The Final Frontier

IAT 814
Knowledge Visualization

Reducing complexity: Space

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Space

- Space is our most important encoding.
- We don’t have enough of it.
- How can we use it most effectively?

So much data, so little space: 1

- Huge amounts of data (many items)
- Rich data (many dimensions)
- heterogeneous data (many sources)

- patterns and relations across sets
- Occlusion and overplotting
- Visual fragmentation
  - Decoding too many different visual forms

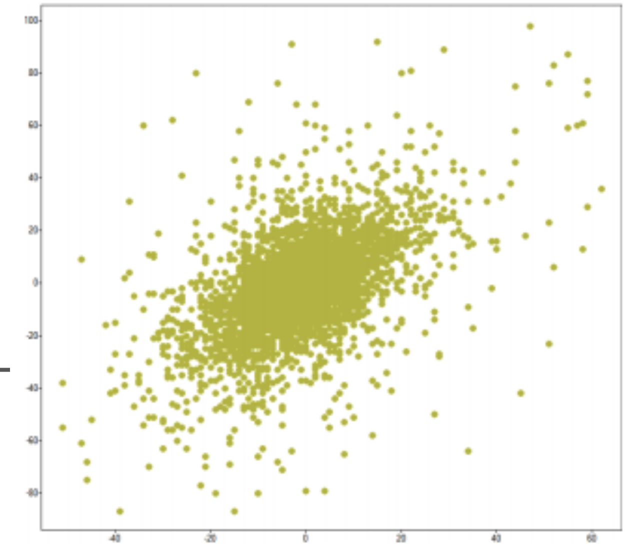
Strategies we have (implicitly) considered so far

- Choose the right data abstractions
- Distribute data across multiple forms and views
  - Cross-cut and slice : **facet**
  - Brushing and linking interactions
- Provide rich interactive techniques

Part of larger set of strategies

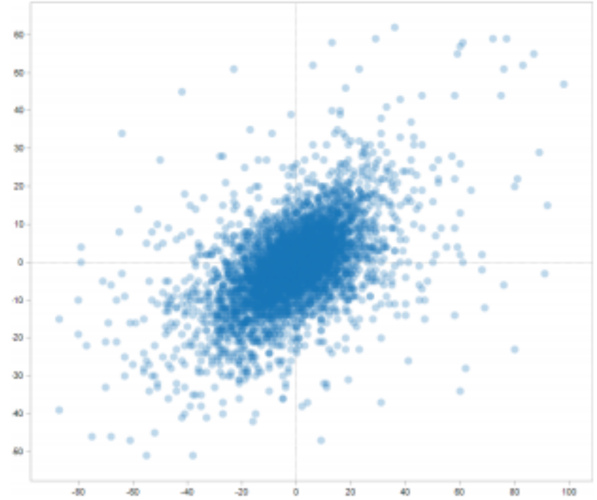
- Mitigate overplotting
- Facet appropriately
- Reduce what we need to draw
- Transform the data

Reducing overplotting [Few]



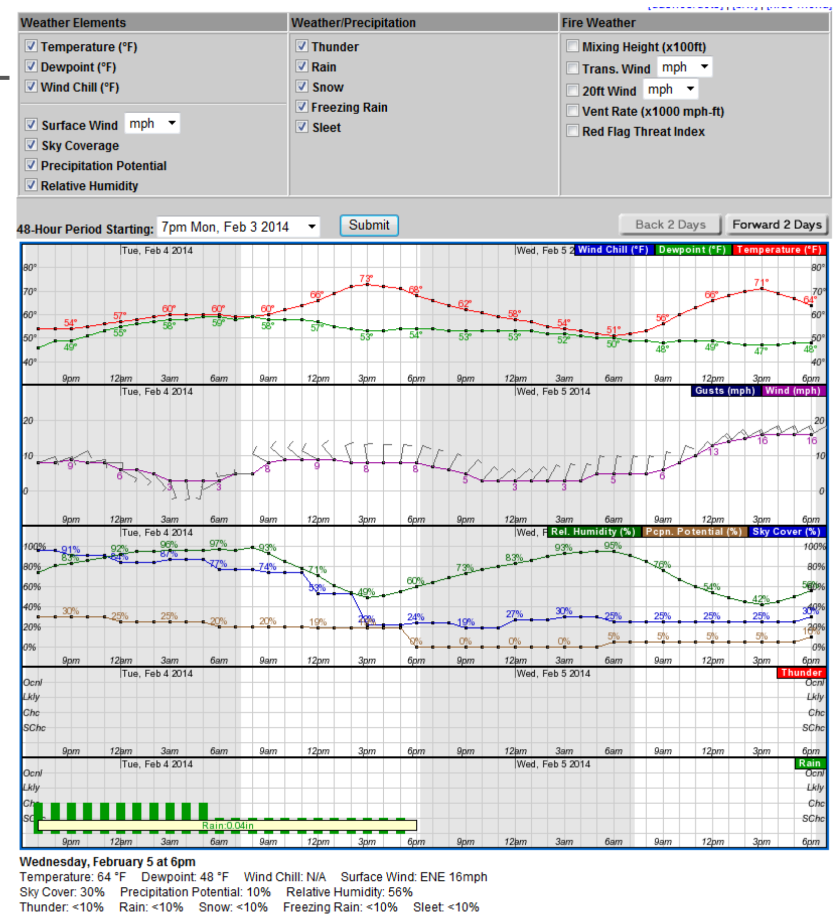
- Reduce size of objects
- Remove fill colour
- Change shape from container (eg circle) to non-container (X)
- *Jitter* the data
- Make data objects transparent

- White space challenges vis
- Graphical tricks only go so far.

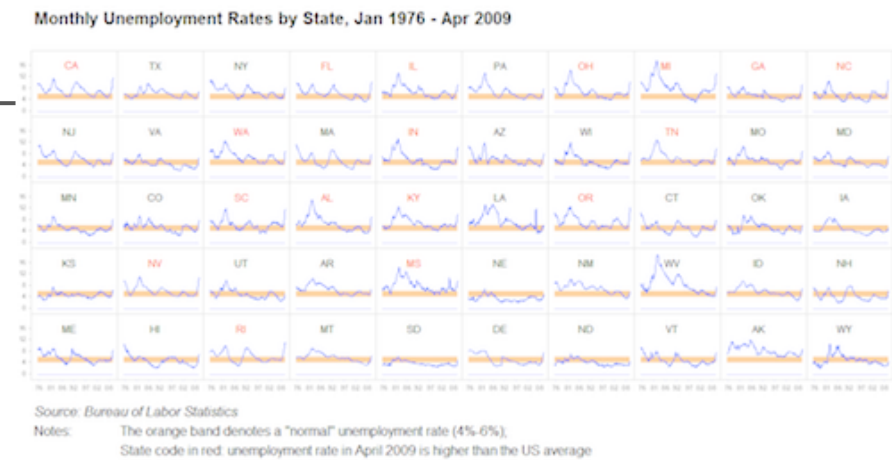


Facets: Dimensional division

- "splitting" dimensions across linked views
- Small multiples
- Trellis displays
- Scatterplot matrices



