
Connectivity

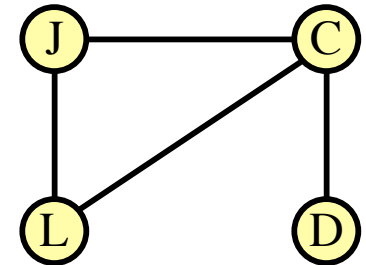
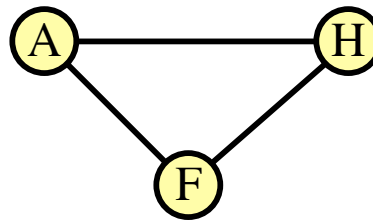
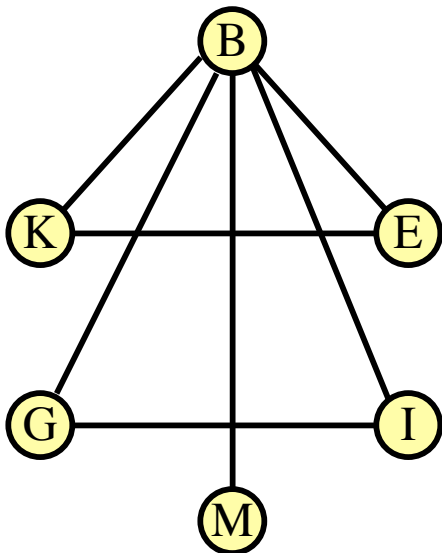
Connections

- Connections throughout our lives and the world
 - Circle of friends
 - Delta's flight plans
 - Telephone network
 - Internet
 - ...
- Model connected set as a Graph
- Treatment of connectedness falls into two classes
 - Networks in which any node can be connected to any other node
 - Trees in which there are no loops

Networks

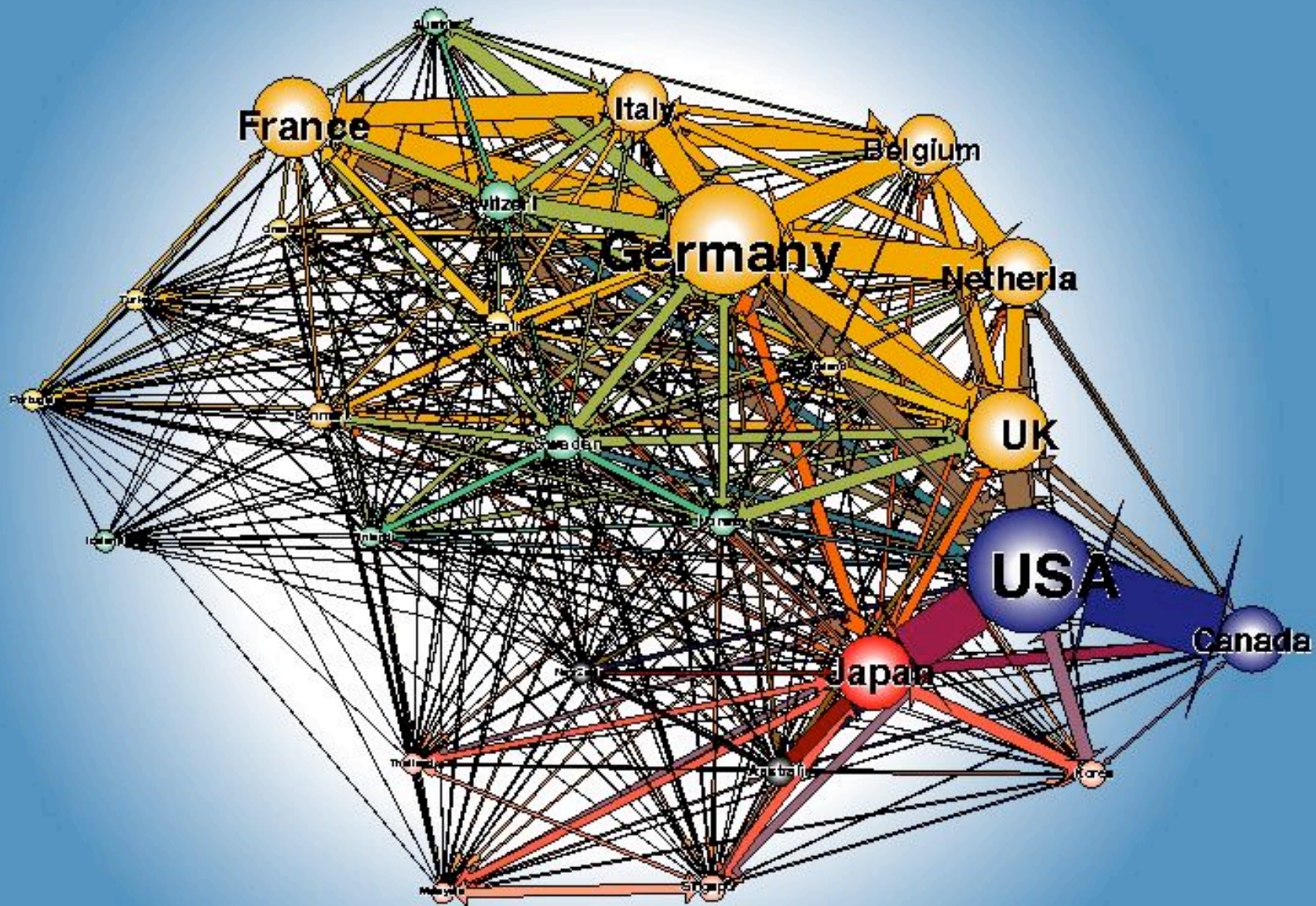
Graphical Representation: A Network

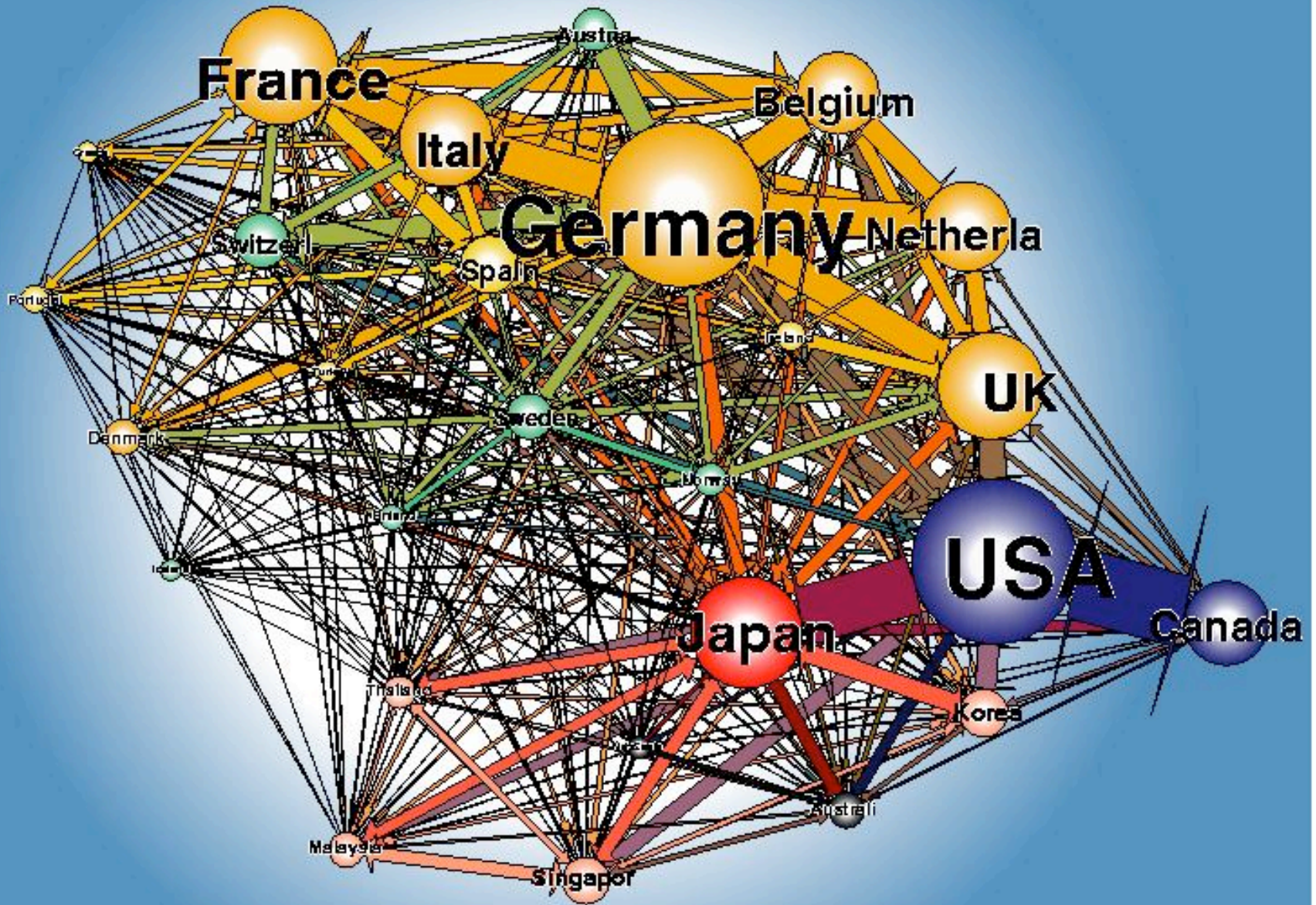
- Connectedness is represented by a graph composed of nodes (vertices) and connecting links (edges)
- Network representing telephone conversations among 13 people
 - Nodes represent people
 - Links represent occurrence of conversations
 - This is a disjoint graph reflecting the absence of conversations between different clusters of individuals



Graph Uses

- Facilitate understanding of complex socio-economic patterns
- Social Science visualization gallery (Lothar Krempel):
 - <http://www.mpi-fg-koeln.mpg.de/~lk/netvis.html>
- Next slides: Krempel & Plumper's study of World Trade between OECD countries, 1981 and 1992:
 - Nodes gives the volume of flows in dollars (imports and exports) for each country
 - Links stands for the volume of trade between any two countries.
 - Colors give the regional memberships in different trade organizations: EC countries (yellow), EFTA countries (green), USA and Canada (blue), Japan (red), East Asian Countries (pink), Oceania (Australia , New Zealand) (black)





1992

Subway Diagrams

- Even information with a ‘geographical’ content can best appear as a ‘network’
- Geographic landmarks largely suppressed on maps, except water (rivers in Paris, London) and asphalt (highways in Atlanta)
- These are more *graphs* than maps!



