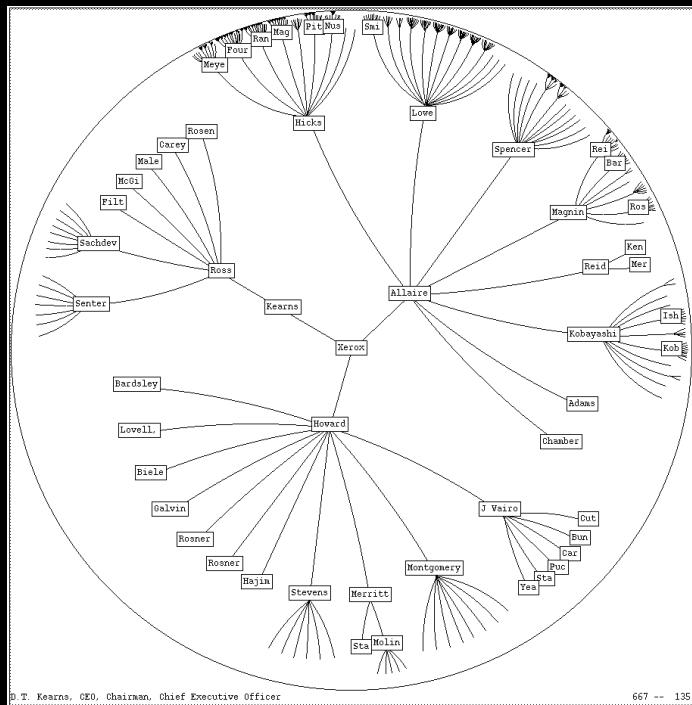
79

79

- Positive
 - More effective area to lay out tree
 - Use of smooth animation to help person track updates
 - Aesthetically pleasing
- Negative
 - As in all 3D, occlusion obscures some nodes
 - Non-trivial to implement and requires some graphics horsepower

80

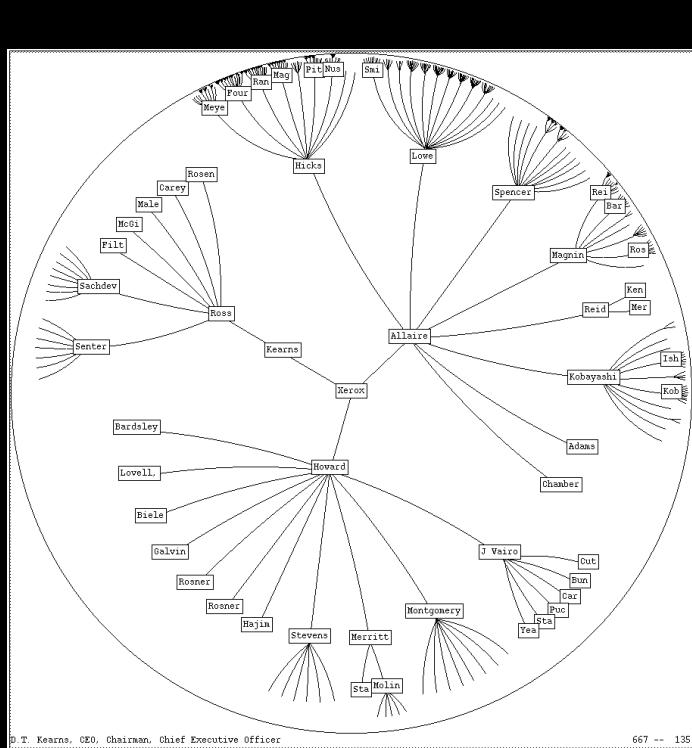
80



[Lampert & Rao, JVLC 1996]

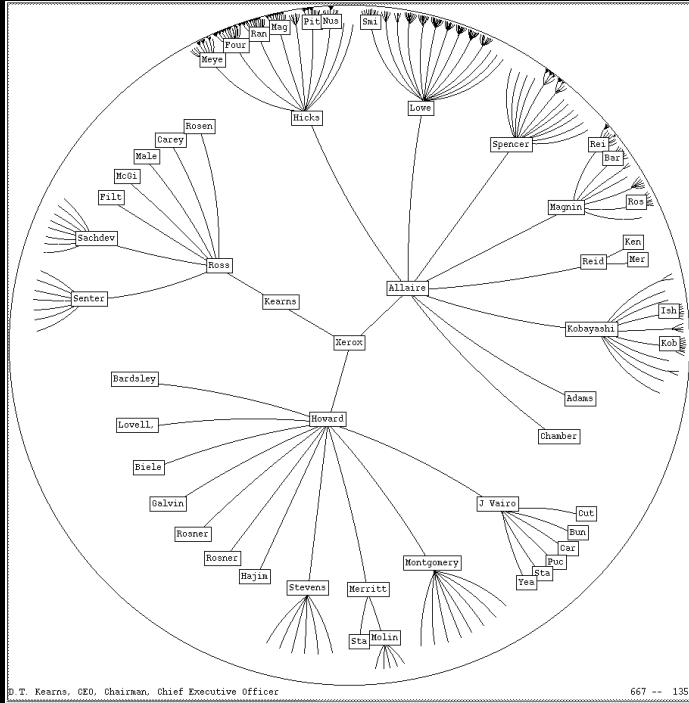
81

81



[Lamping & Rao, JVLC 1996]

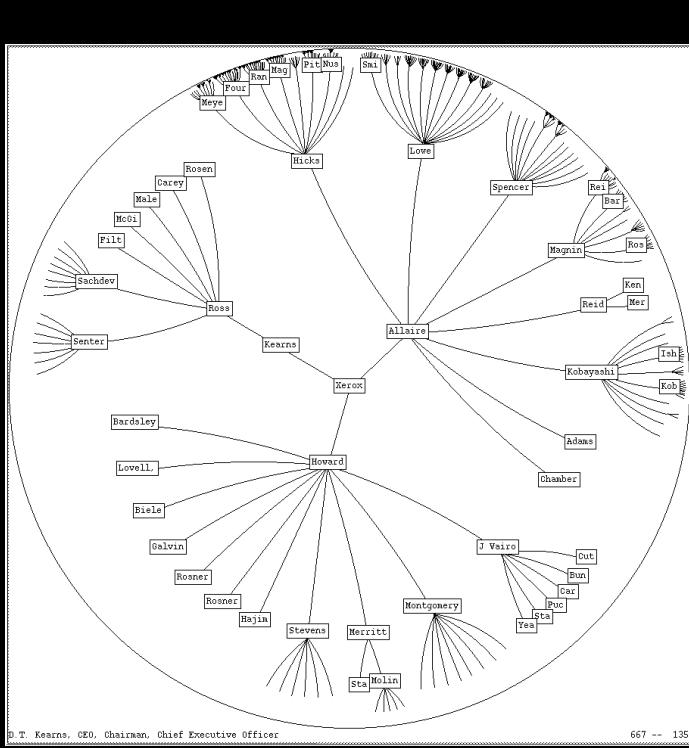
82



[Lamping & Rao, JVLC 1996]