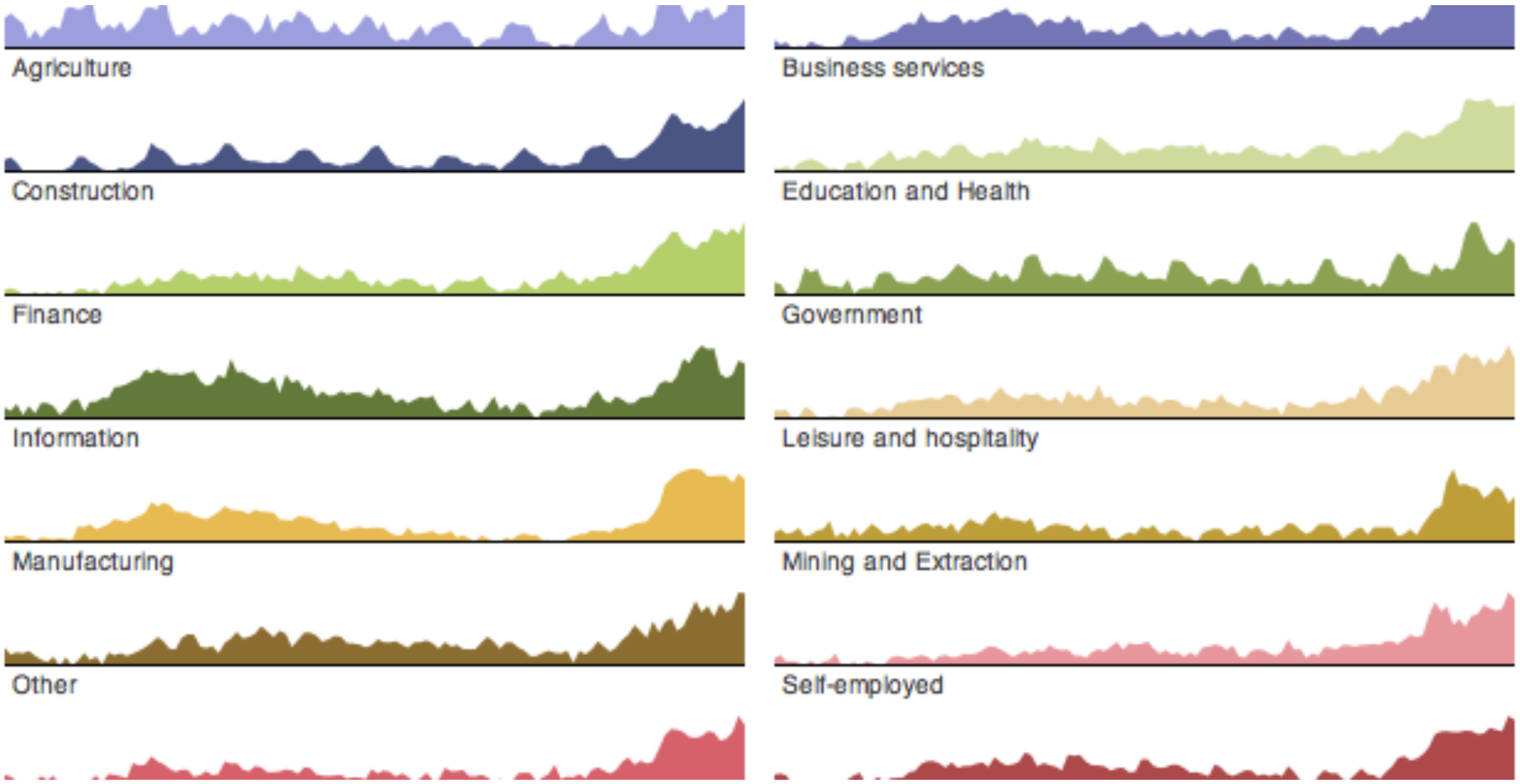
Facets: Small multiples



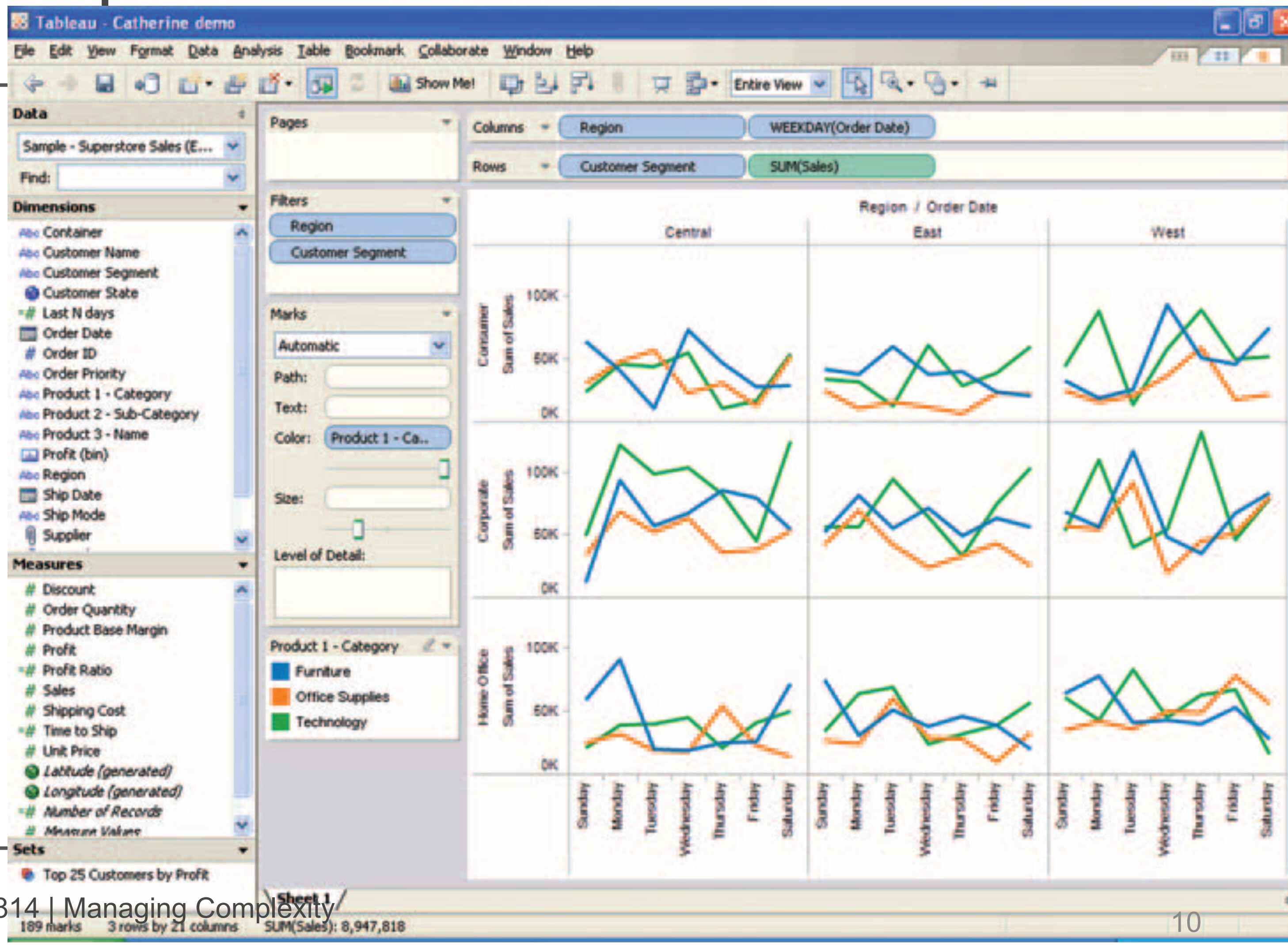
- use the same basic graphic or chart to display difference slices of a data set
- rich, multi-dimensional data without trying to cram all that information into a single, overly-complex chart.
- Singular design reduces decoding effort.