Paris



(A) St Germain-en-Laye
(A3) Cergy-St Christophe
(A5) Poissy
RER A

RATP/CML 2005 Janvier 1992 - Propriété de la RATP

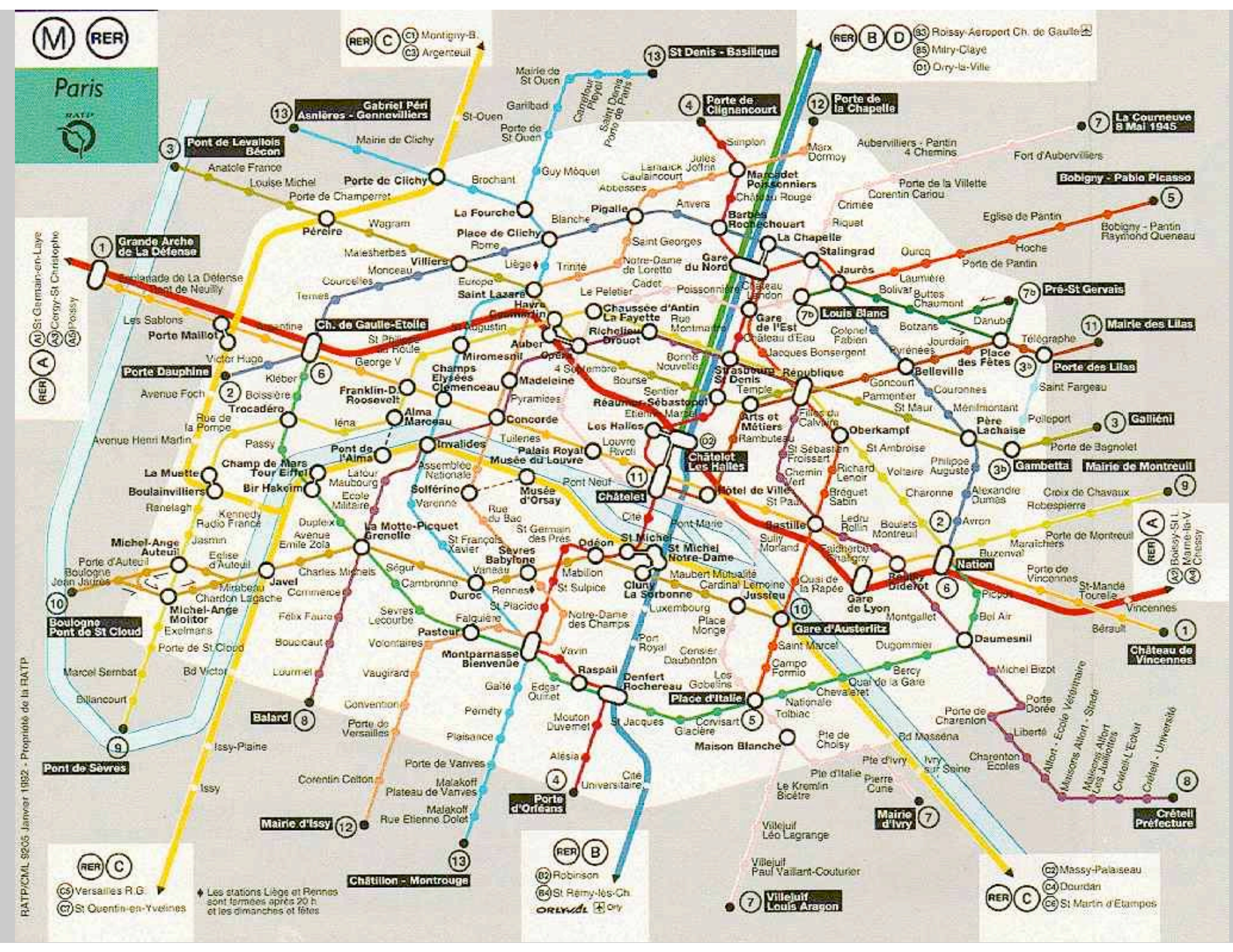
(C) Versailles R.G.
(C7) St Quentin-en-Yvelines
Les stations Liège et Rennes sont fermées après 20 h et les dimanches et fêtes

RER C
(C1) Montigny-B.
(C3) Argenteuil

RER B D
(B3) Roissy-Aéroport Ch. de Gaulle
(B5) Mitry-Claye
(D1) Orly-la-Ville

RER B
(B2) Robinson
(B4) St Remy-lès-Ch.
ORLY Only

RER C
(C2) Massy-Palaiseau
(C4) Dourdan
(C6) St Martin d'Etampes



Pont de Sèvres

Mairie d'Issy

Châtillon - Montrouge

Porte d'Orléans

Place d'Italie

Gare d'Austerlitz

Nation

Château de Vincennes

Créteil Préfecture

Villejuif Louis Aragon

Mairie d'Ivry

Liberté

Daumesnil

Porte de Vincennes

Porte de Montreuil

Gambetta

Mairie de Montreuil

Porte des Lilas

Mairie des Lilas

Bobigny - Pablo Picasso

Le Courneuve 8 Mai 1945

Porte de Clignancourt

Porte de la Chapelle

St Denis - Basilique

Pont de Levallois Bécon

Grande Arche de La Défense

Porte Dauphine

Champ de Mars Tour Eiffel

Michel-Ange Maitrot

Boulogne Pont de St Cloud

Balard

Mairie d'Issy

Châtillon - Montrouge

Gabriel Péri Asnières - Gennevilliers

Porte de Clichy

Ch. de Gaulle-Etoile

Franklin-D. Roosevelt

Invalides

La Motte-Picquet Grenelle

Montparnasse Bienvenue

Porte de Versailles

Porte d'Orléans

Châtillon - Montrouge

Mairie de St Ouen

Porte de St Ouen

Place de Clichy Rome

Champs Elysées Clemenceau

Concorde

Palais Royal Musée du Louvre

St Michel Notre-Dame

Denfert Rochereau

Porte d'Orléans

Porte d'Orléans

Châtillon - Montrouge

Porte de Clignancourt

Porte de la Chapelle

Chaussee d'Antin La Fayette

Châtelet Les Halles

Châtelet

St Michel Notre-Dame

Place d'Italie

Porte d'Orléans

Porte d'Orléans

Châtillon - Montrouge

Porte de la Chapelle

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The US Telephone Network

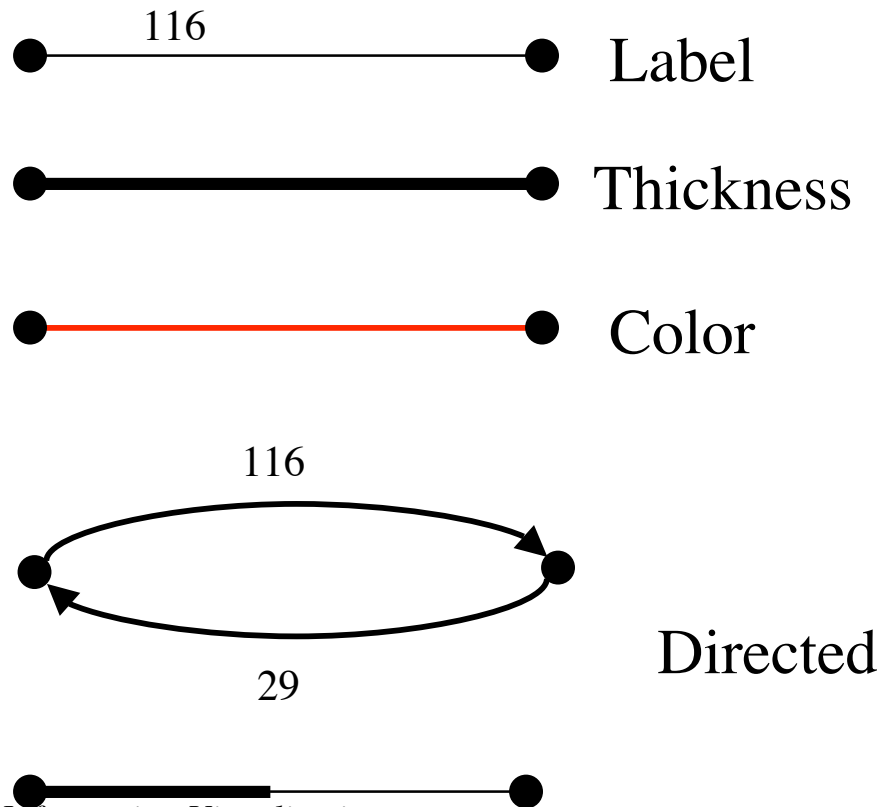
- AT&T long distance network within the US
 - 110 Nodes (switches)
Geographical location
 - Connected by 12,000 links
Directed, almost completely connected
- Data is collected every 5 minutes
 - Node data included aggregated incoming and outgoing traffic
 - Link data includes traffic flow, capacity and overload
- Gaining insight into the network
Example is San Francisco EARTHQUAKE!!!
 - Oct. 17, 1989

Questions

- Where are the overloads?
- Which links are carrying most traffic?
- Was there network damage?
- Is there underutilized capacity?
- Are calls getting in to affected area or are there bottlenecks?
- Is overload increasing or decreasing?