83

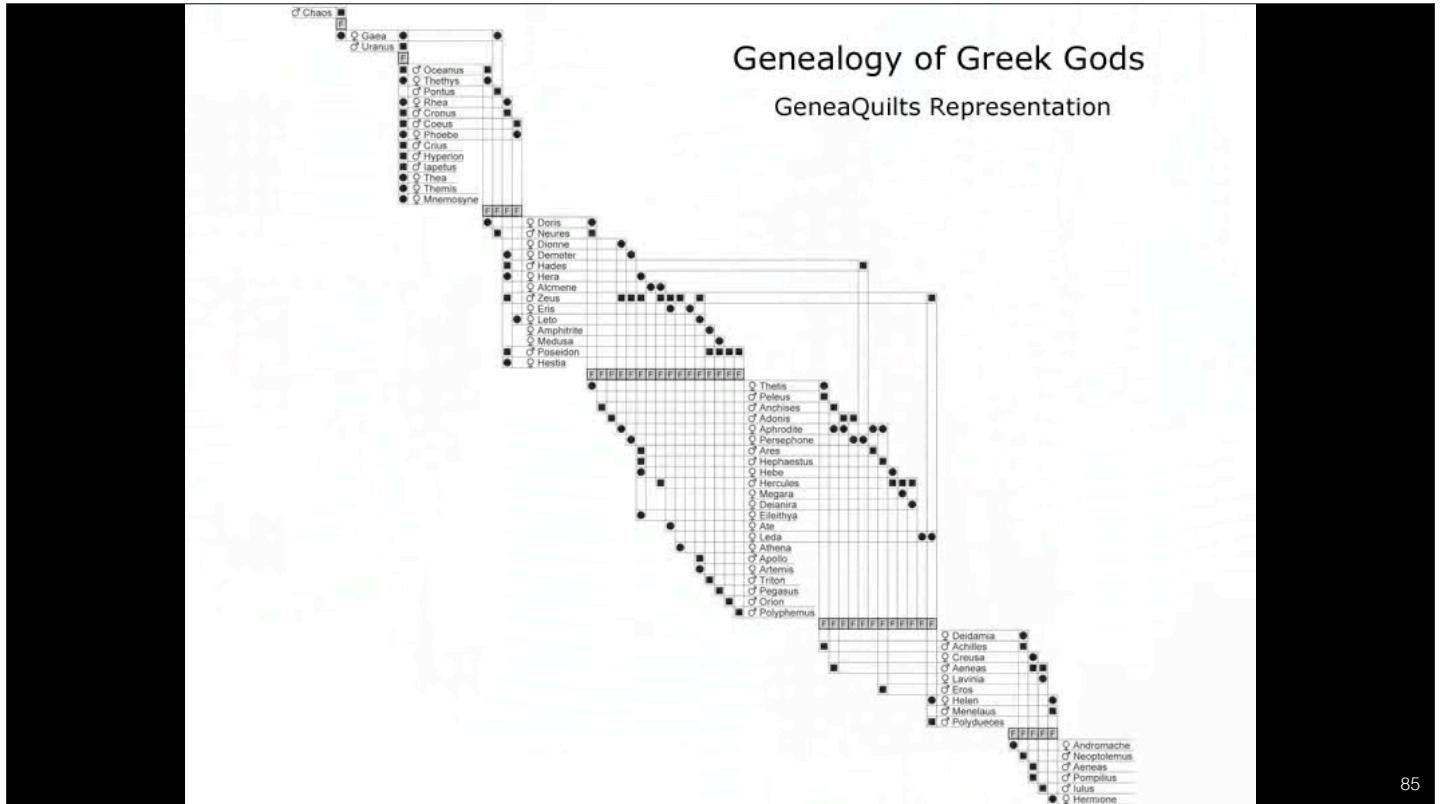
83



[Lamping & Rao, JVLC 1996]

84

84



85

85

Encoding more variables in node-link is difficult

- Shape
- Color
- Size

86

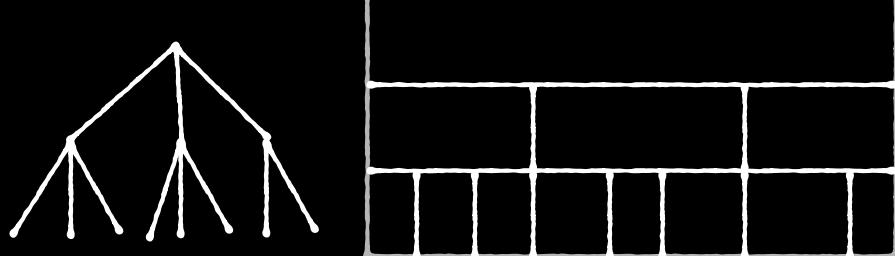
86

Let's use all the space



87

87



- Each item occupies an area
- Children contained under parent

88

88

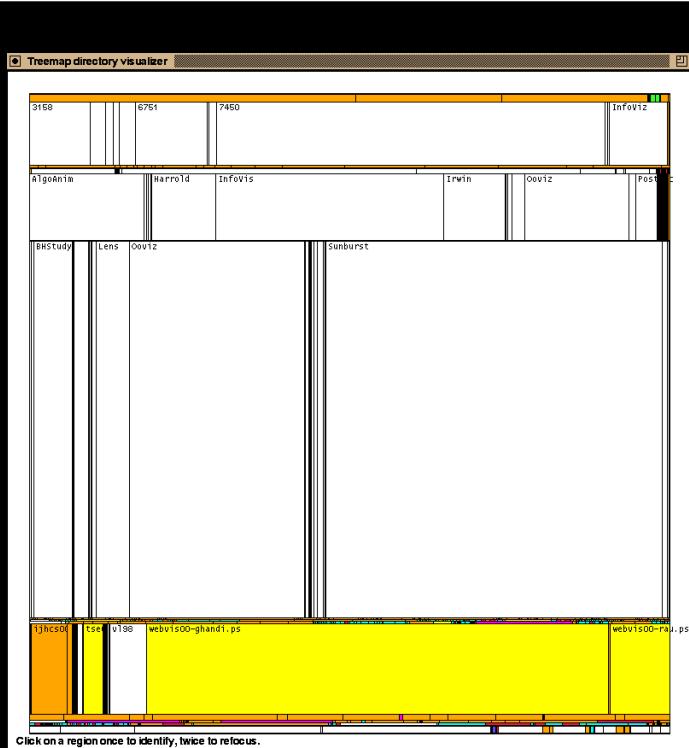
Treemap

- Space-filling approach
- Slice-and-dice
- Use area to encode a variable

[Shneiderman & Johnson, Vis '91]