E. Tufte "The Visual Display of Quantitative Information," p. 42 and "Envisioning Information," p. 29

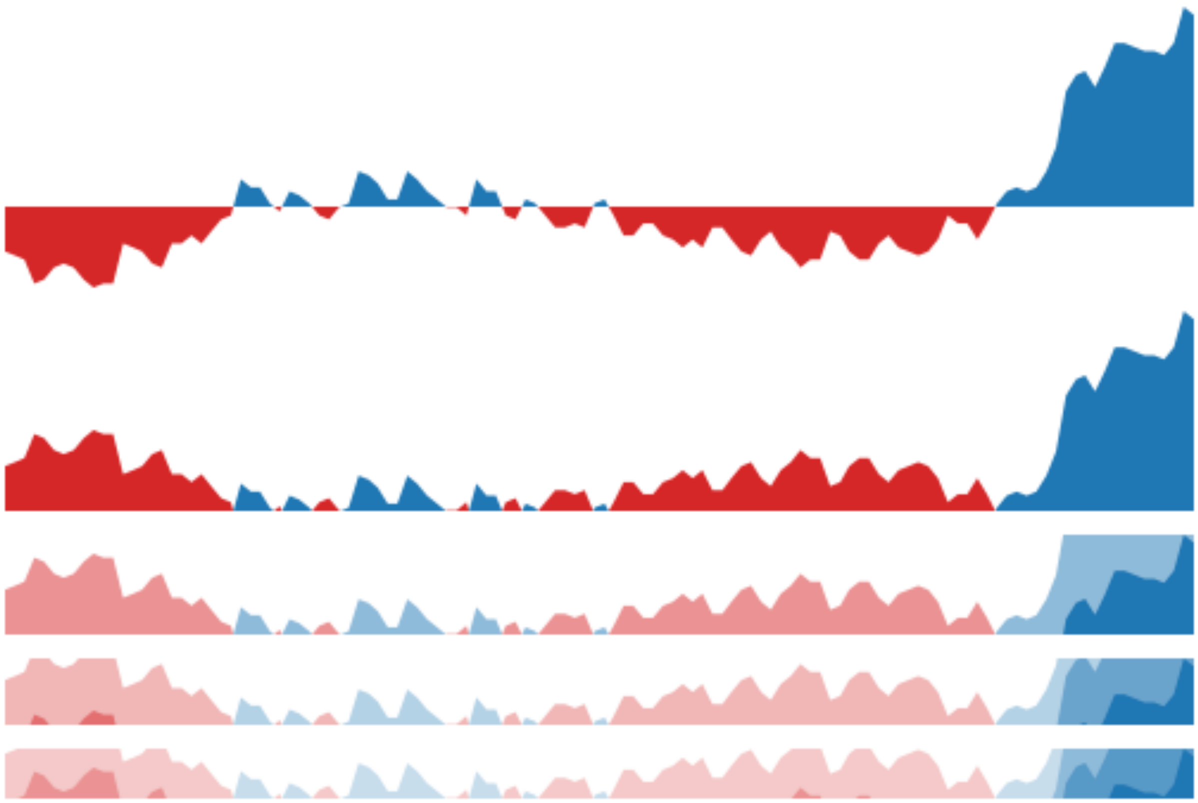
Facets: Small multiples



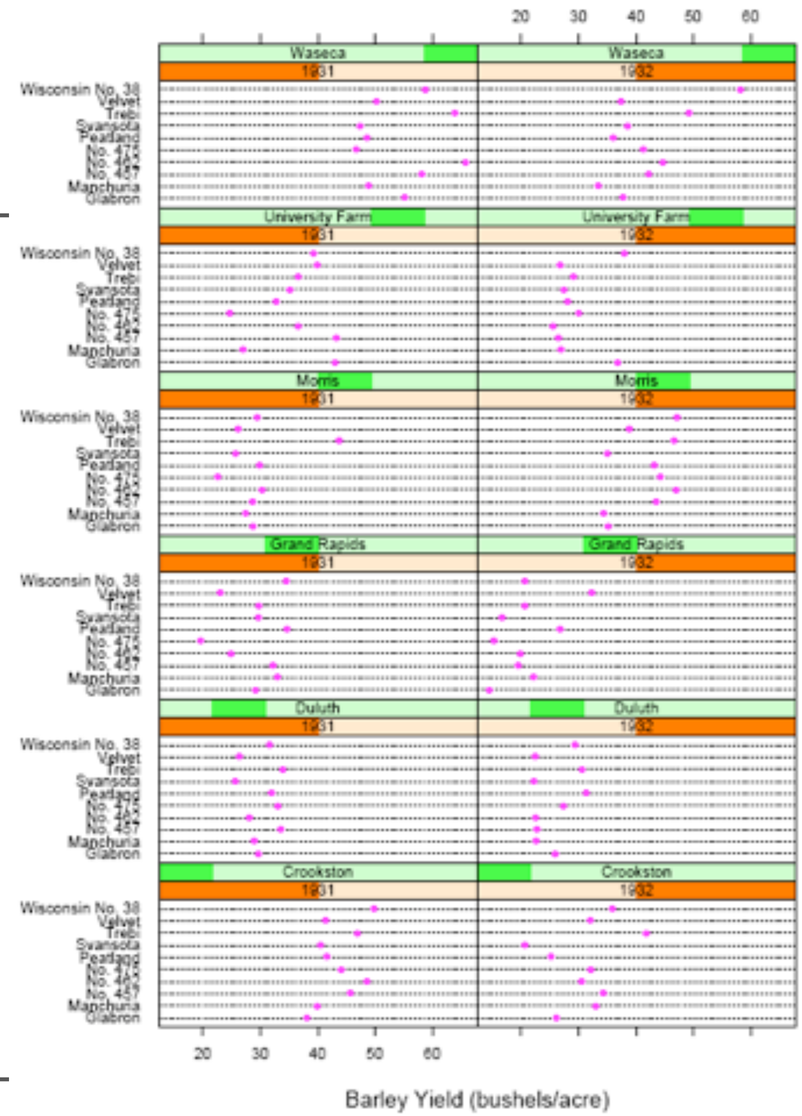
Small multiples



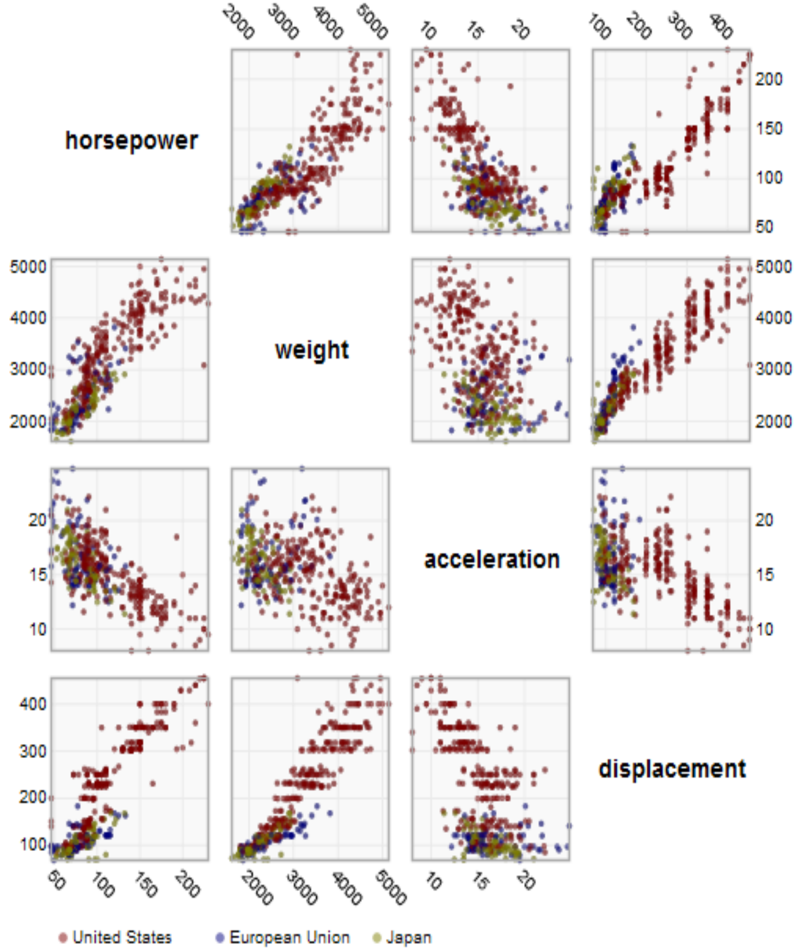
Horizon graphs



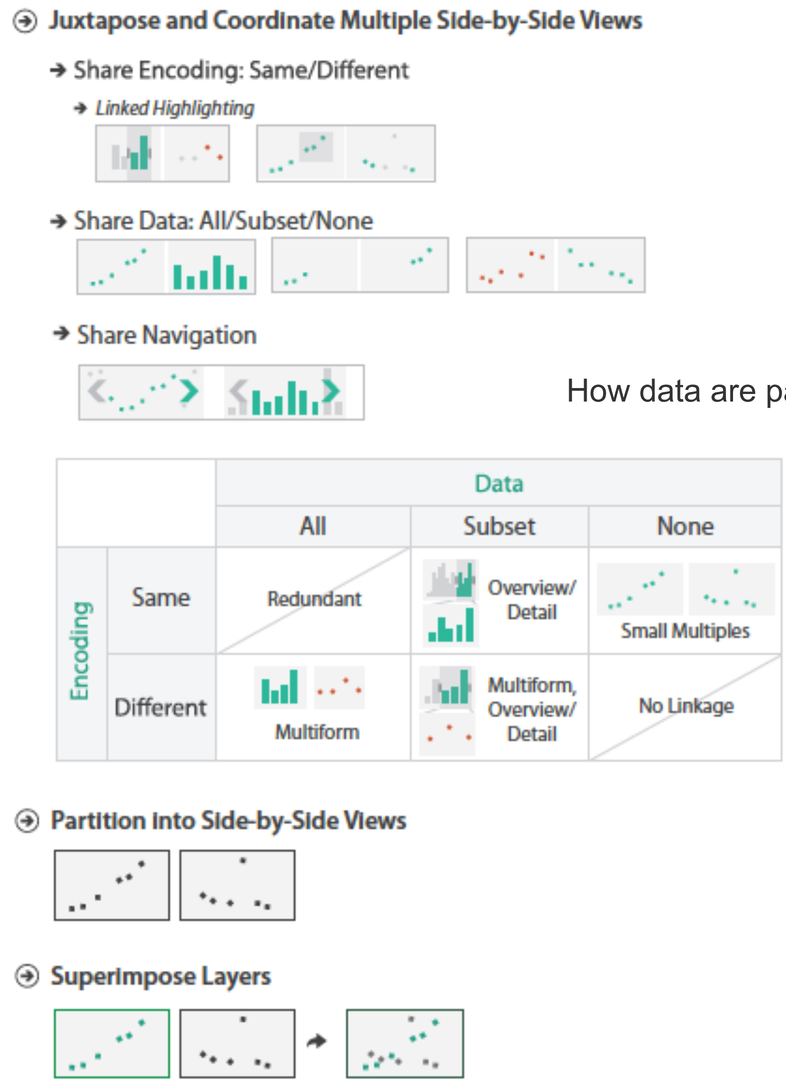
Trellis plots



Scatter plot matrices



Facet choices



How data are partitioned between views

Basic approaches

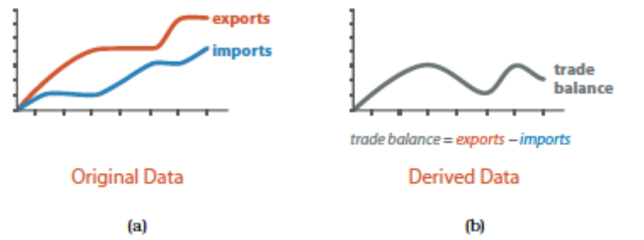
- How do we reduce the amount of stuff to draw?
  - Connected with view and facet composition decisions
  - Reduce overplotting

- Reduce the number of **data points**
  - **Item reduction**
  - Interaction

- Reduce the number of **dimensions**
  - **Attribute reduction**

5 strategies for managing complexity

1. Derive new data elements



2. Manipulate the view
   - Change over time
   - Navigation
   - **Overview first, filter + zoom, details on demand** [Shneiderman]
3. Facet into multiple views
4. Reduce data items and attributes
5. Focus + Context

Manipulating views [Munzner]

- Filter and navigation
  - Leave some things out
- Overviews
  - Sequential/temporal with **navigation**
  - Separate linked views
  - Focus and context
    - Selective filtering
    - Distortion techniques
- Aggregation
  - Merge things together
- Zoom in/out