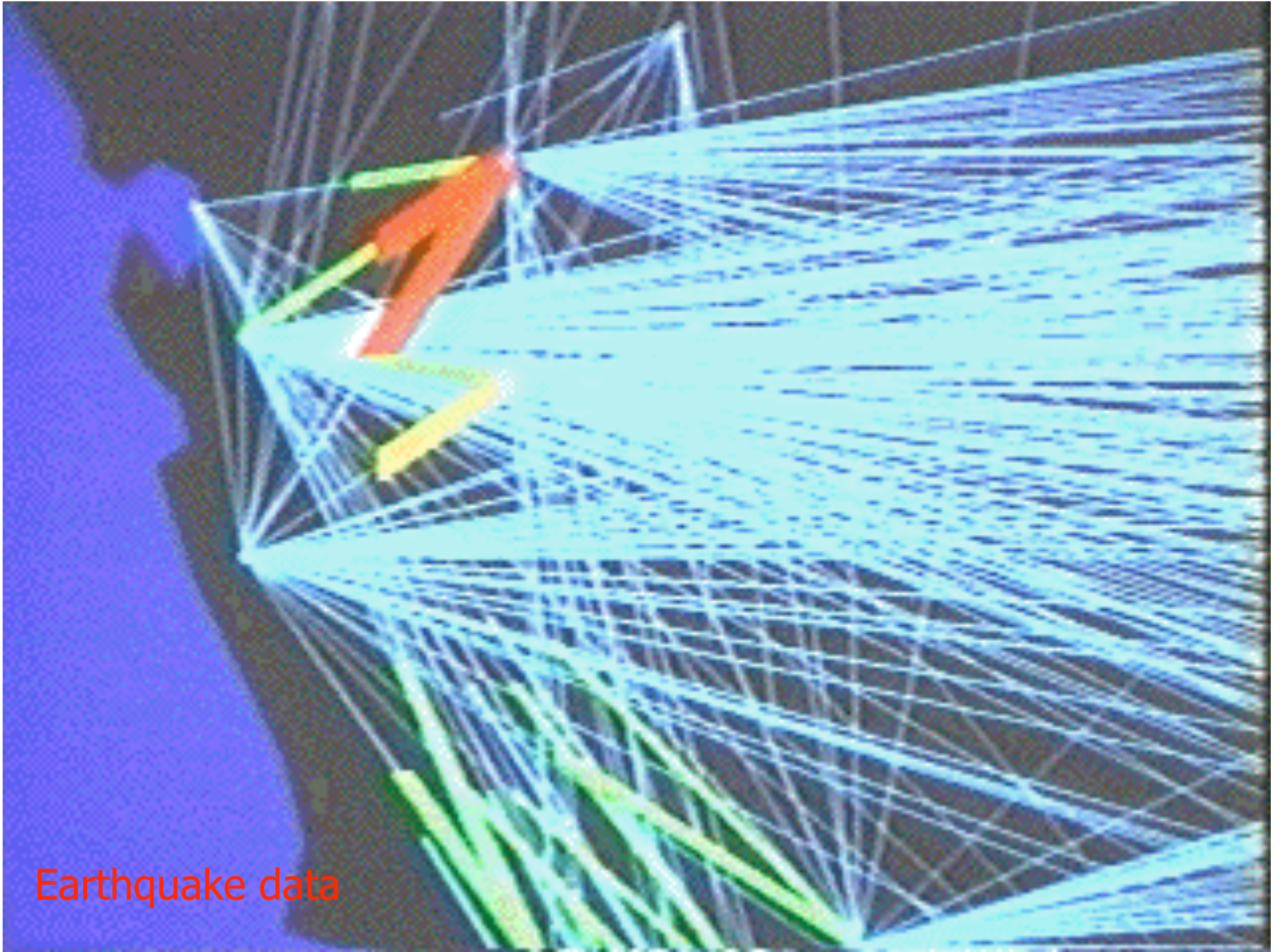
Representing Connections

Use line segments between the nodes and characterize the traffic flow quantitatively by thickness or color
Directional property can be indicated either by using two links or by dividing the link into two segments

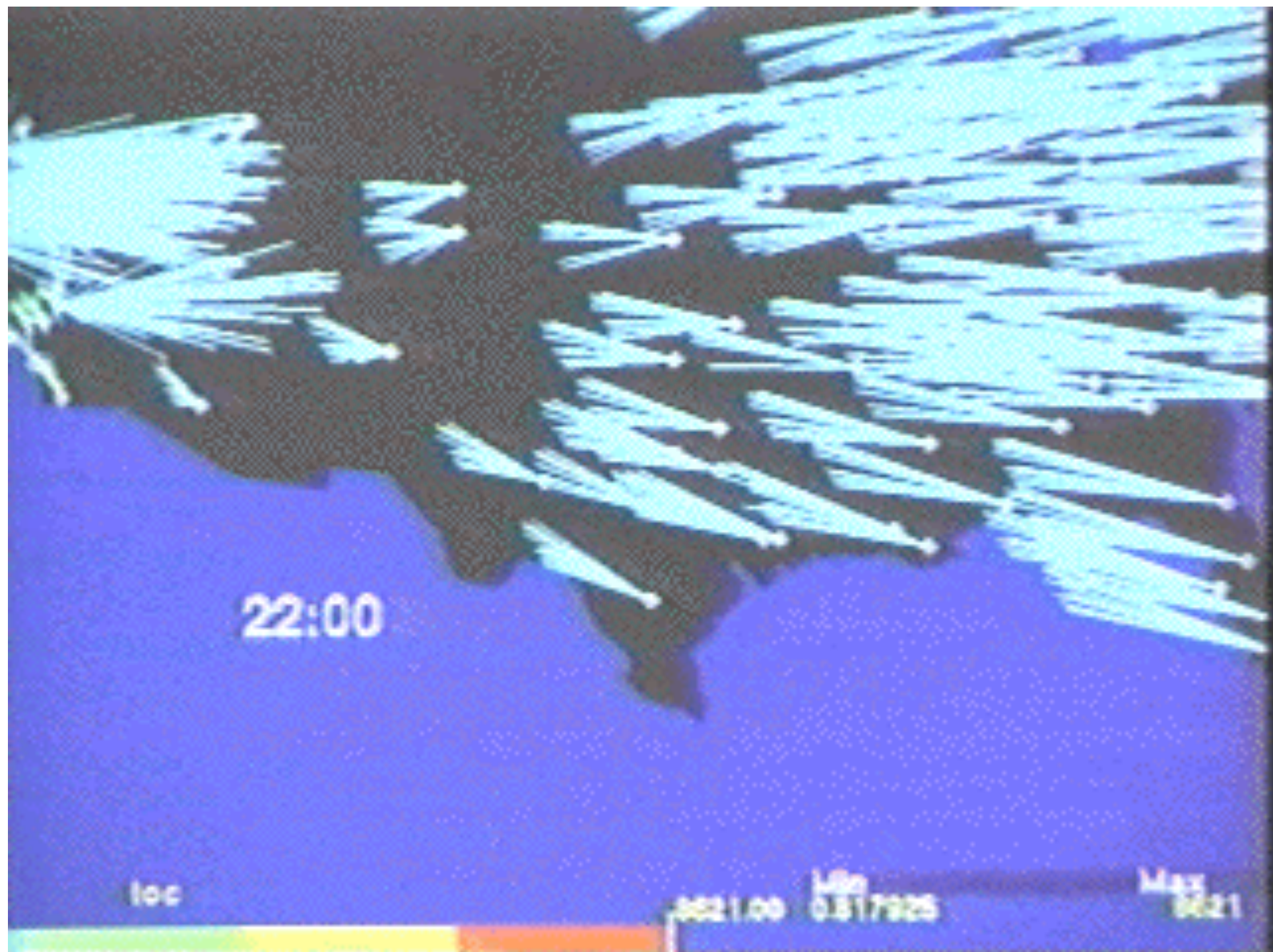


Problems

- Too many lines!
 - Occlusion
 - Long lines become “more important”
 - Can’t see what happens in Midwest
- Solutions
 - Use half/half technique out/out
 - Draw most important last
 - Use thickness & color for traffic
- Shorten all lines so as to de-emphasize transcontinental links



Earthquake data



Visualization of NSFNET

- Exponential growth of networking in the US and World
- Example:
 - Inbound traffic measured in billions of bytes on the NSFNET T1 backbone for September 1991.
 - The traffic volume range is depicted from purple (zero bytes) to white (100 billion bytes).
 - Data collected by Merit Network, Inc.



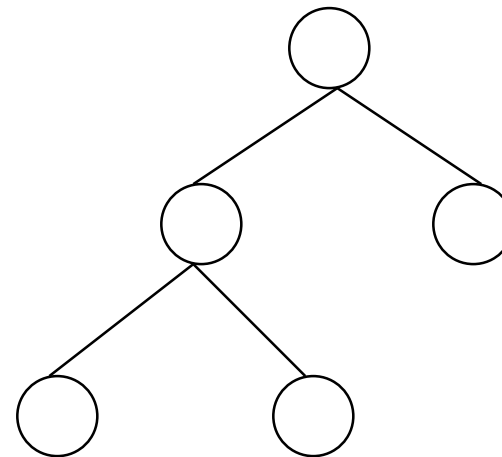
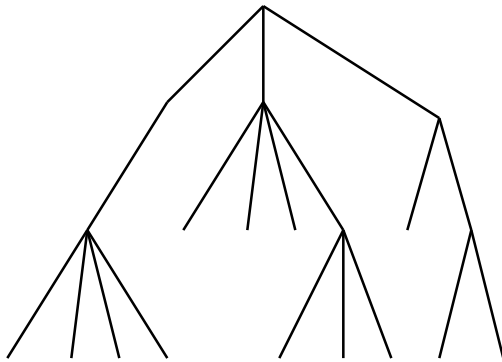
Hierarchies - Trees

Hierarchies

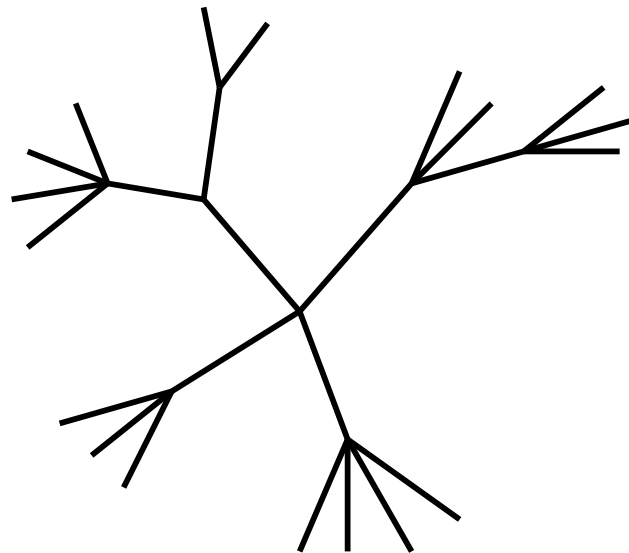
- Definition
 - Data repository in which cases are related to subcases
 - Can be thought of as imposing an ordering in which cases are parents or ancestors of other cases
- Examples
 - Family histories, ancestries
 - File/directory systems on computers
 - Animal kingdom: Phylum, ..., genus, ...
 - Object-oriented software classes
 -
- Hierarchies often represented as trees
 - Directed, acyclic graph
- Two main representation schemes
 - Node-link
 - Space-filling