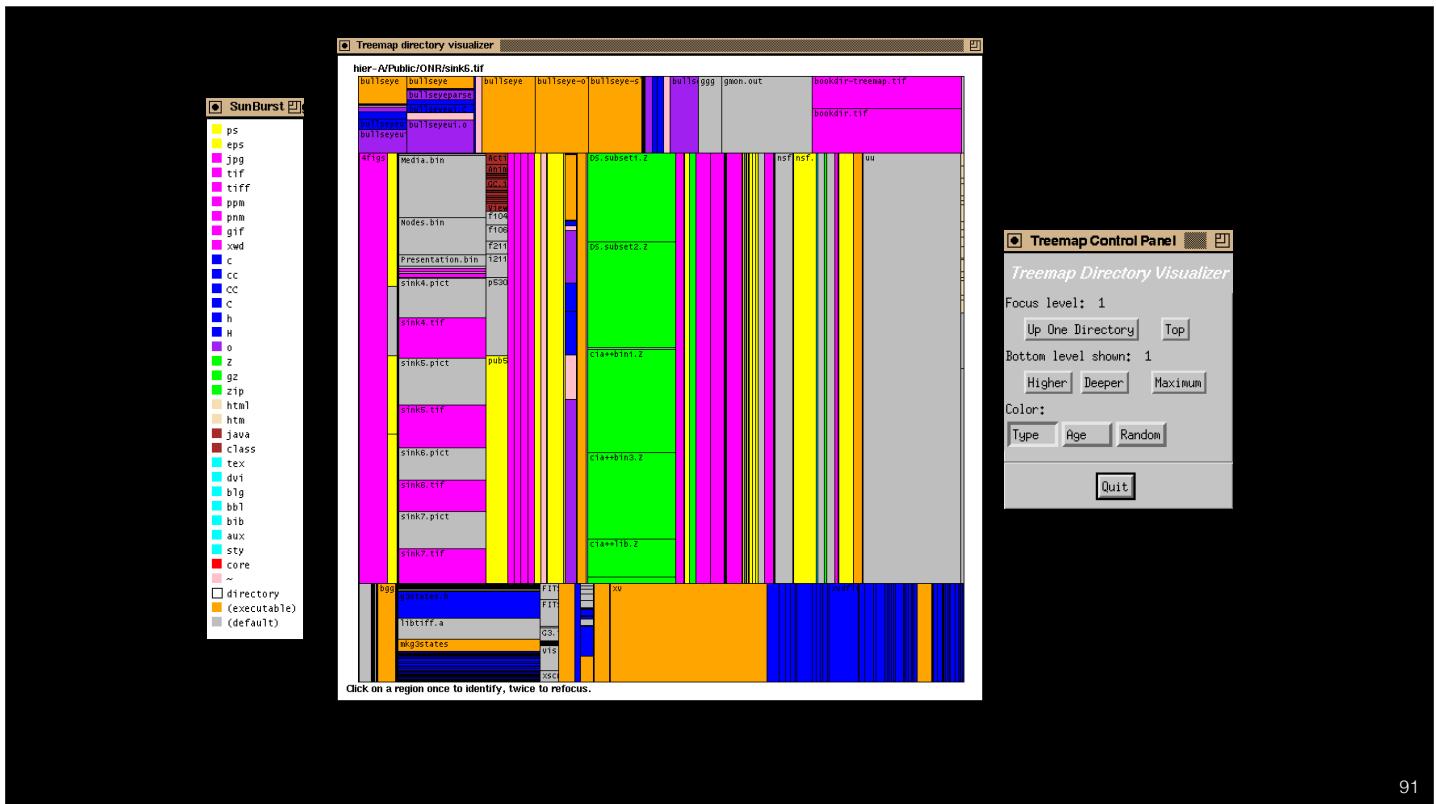
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Draw()

{

Change orientation from parent (horizontal/vertical)

Read all nodes at this level

Make rectangle for each, scaled to size

Draw rectangles using appropriate size and color

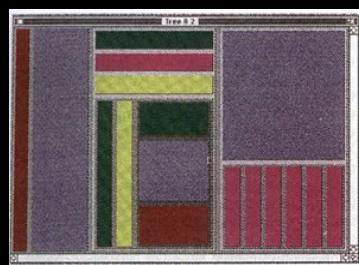
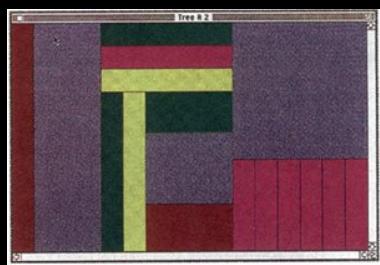
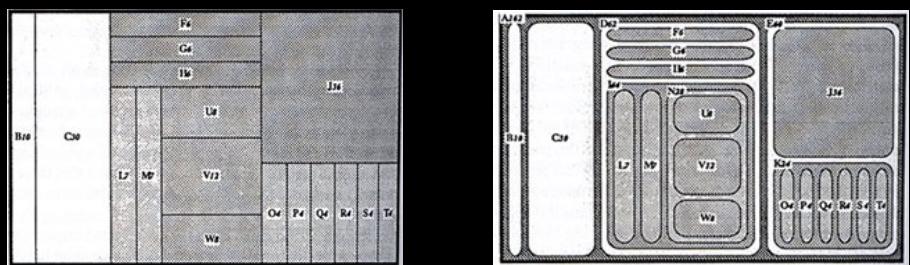
For each child