  - Semantic hierarchy
  - Details on demand

View transformations

- Viewpoint controls
  - Zoom, pan, clip
  - Overview+detail
- Focus+Context
  - Bifocal : Perspective Wall, Document Lens
  - Polyfocal : Table Lens
  - Based on levels of interest: Fish Eye Lens

- Location probes
  - Details on demand
  - Brushing
  - Magic lenses
- Location probes support dimensional slicing/faceting and cutting

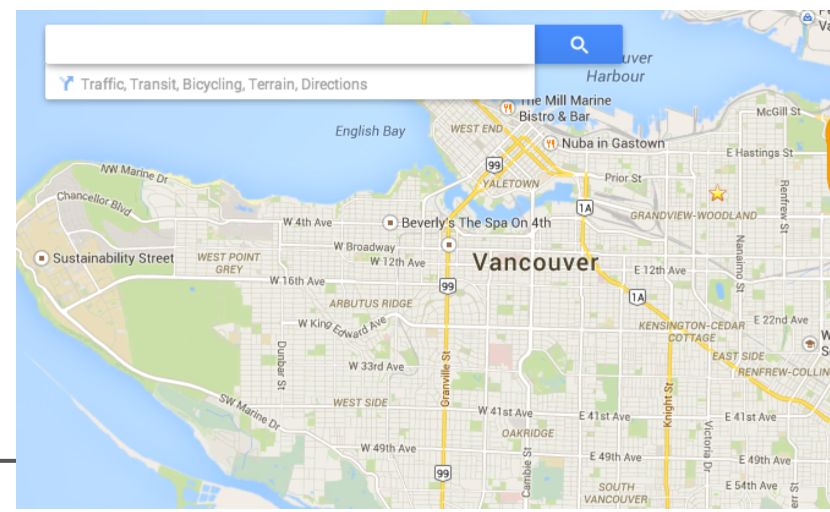
So much data, so little space

Scale - Many data sets are too large to visualize on one screen

- May simply be too many cases
- May be too many dimensions
- May only be able to highlight particular cases or particular variables, but viewer's focus may change from time to time

Common Solution- Scroll/Pan

- larger, virtual screen allows user to move to different areas
  - Requires one or more of
    - Dedicated interaction operation (mouse, touch)
    - Peripheral scroll bars



- Benefits?
- Issues ?

Panning and Zooming

- Panning
  - Smooth movement of camera across scene (or scene moves and camera stays still)
- Zooming
  - Geometric: changes the magnification of the objects in a scene
  - Semantic: shows the data at different levels of detail
    - Representation changes according to available pixels
- Useful for changing focal point

Pan and Zoom

How to show a lot of information in a small space?