Node-Link Diagrams

- Root at top, leaves at bottom is very common

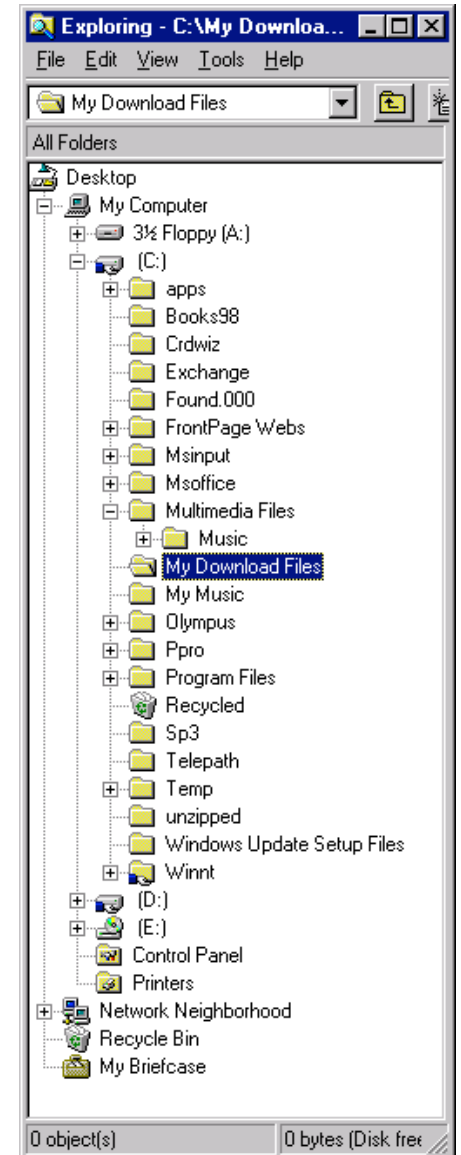
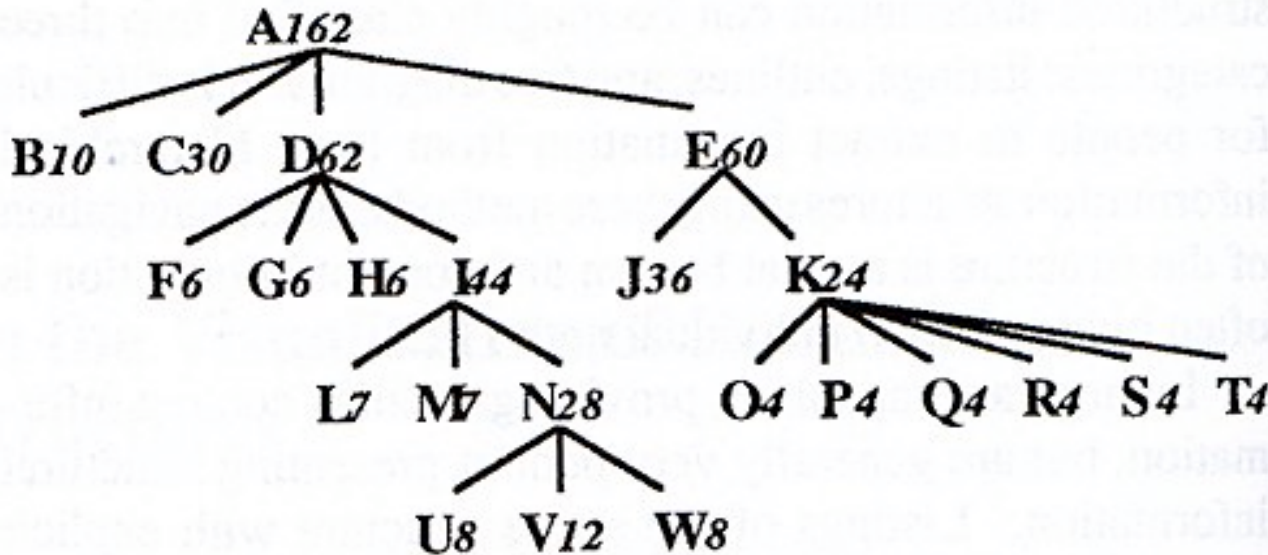


Centered Root View



Root can be at center
with levels growing
outward.

Examples



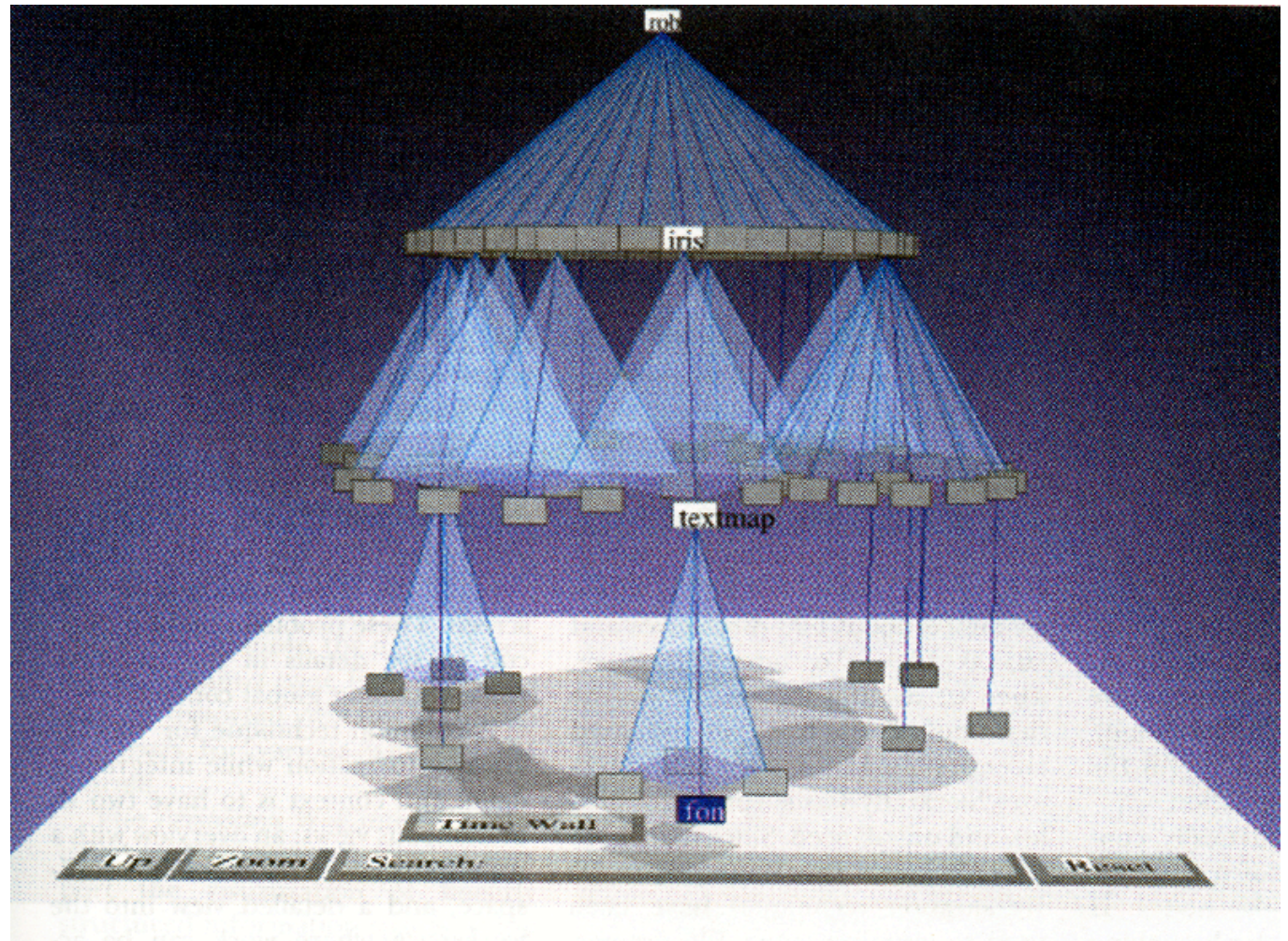
Tree Problem and 3D Approach

- For top-down, width of fan-out uses up horizontally
 - At level n , there are 2^n nodes for binary tree
- Tree might grow a lot along one particular branch
 - Hard to draw it well in view without knowing how it will branch
- 3D approaches
 - Add a third dimension into which layout can go
 - Compromise of top-down and centered techniques
 - Children of a node are laid out in a cylinder “below” the parent