Make recursive call using its rectangle as focus

}

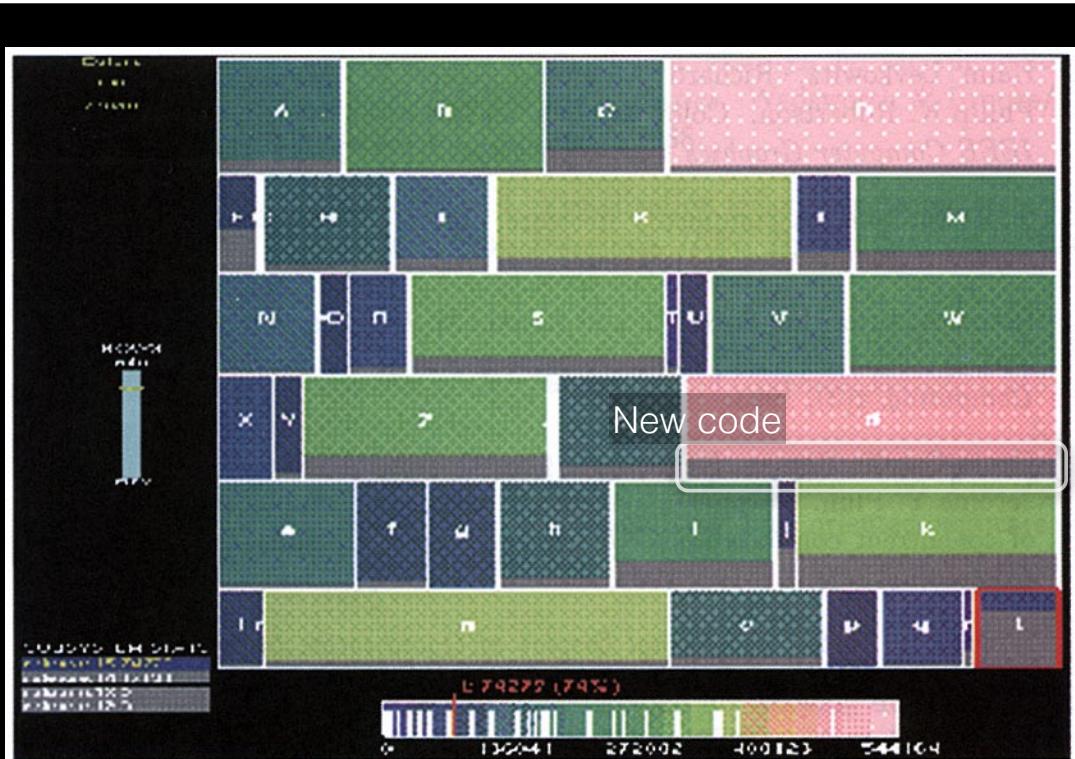
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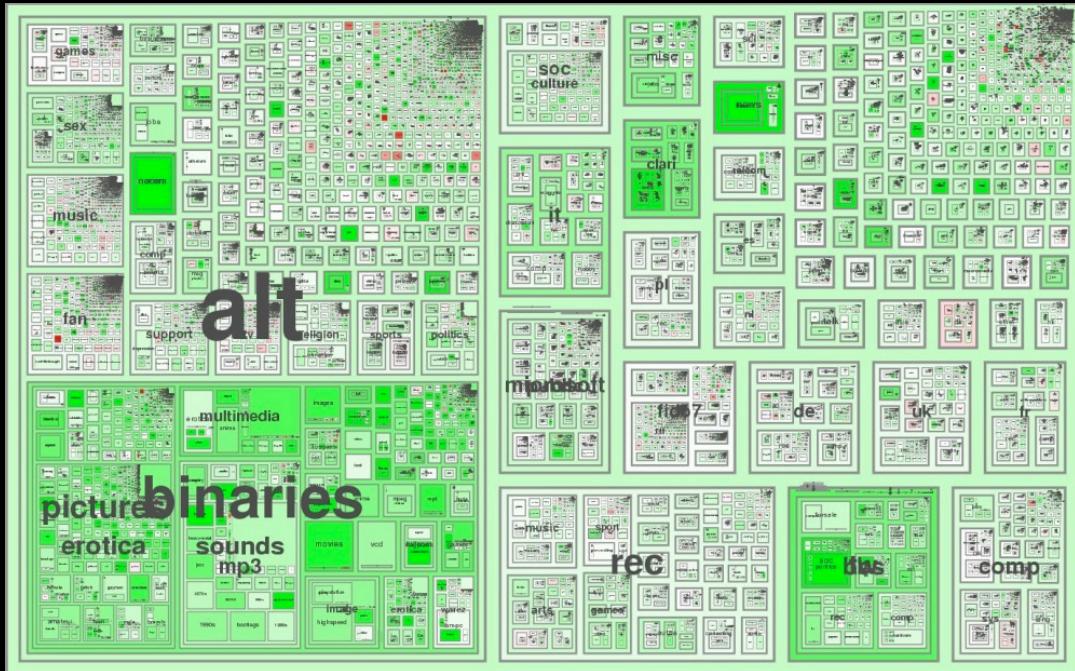
93



[Baker & Eick, JVLC '95]

94

94



[Fiore & Smith, Microsoft Tech Report '01]

95

95

What's good about Treemaps ?

- Focuses on nodes and attributes
- Color
- Area

96

96

What's not so good ?

97

97

These kinds of rectangles are visually unappealing



Which has the bigger area?

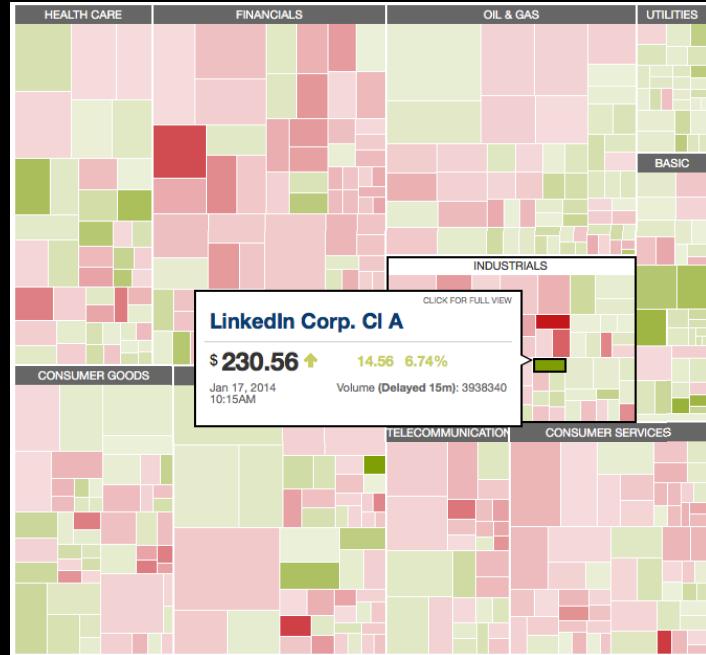
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98

Can we make rectangles more square?

99

99

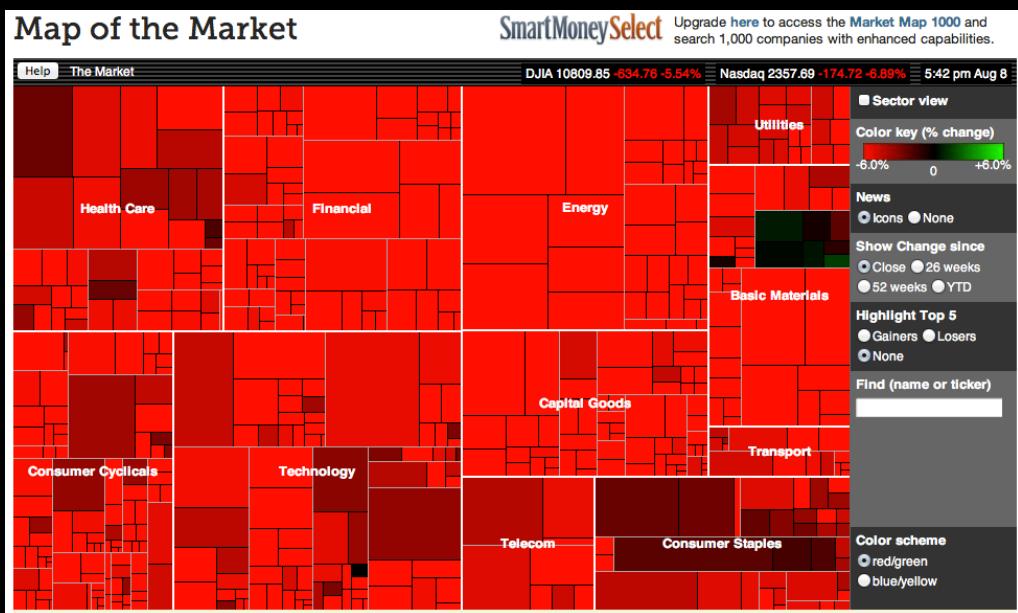


[www.marketwatch.com/tools/stockresearch/marketmap, January 17, 2014]

100

100

2011-08-08



[Wattenberg, CHI '99]