- Multiple Levels of Resolution
  - The view changes depending on the “distance” from the viewer to the objects

- multiscale-based variable representations
  - Keep a steady overview, make some objects larger while simultaneously shrinking others

Taxonomy

- Zooming: temporal separation
- Overview+detail: spatial separation
- Focus+Context: integrated/embedded

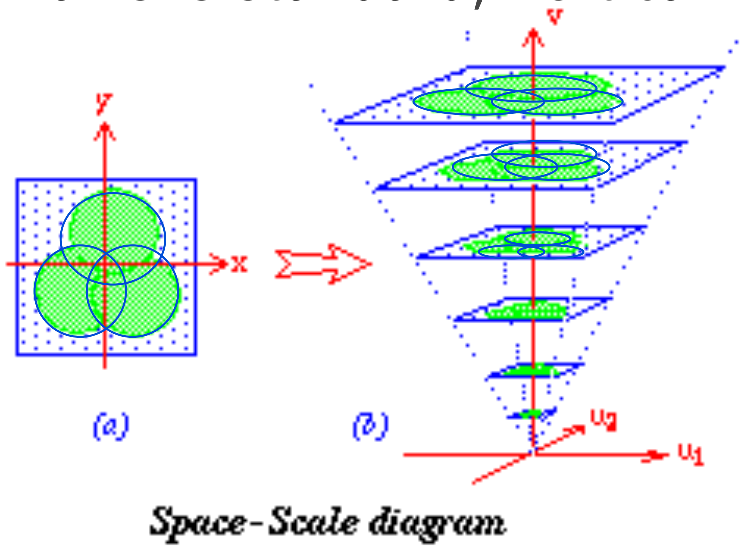
A review of overview+detail, zooming, and focus+context interfaces. Andy Cockburn, Amy Karlson, and Benjamin B. Bederson. ACM Computing Surveys 41(1), 2008.

Zooming

- Standard Zooming
  - Get close in to see information in more detail
  - Example: Google earth zooming in
- Intelligent Zooming
  - Show semantically relevant information out of proportion
  - Example: speed-dependent zooming, Igarishi & Hinkley
  - OrthoZoom 1D
- Semantic Zooming
  - Zooming shows the data at different levels of semantic detail,
  - Example : Multiscale , Pad++ and Piccolo projects
    - http://hcil.cs.umd.edu/video/1998/1998_pad.mpg

Space-Scale Diagrams

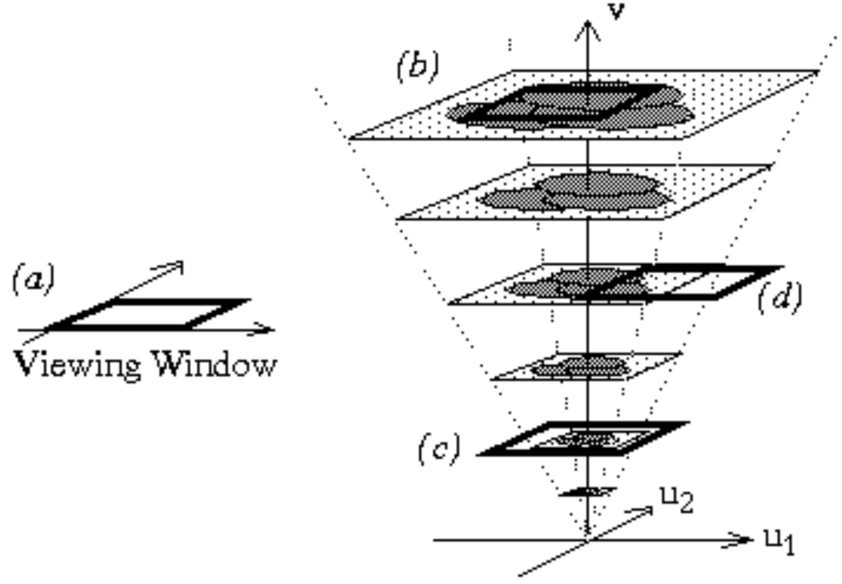
- Reasoning about navigation and trajectories
- Horizontal axis is standard, vertical is scale



[Space-Scale Diagrams: Understanding Multiscale Interfaces. George Furnas and Ben Bederson, Proc SIGCHI '95.

Space-Scale Diagrams

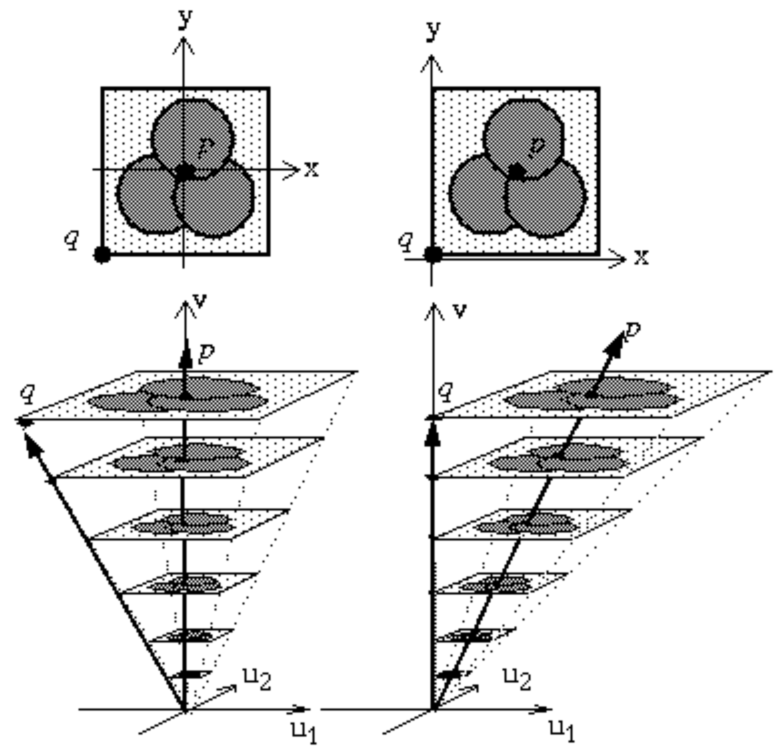
- User has a fixed-sized viewing window
- Moving it through 3D space yields all possible sequences of pan & zoom



[Space-Scale Diagrams: Understanding Multiscale Interfaces. George Furnas and Ben Bederson, Proc SIGCHI '95.

Space-Scale Diagrams

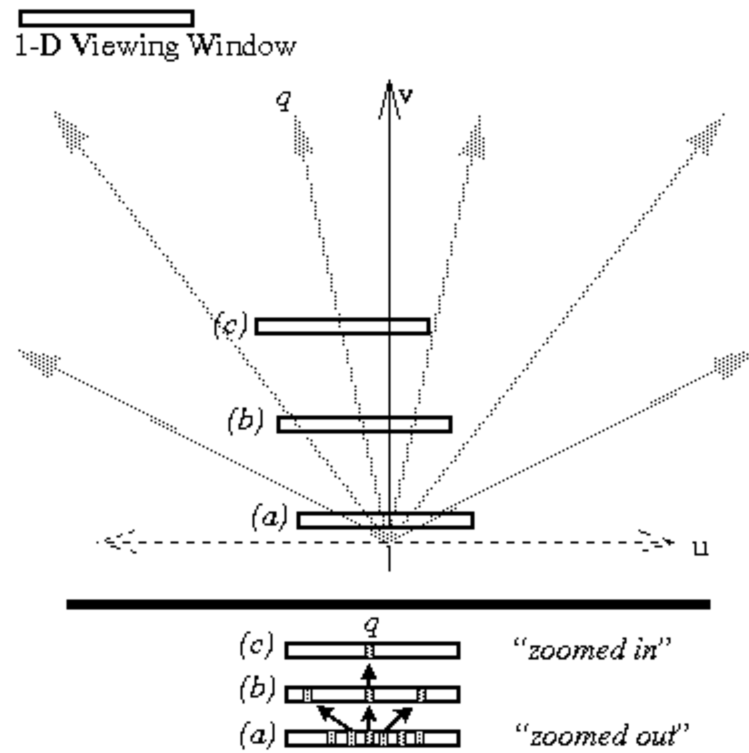
- If you move the origin of the 2D plane, the properties of the original 2D picture do not change
- Therefore, the absolute angles between the rays should not be assigned any meaning



[Space-Scale Diagrams: Understanding Multiscale Interfaces. George Furnas and Ben Bederson, Proc SIGCHI '95.