Cone Trees

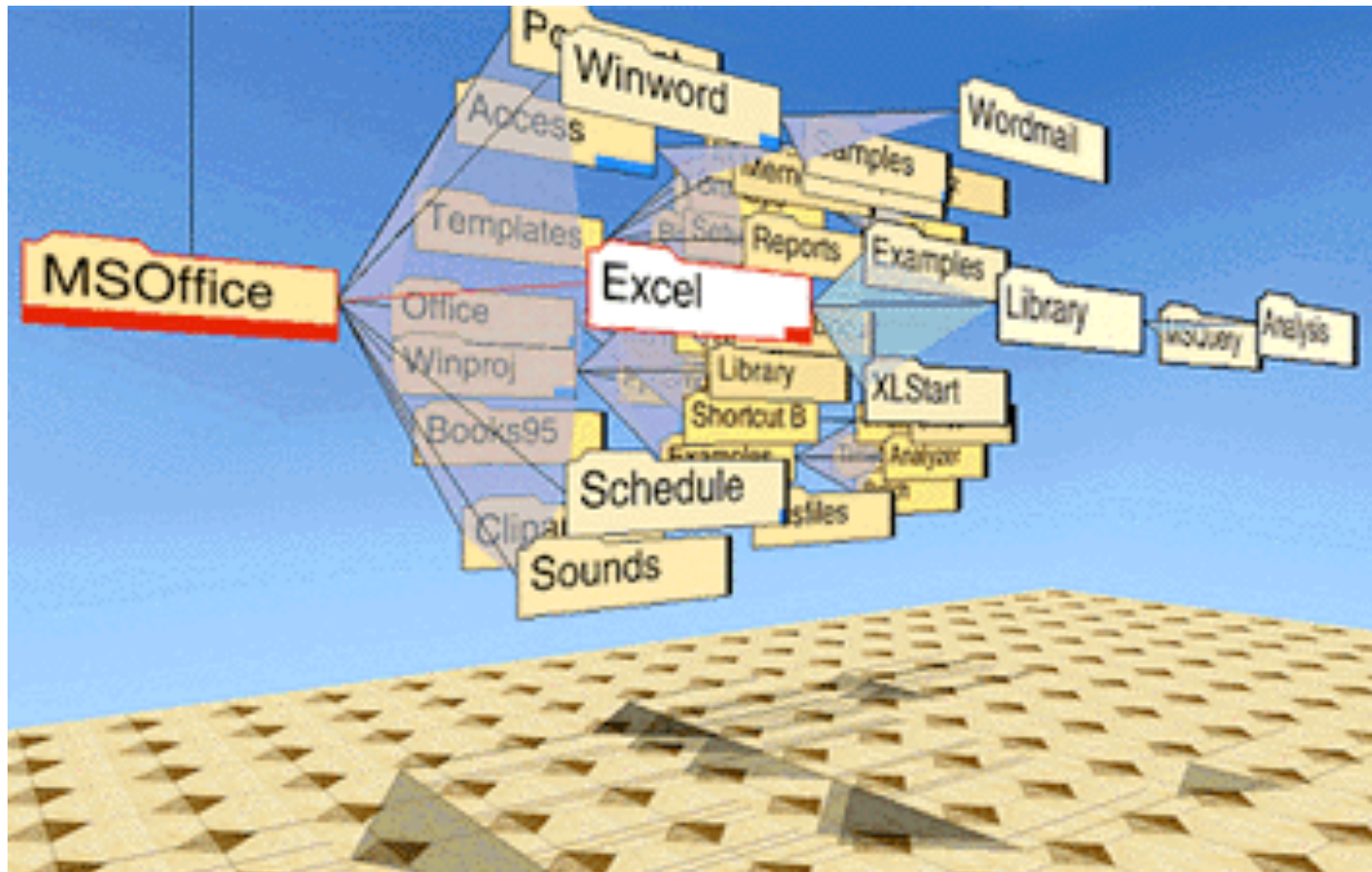
Developed at
Xerox PARC

3D views of
hierarchies
such as file
systems



Robertson, Mackinlay, Card, 1991

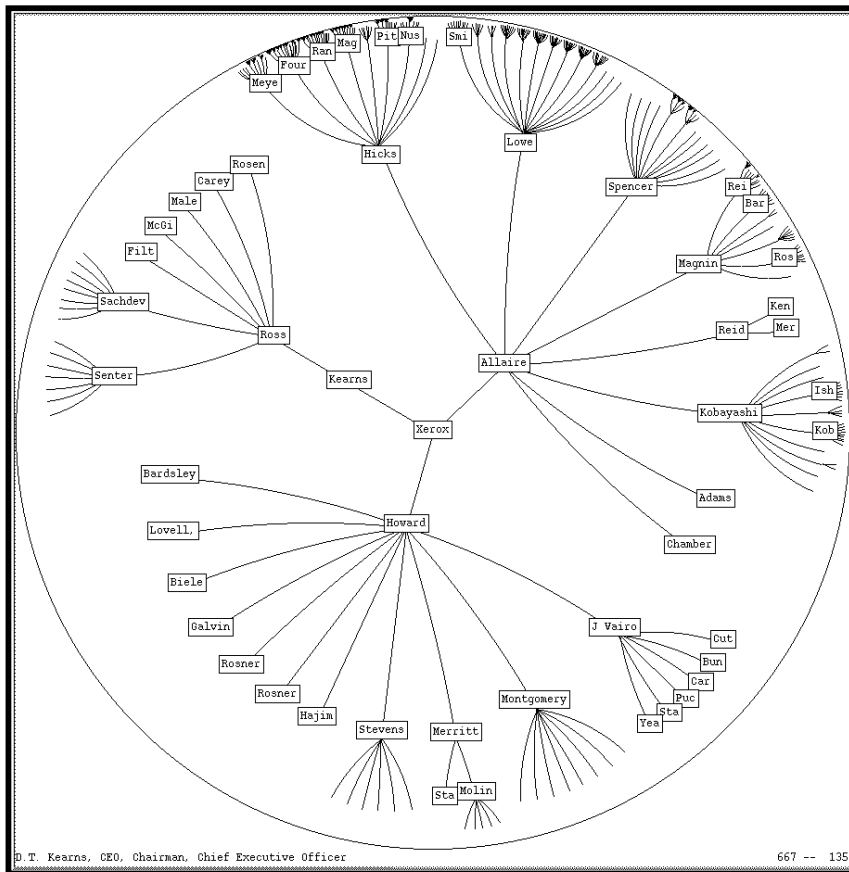
Alternate View



Hyperbolic Browser

- An entire tree can be kept within the confine of a circular area on a display [Lamping and Rao, 1994]
- Apply a hyperbolic transformation to the space
- Root is at center, subordinates around
- Apply idea recursively, distance decreases between parent and child as you move farther from center, children go in wedge rather than circle
- Focus + Context Technique
 - Detailed view blended with a global view

2D Hyperbolic Browser

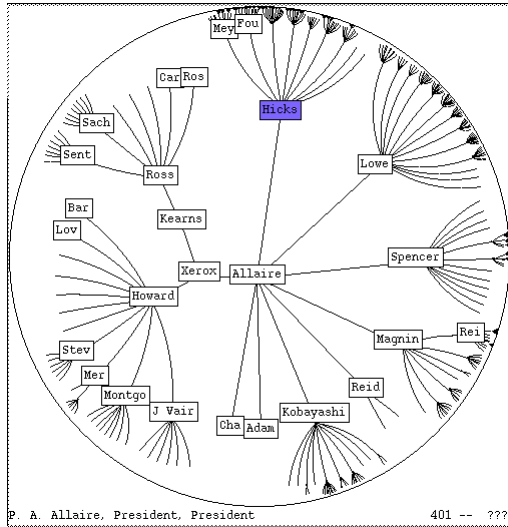


- **Approach:** Lay out the hierarchy on the hyperbolic plane and map this plane onto a display region.

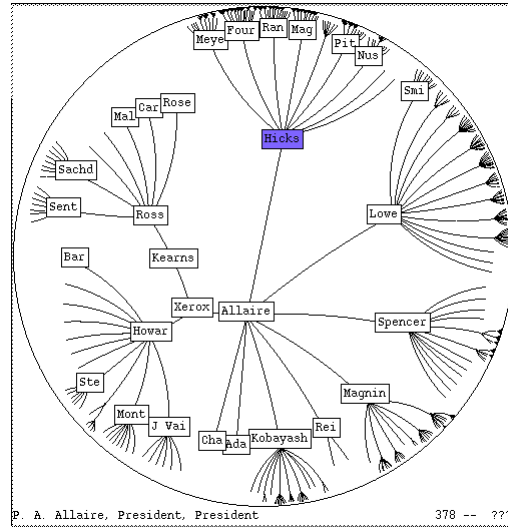
Node's context can be viewed in all directions within the tree: its parent, siblings and children

- **Comparison**
 - A standard 2D browser: 100 nodes (w/3 character text strings)
 - Hyperbolic browser: 1000 nodes, about 50 nearest the focus can show from 3 to dozens of characters

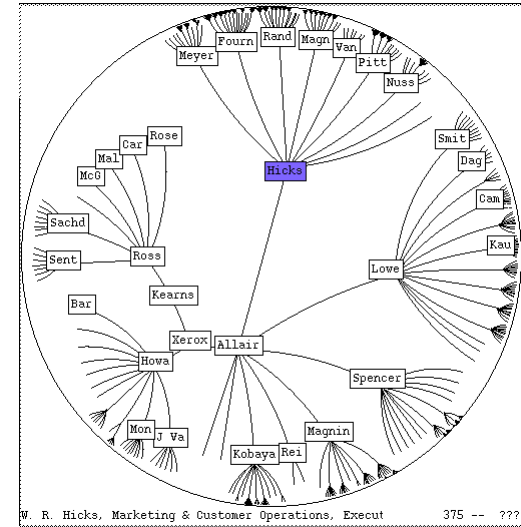
Interaction



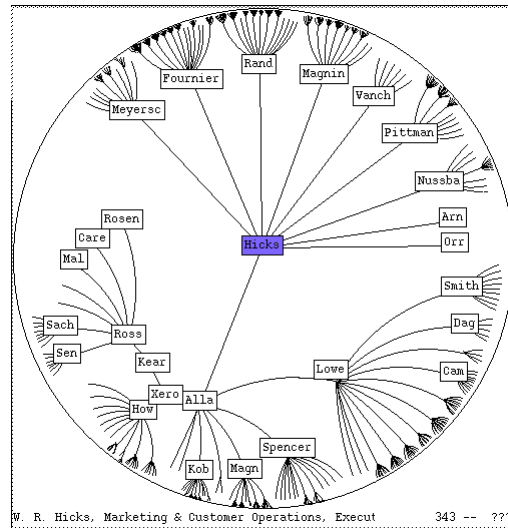
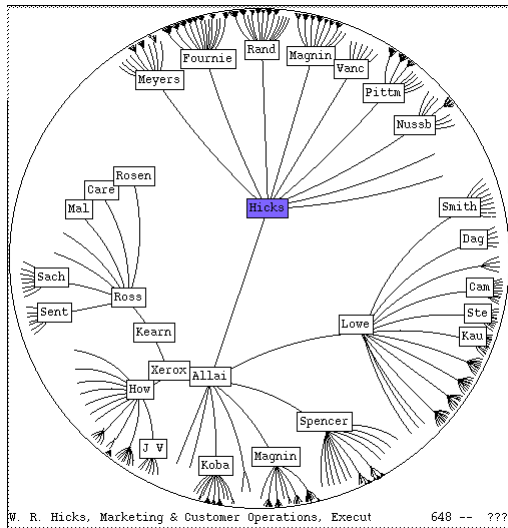
1