101

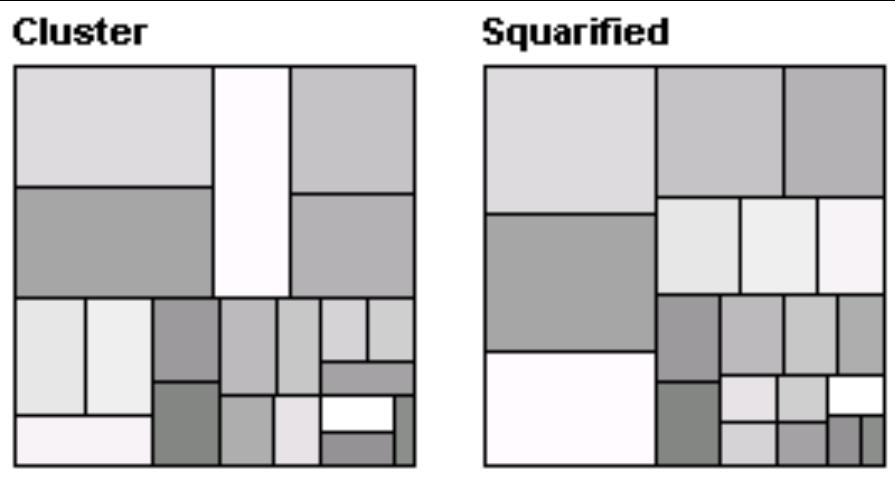
101

What's good about the map of the market?

- Macro-micro readings
- Interaction
- Real-world application of InfoVis

102

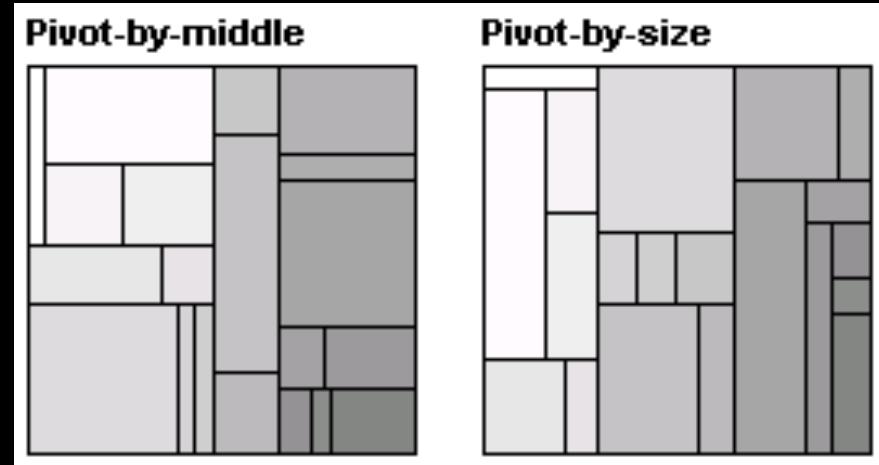
102



[Bruls, Huizing & van Wijk, EuroGraphics '00]

103

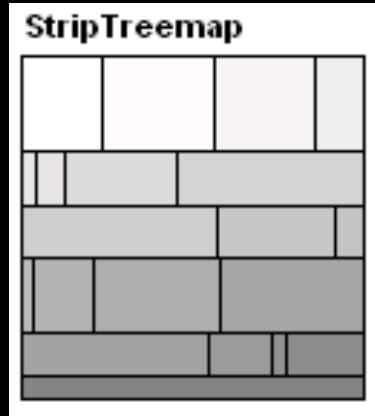
103



[Shneiderman & Wattenberg, InfoVis '01]

104

104

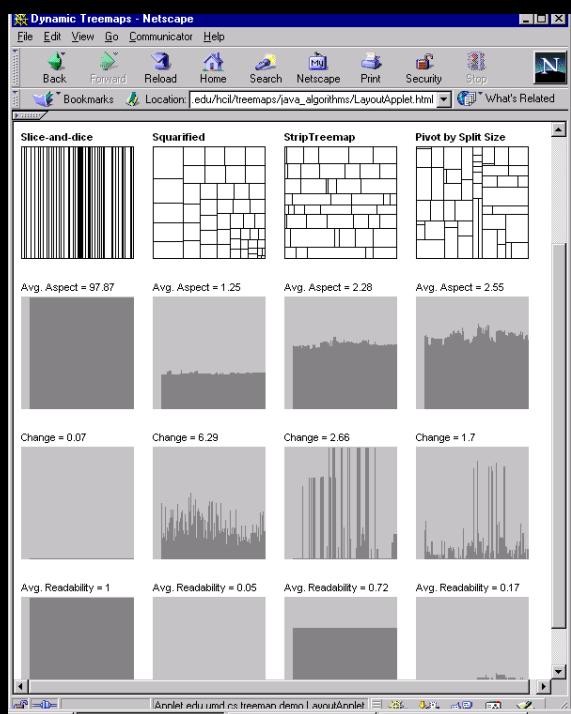


[Bederson, Shneiderman & Wattenberg, ToG '02]

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105

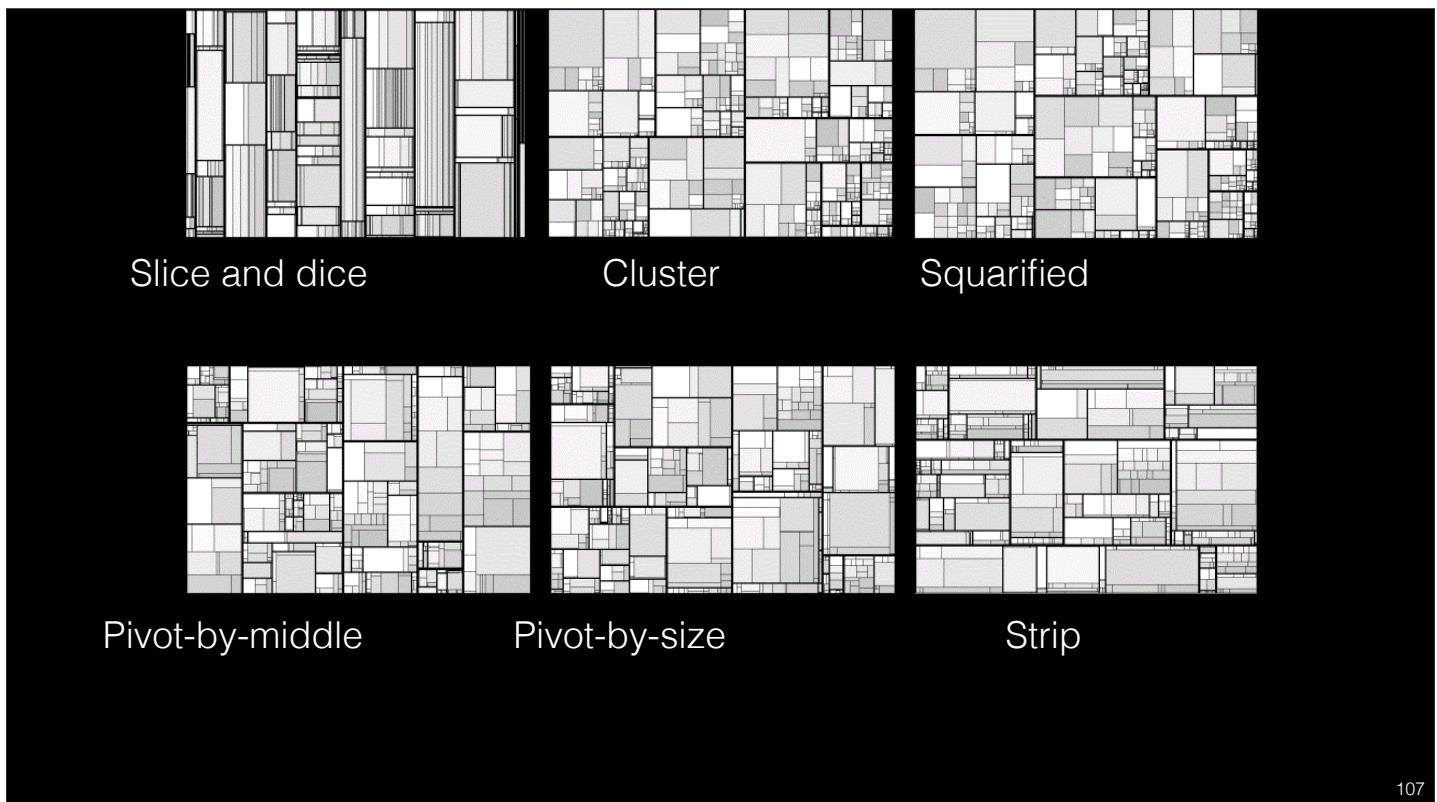
Compare algorithms by
 * aspect ratio
 * structural stability
 * readability