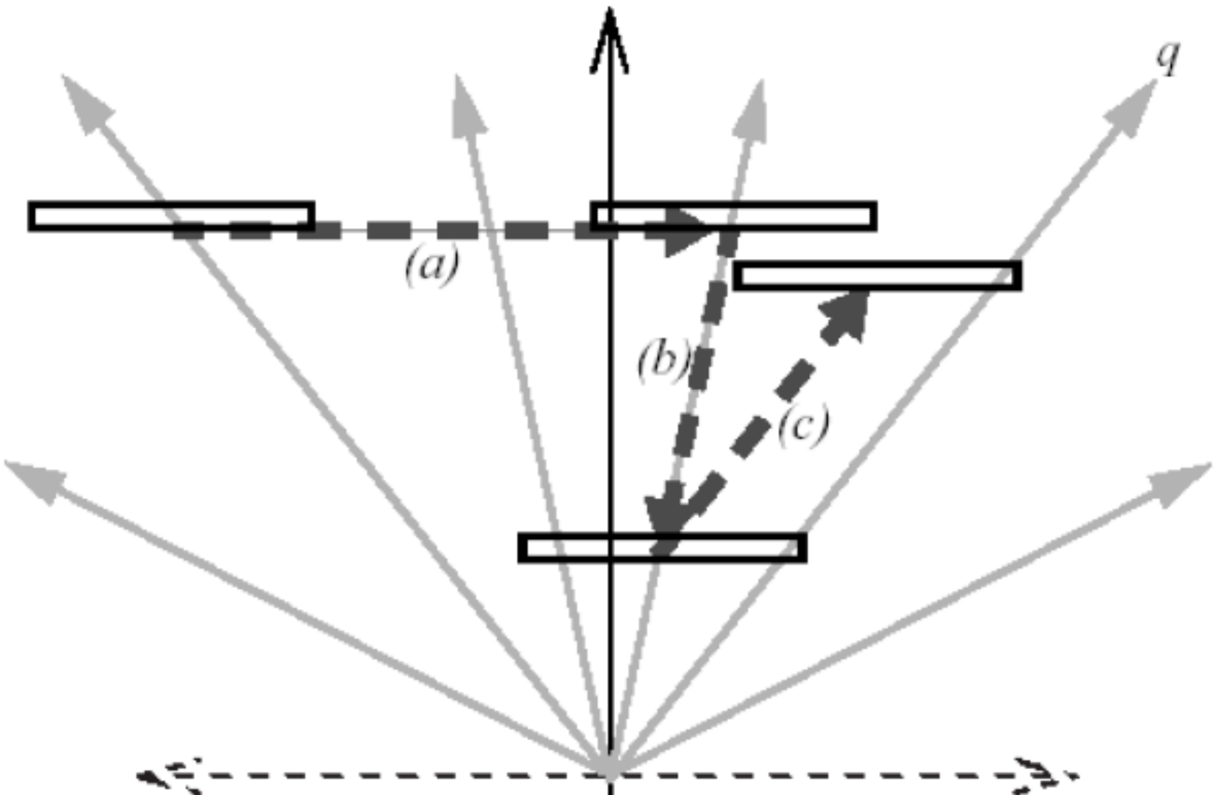
Space-Scale Diagrams

- We can think of this in terms of 1D
- When zoomed out, you can see wider set of points



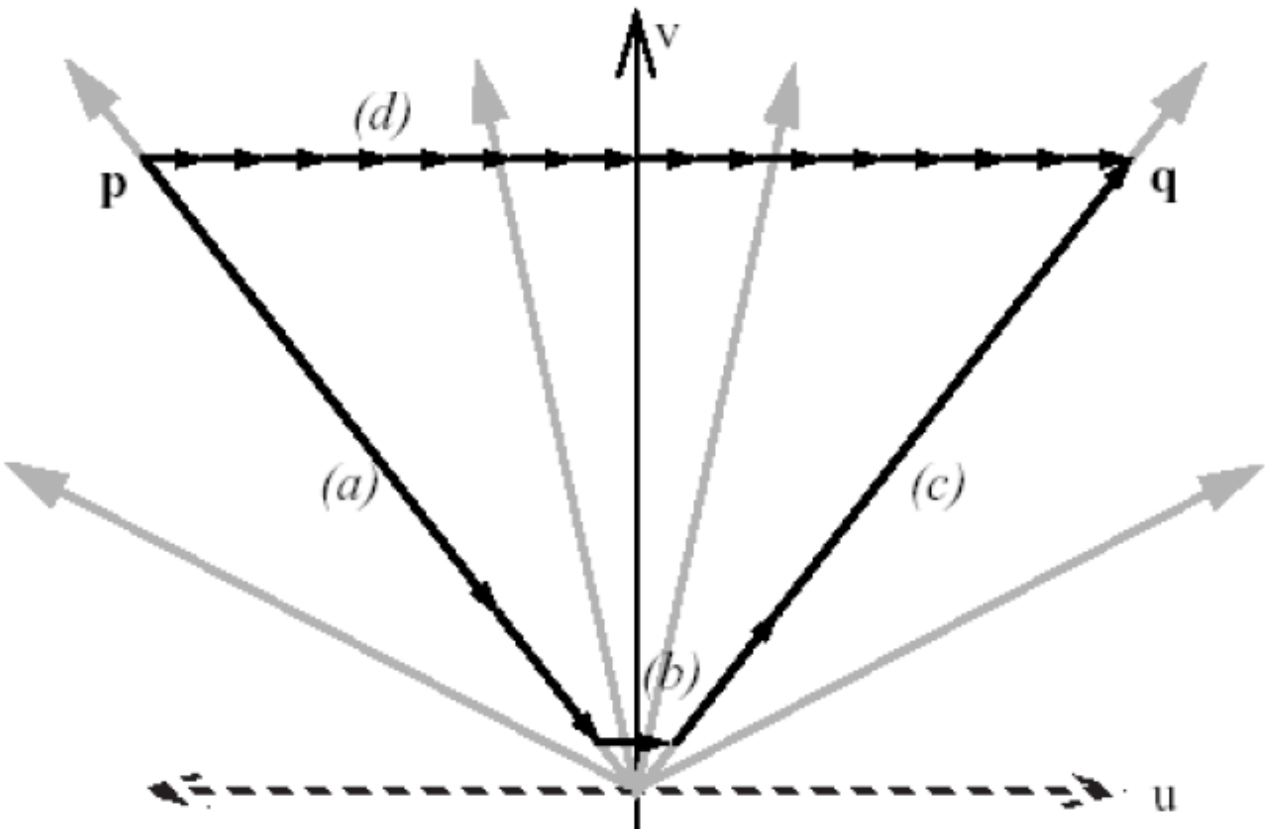
[Space-Scale Diagrams: Understanding Multiscale Interfaces. George Furnas and Ben Bederson, Proc SIGCHI '95.

Pan-Zoom Trajectories



[Space-Scale Diagrams: Understanding Multiscale Interfaces. George Furnas and Ben Bederson, Proc SIGCHI '95.

Shortest path



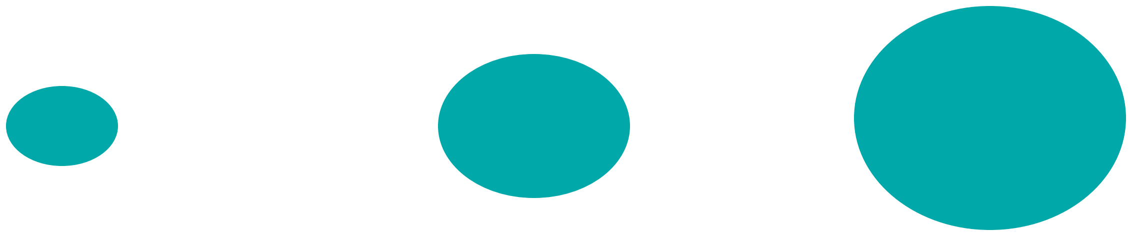
Space-Scale Diagrams

What about panning and zooming at the same time?