2



3



5

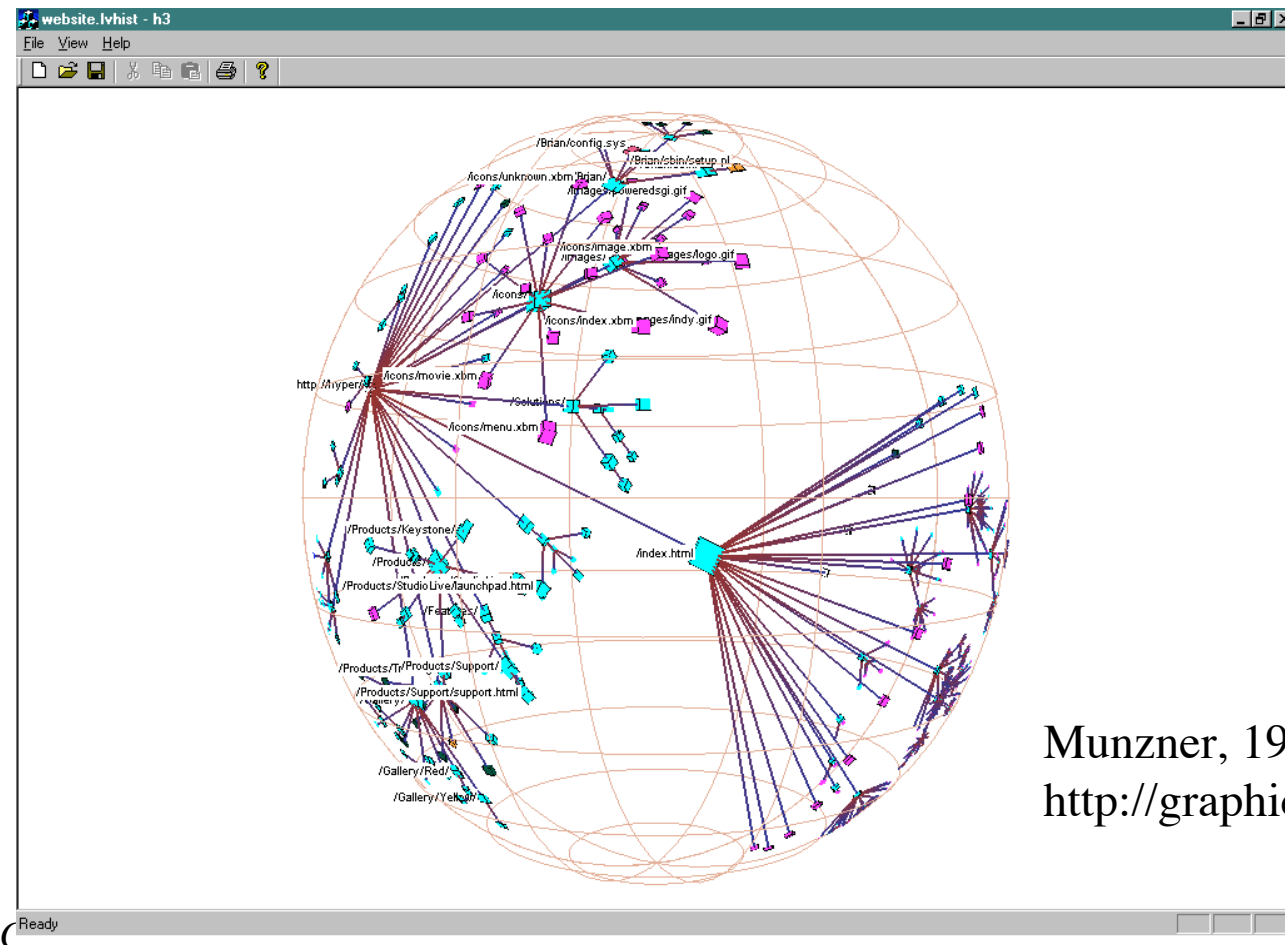
Any node of interest can be moved into the central area so more detail

Dragging or clicking blue node

Inxight web site has an applet demo.

3D Hyperbolic Viewer

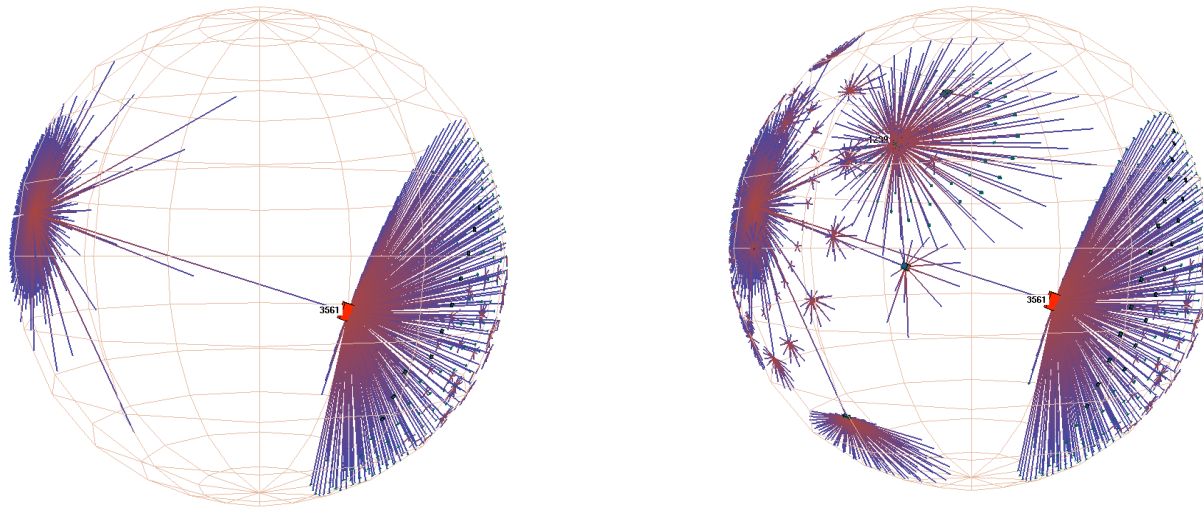
- Nodes are laid out on the surface of a hemisphere
- Handle much larger graphs, i.e. >100,000 edges
- Support dynamic exploration & interactive browsing



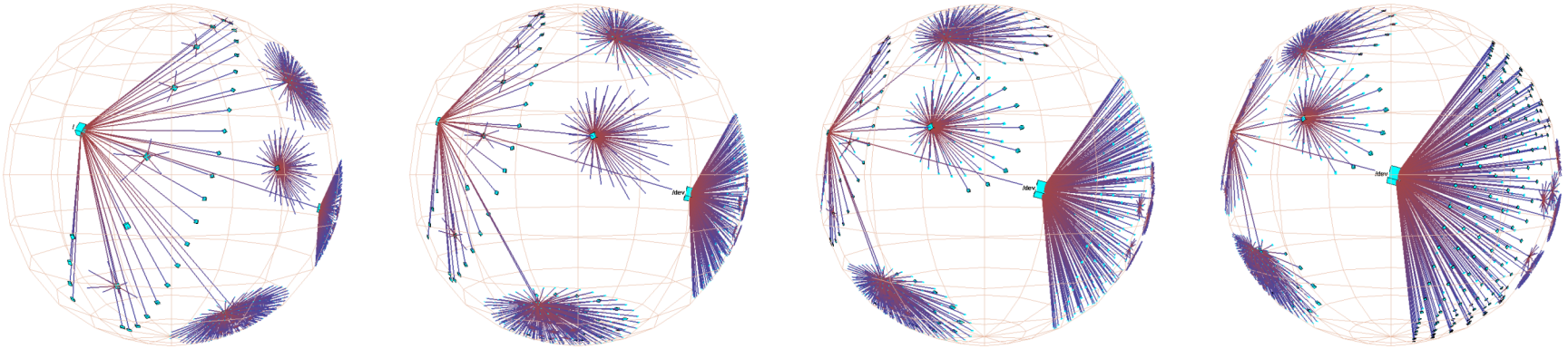
Munzner, 1998
<http://graphics.stanford.edu/~munzner/>

Drawing

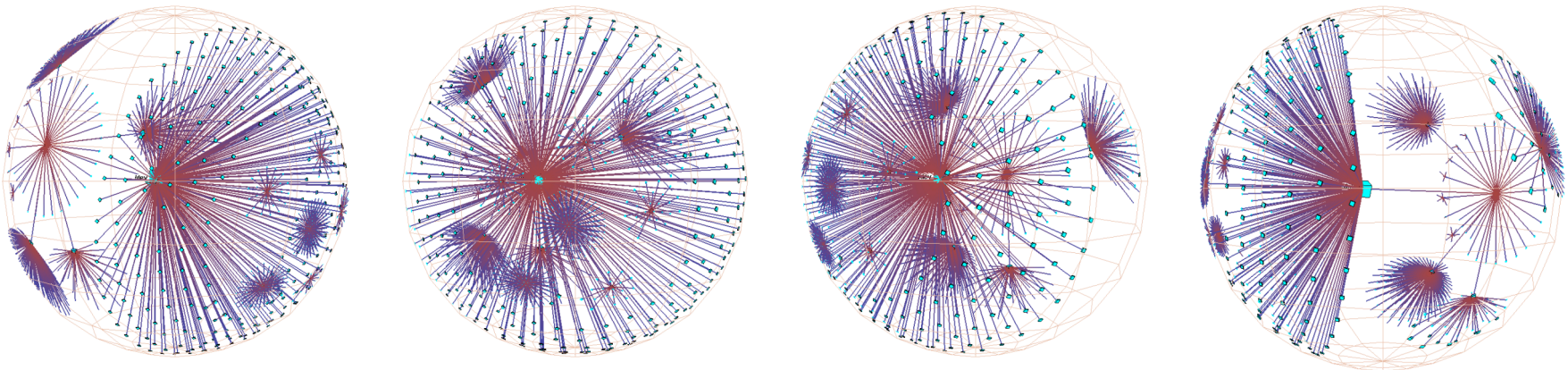
- Maintain a target frame by showing less of the context surrounding the node of interest during interactive browsing
- Fill in more of the surrounding scene when the user is idle