[www.cs.umd.edu/hcil/treemap-history/java_algorithms/LayoutApplet.html]

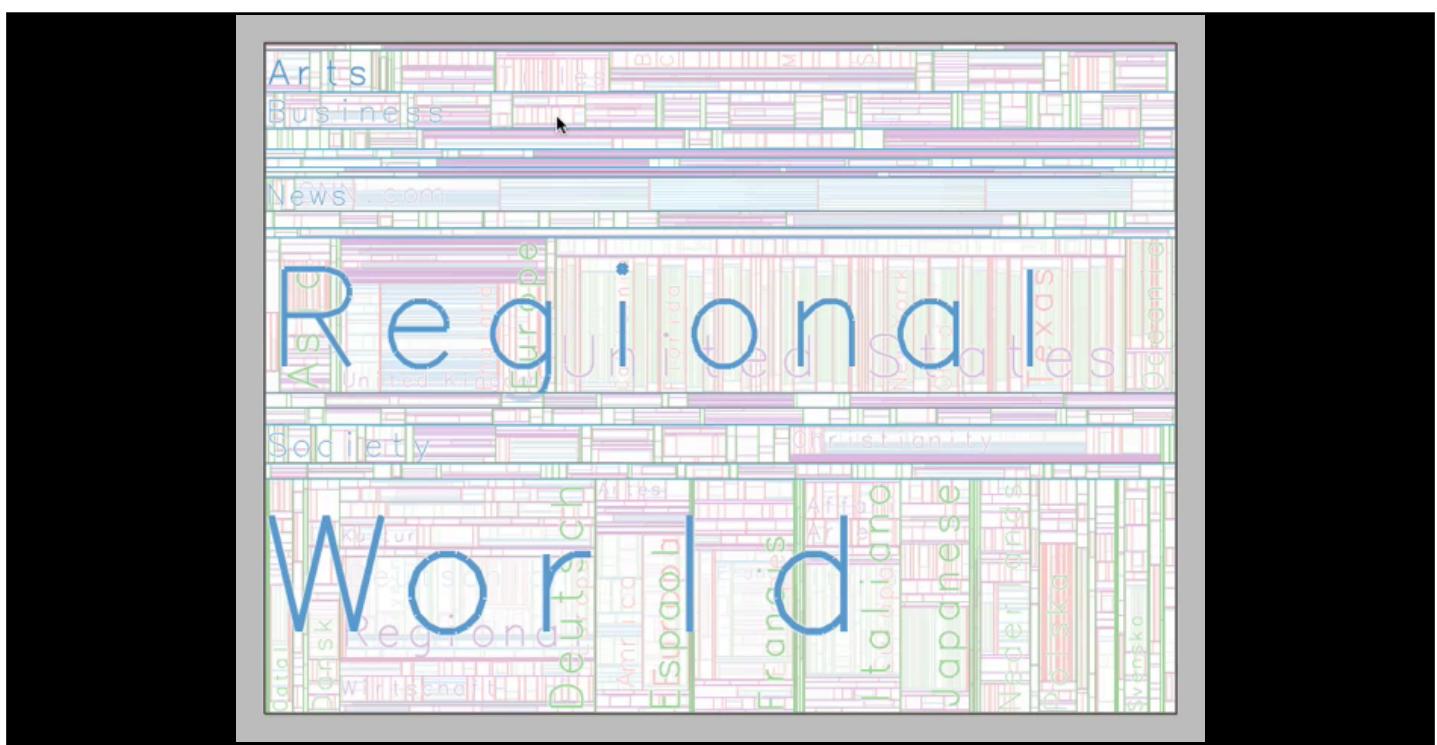
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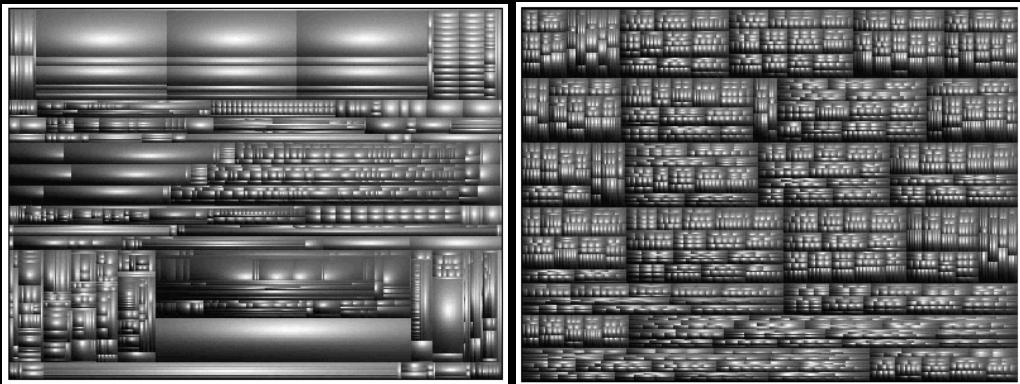
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[Blanch & Lecolinet, IEEE TVCG '07]

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[van Wijk & van de Wetering, InfoVis '99]

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[SequoiaView, '02; www.win.tue.nl/sequoiaview]

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What if zero is an important value?