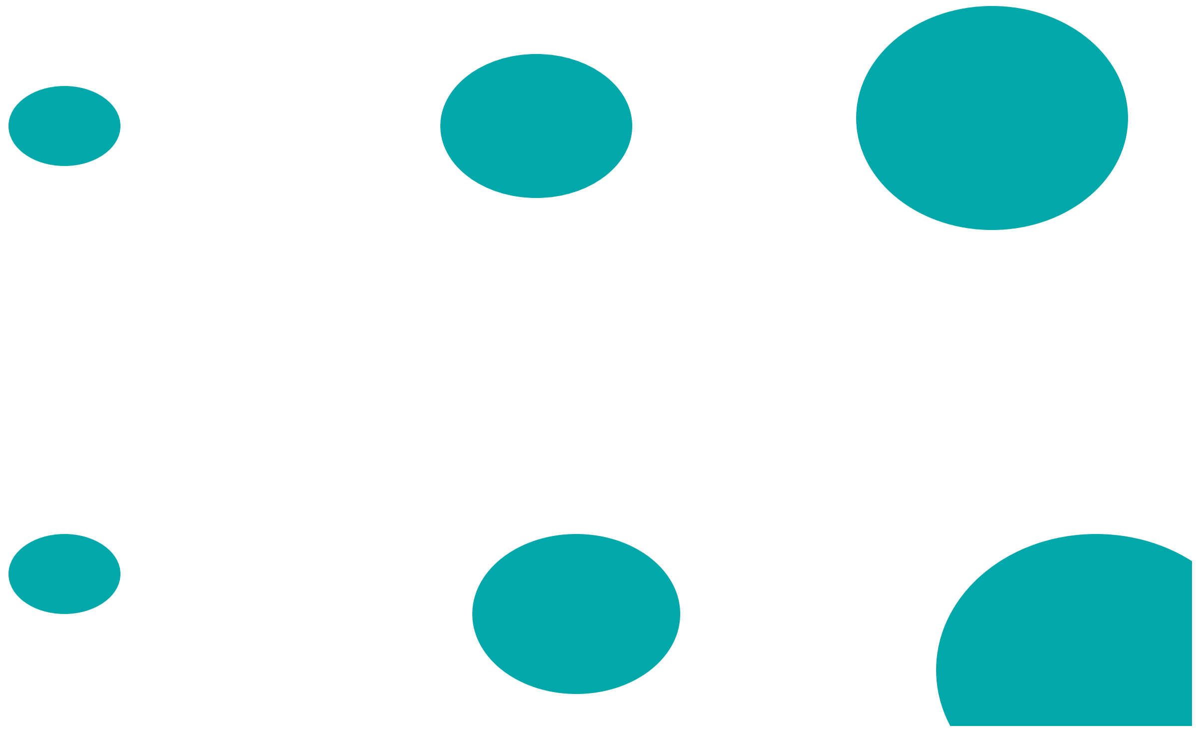
- Panning is linear
- Zooming is logarithmic
- The two effects interact
  - If you compute the two separately and run them in parallel you get problems
  - When zooming in, things go exponentially fast
  - Panning can't keep up
    - The target "runs away" out of view

[Space-Scale Diagrams: Understanding Multiscale Interfaces. George Furnas and Ben Bederson, Proc SIGCHI '95.

How to Pan While Zooming?

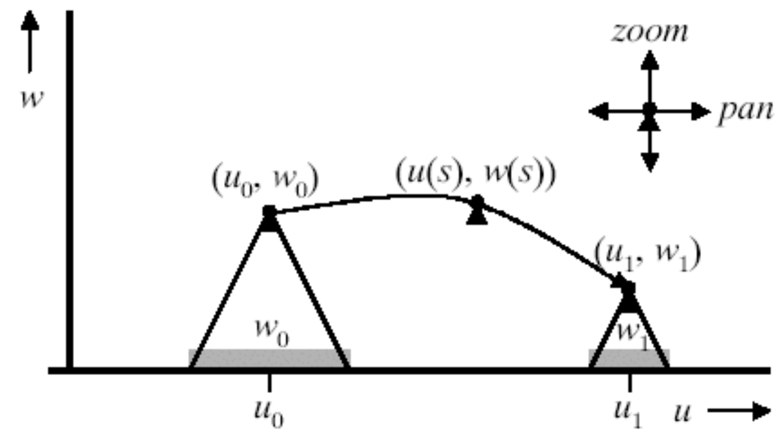


How to Pan While Zooming?



Smooth and Efficient Zooming

- Parametric space,
- u = pan, w = zoom
- Developed algorithm for optimal paths through the space



Smooth and Efficient Zooming and Panning. Jack J. van Wijk and WimA.A. Nuij, Proc. InfoVis 2003, p. 15-22

Pad++

- Infinitely zoomable user interface (ZUI)
- Can get infinitely close to the surface too
- Navigate by panning and zooming
- Pan:
  - move around on the plane
- Zoom:
  - move closer to and farther
  from the plane
  - http://hcil.cs.umd.edu/video/1998/1998_pad.mpg

[Pad++: A Zooming Graphical Interface for Exploring Alternate Interface Physics. Bederson and Hollan, Proc UIST 94]

Zoomable UIs

Panning across objects in two directions. | **Zooming out for an overview.** | **Zooming in for greater detail.**

Important Concepts

- Portals
- Lenses
- Sticky objects
- Semantic zooming

Portals

- Views onto another place in the world
- Implemented typically as separate rectangular region
- Zooming, panning, I/O all work independently in there
- Can be used to create overviews or focus regions

Lenses

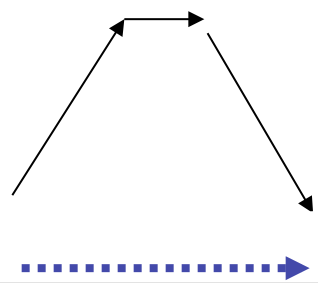
- Rectangular regions/objects that can be moved around on display
- Objects that alter the appearance and behavior of objects seen through them

Sticky Objects

- Objects in the world that do not respond to the basic zoom/pan interface physics
- Objects are “stuck” to the display
  - They never change position
  - They never change size

Navigation in Pad++

- How to keep from getting lost?
  - Animate the traversal from one object to another using “hyperlinks”
    - If the target is more than one screen away, zoom out, pan over, and zoom back in
  - Goal: help viewer maintain context



The Role of Portals

- All this panning and zooming can get confusing (maybe even dizzying)
- Portals allow for zooming a small piece of the dataset while keeping everything else in the same position
  - Pad++ is one big stretchy sheet
  - A portal is more like a special window into a piece of the sheet
  - That window behaves independently of the rest

Standard vs. Semantic Zooming

- Geometric (standard) zooming:
  - The view depends on the physical properties of what is being viewed

- Semantic Zooming:
  - When zooming away, instead of seeing a scaled-down version of an object, see a different representation
  - The representation shown depends on the meaning to be imparted.