Navigation



Translation of a node to the center

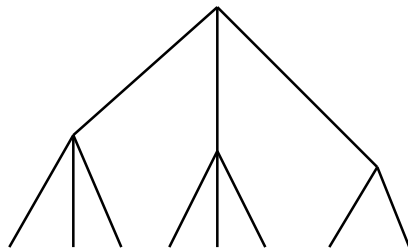


Rotation around the same node

Space-Filling Representation

Each item occupies an area

Children are “contained” under parent

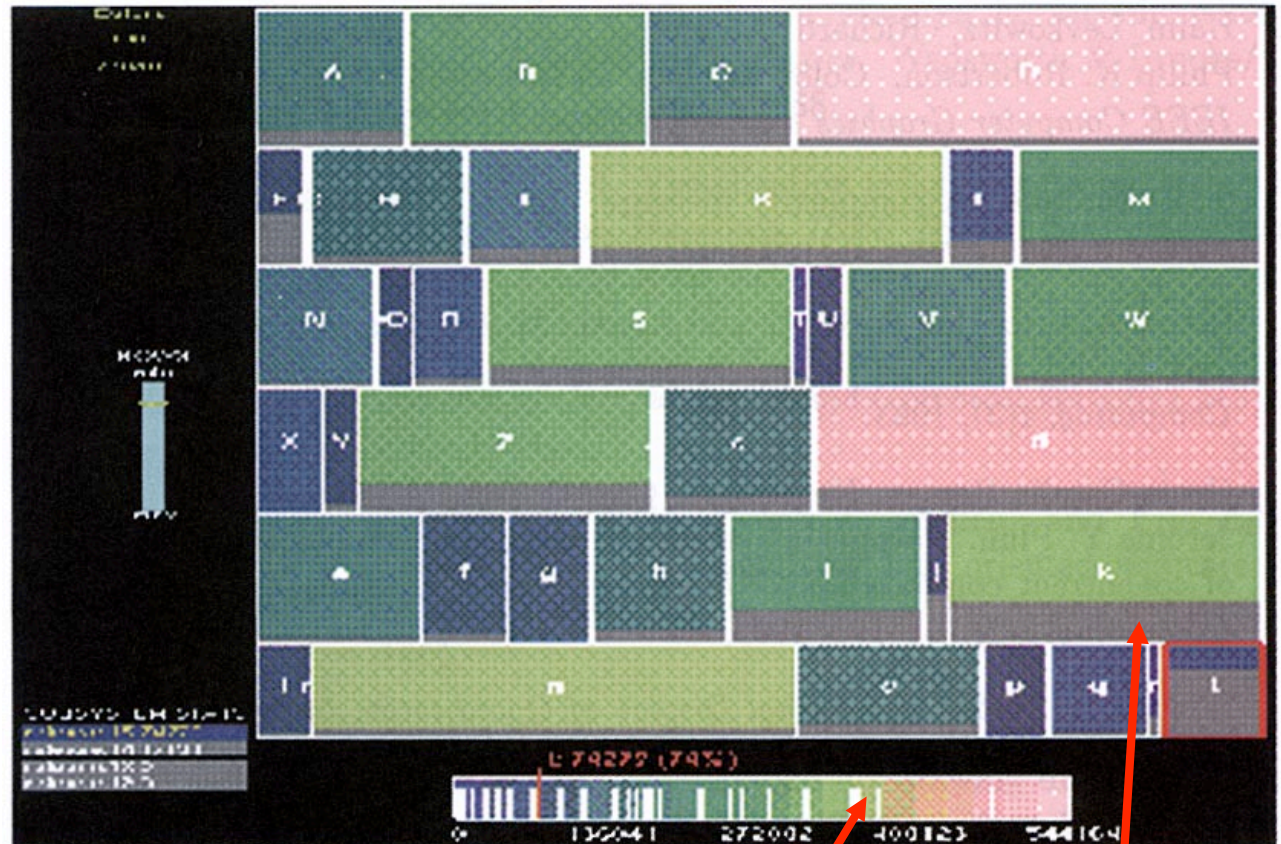


One example

Software Visualization Application

Subsystems in a software system. Each rectangle represents the non-comment source code in a subsystem. Area means size

- SeeSys: Software Metrics Visualizing System
- Uses treemap-like visualization to present different software metrics
- Displays:
 - Size
 - Recent development
 - High fix-on-fix rates
 - History and growth