- Stock or mutual-fund portfolios
- Zero size → zero area

111

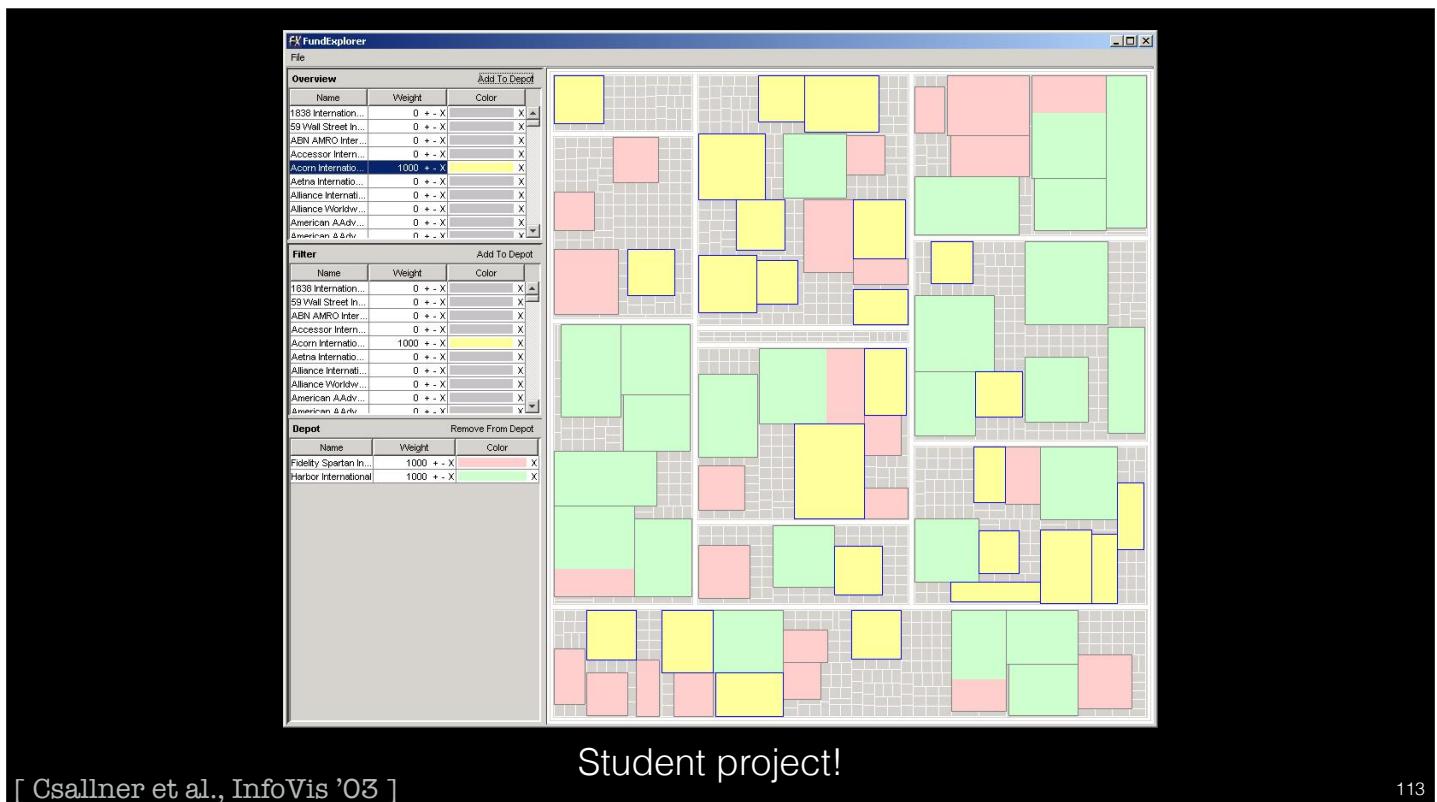
111

FundExplorer

- Help the user manage diversification.

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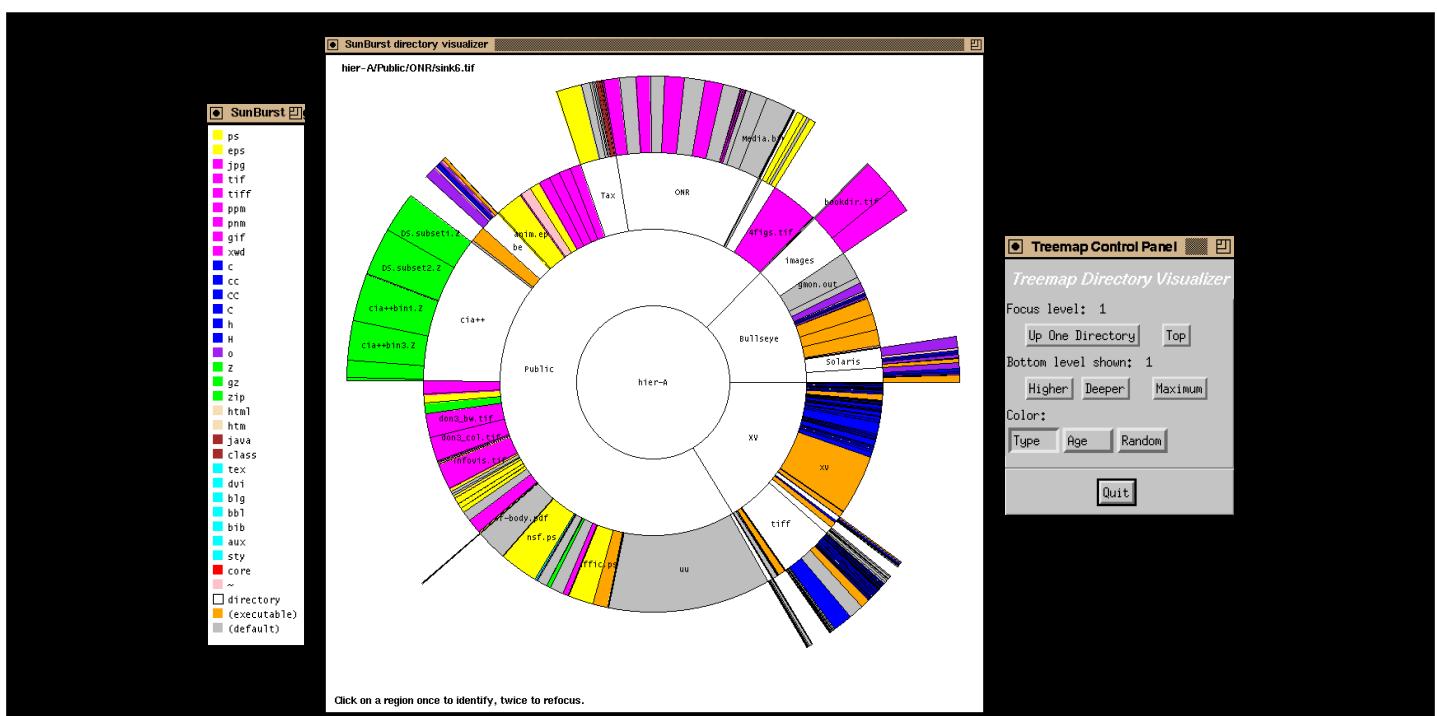


Student project!