Baker and Eick, 1995

Tennis Viewing Application

Match view

Bond won

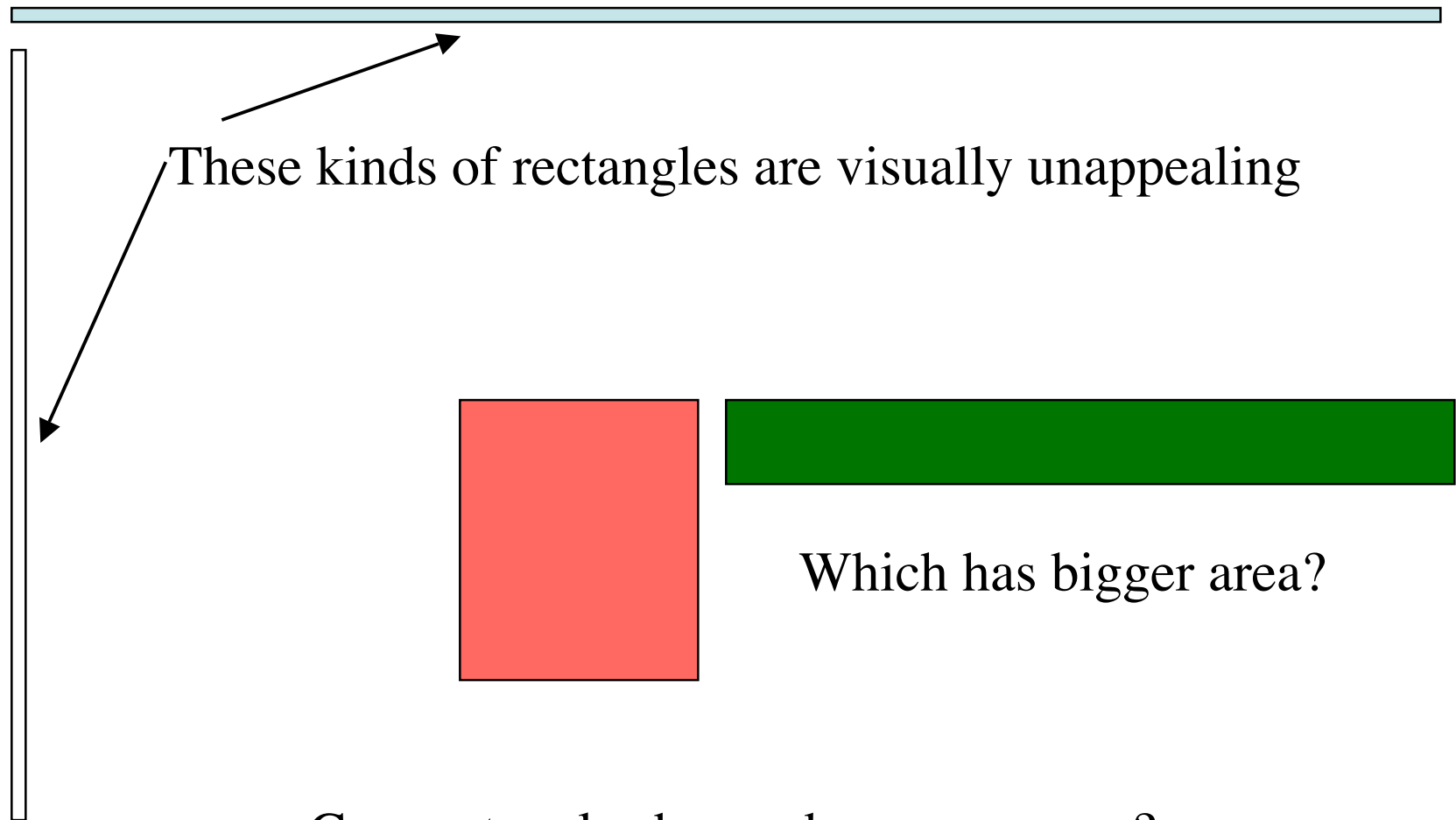
Set results

Lens showing
ball movement on
individual points

Game results



Problem - Aspect Ratios

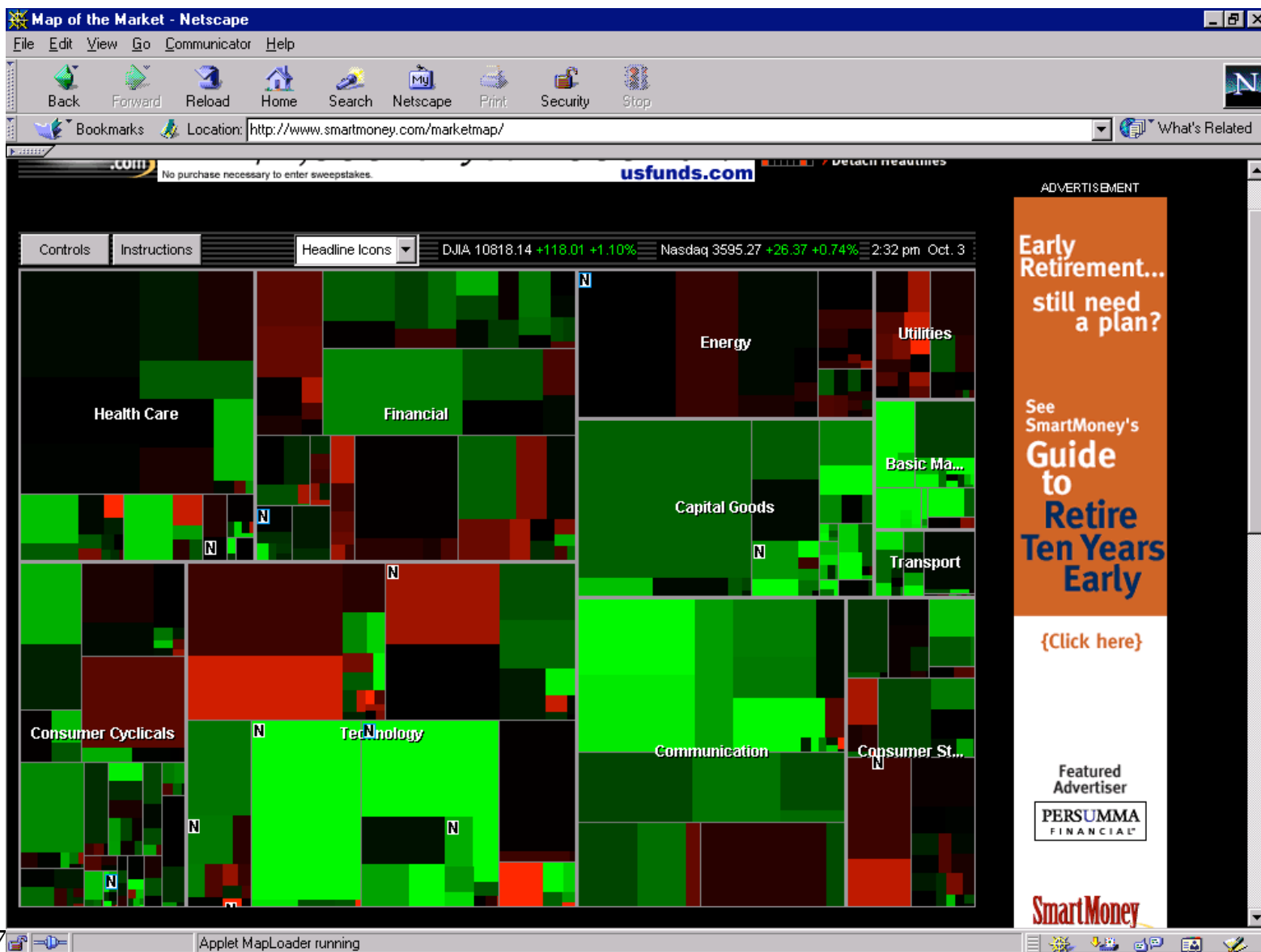


These kinds of rectangles are visually unappealing

Which has bigger area?

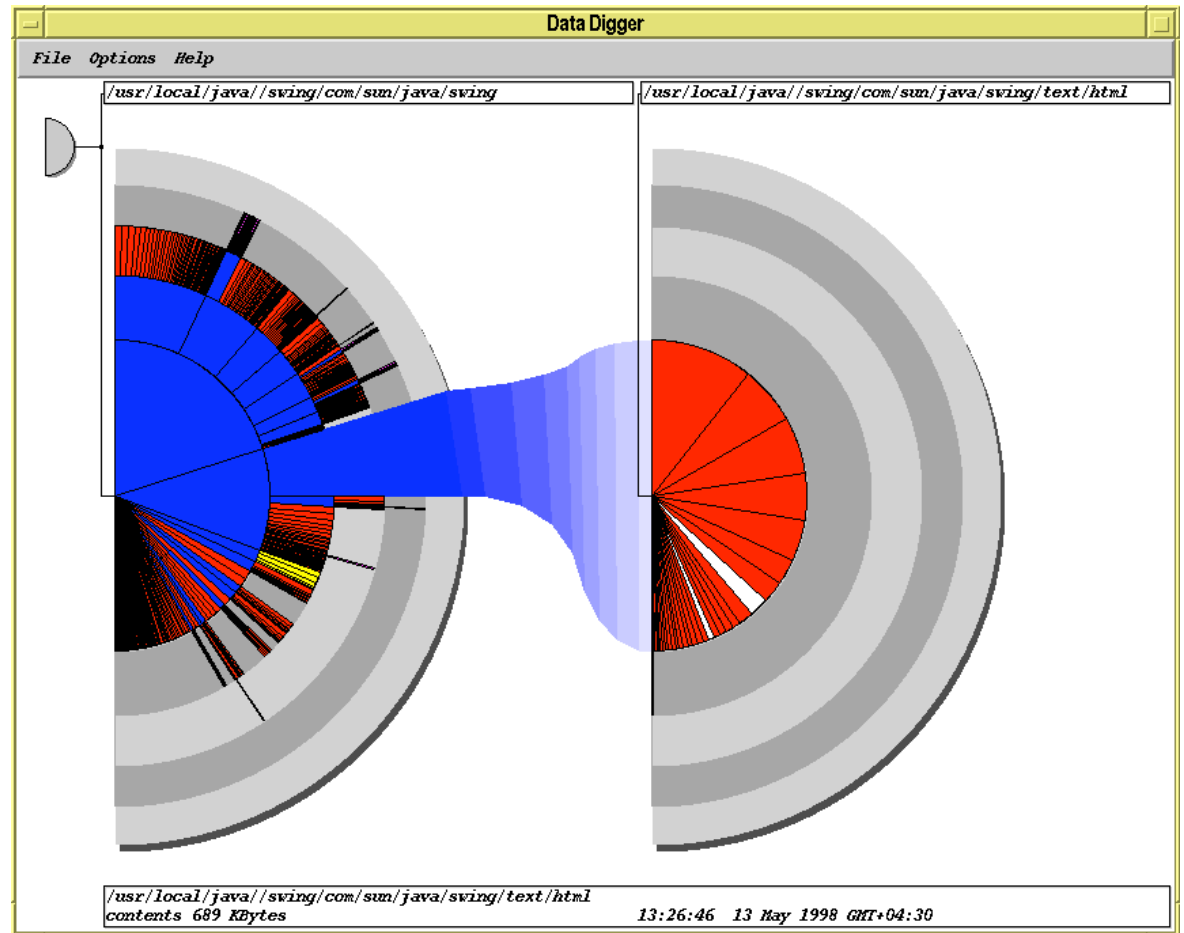
Can rectangles be made more square?

Avoiding Bad Aspect Ratios



Radial-Space Filling

- Use a radial rather than a rectangular space-filling technique:
 - We saw node-link trees with root in center and growing outward already...
- Make pie-tree with root in center and children growing outward
 - Radial angle now corresponds to a variables rather than area

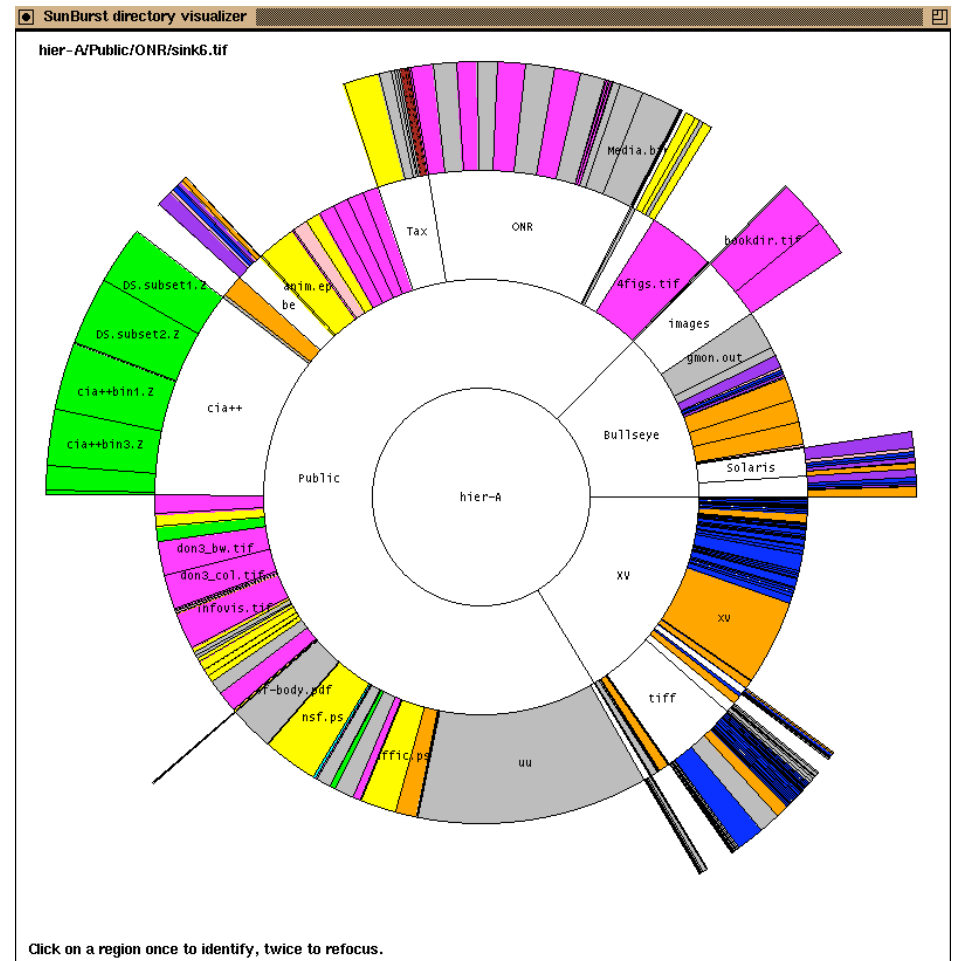


Chuah, Andrews and Heidegger, 1998

B. B. Karki, LSU

SunBurst

- Root directory at center, each successive level drawn farther out from center
- Sweep angle of item corresponds to size
- Color maps to file type or age
- Interactive controls for moving deeper in hierarchy, changing the root, etc.
- Double-click on directory makes it new root



3 Solutions to SunBurst Problem

- In large hierarchies, files at the periphery are usually tiny and very difficult to distinguish
- Three techniques for this
 - Angular detail
 - Detail outside
 - Detail inside