[Csallner et al., InfoVis '03]

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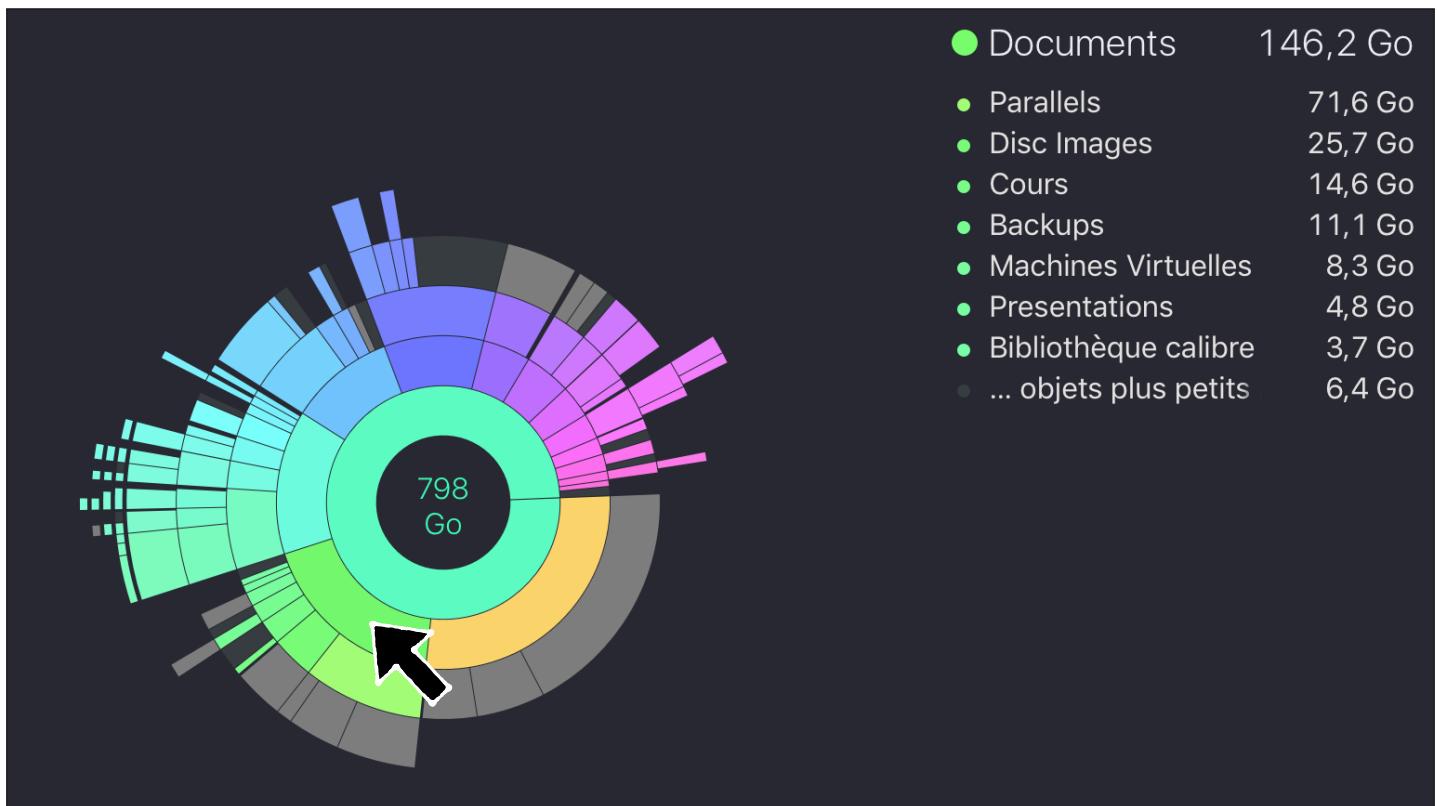
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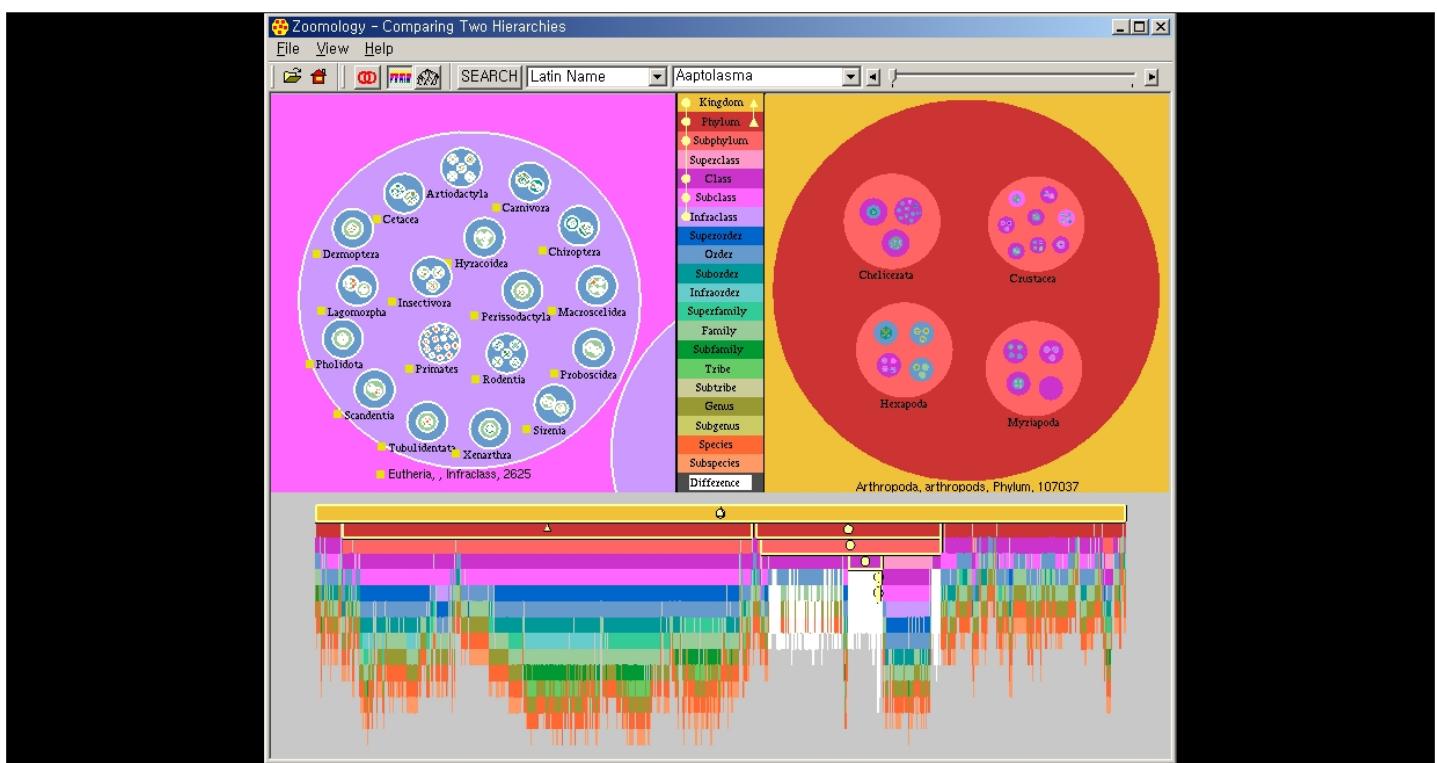
[Stasko et al., IJHCS '00]

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[Hong et al., InfoVis Contest Winner '03]

Student project!

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