Semantic Zooming

- Zooming that is not simply a change in size or scale like simple magnification
- Objects change fundamental appearance/presence at different zoom levels
- Zooming is like step function with boundaries where a semantic transition takes place

Concept of Semantic Zoom

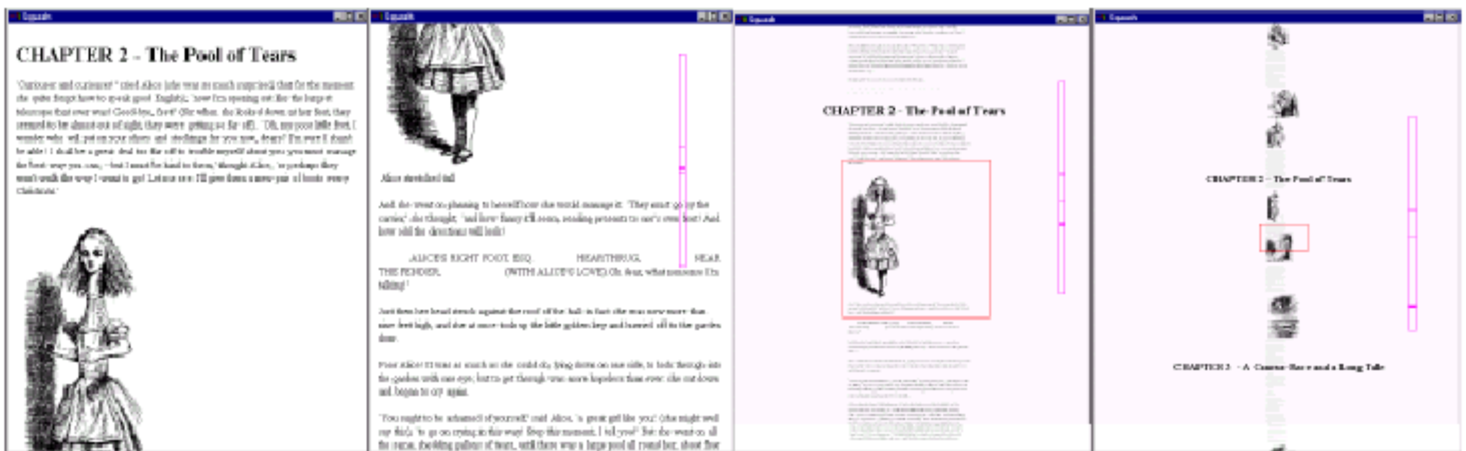
- Infinitely scalable painting program
  - close in, see flecks of paint
  - farther away, see paint strokes
  - farther still, see the holistic impression of the painting
  - farther still, see the artist sitting at the easel

Examples of Semantic Zoom

- Information Maps
  - zoom into restaurant
    - see the interior
    - see what is served there
  - maybe zoom based on price instead!
    - see expensive restaurants first
    - keep zooming till you get to your price range

- Browsing an information service
  - Charge user successively higher rates for successively more detailed information

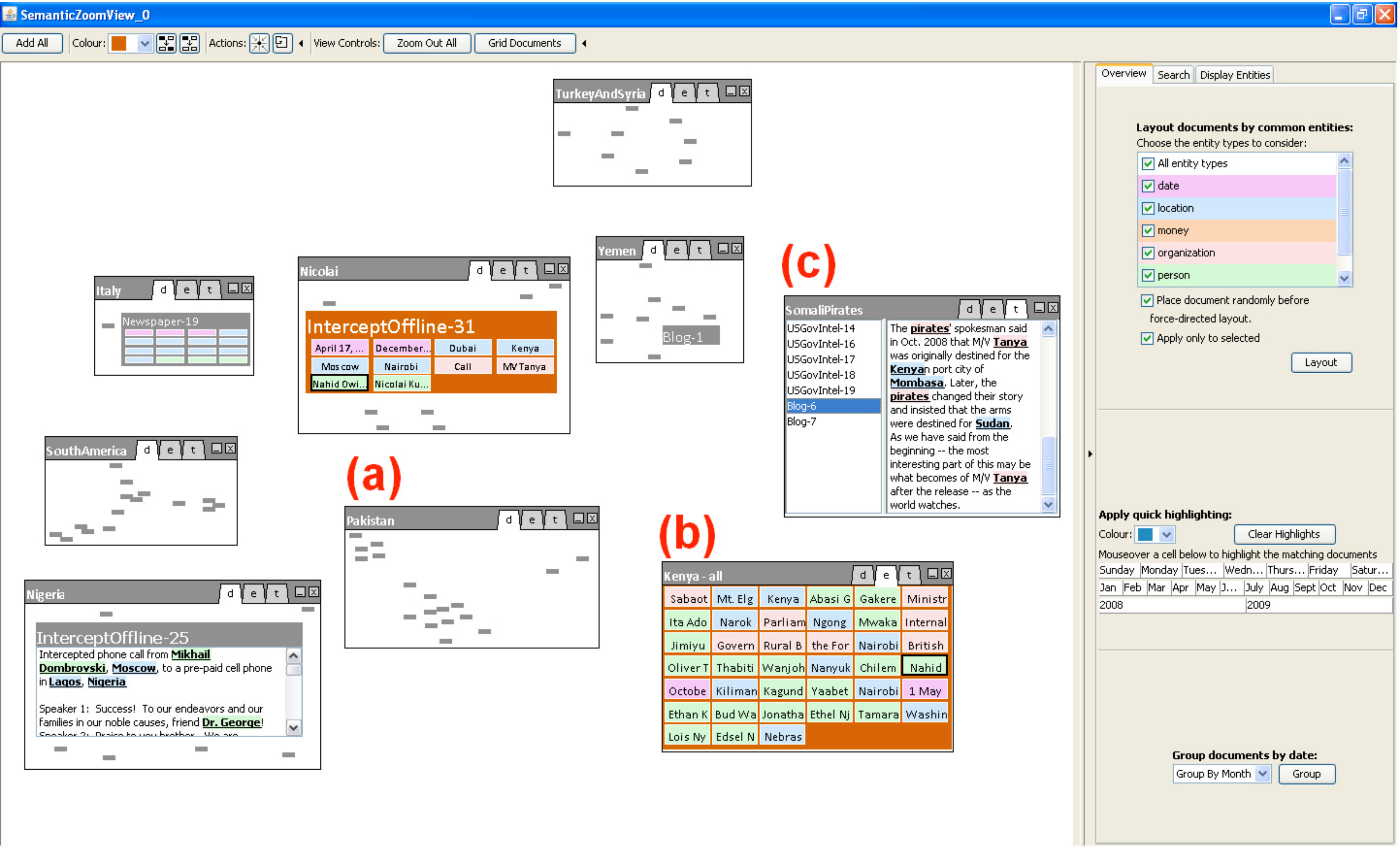
Speed-dependent Zooming
by Igarashi & Hinkley 2000



a) Static view b) Scrolling slowly c) Scrolling fast d) Scrolling very fast

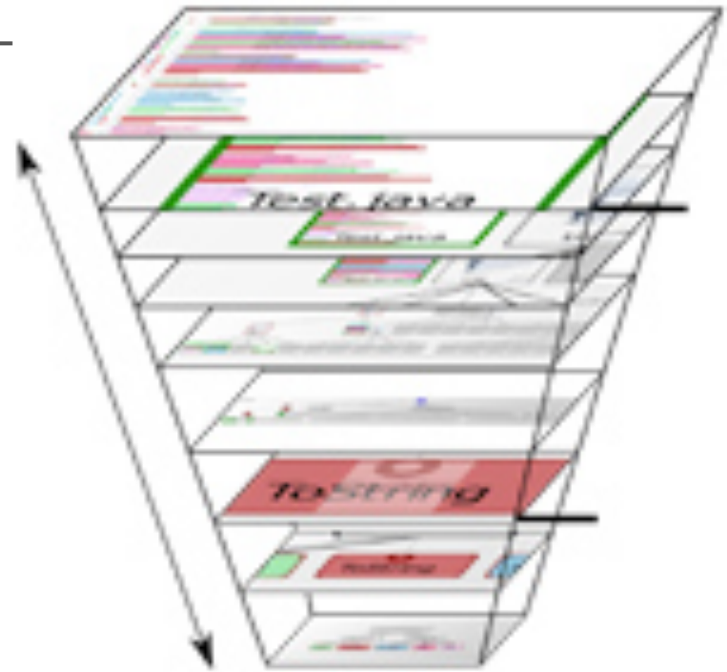
http://www-ui.is.s.u-tokyo.ac.jp/~takeo/video/autozoom.mov
http://www-ui.is.s.u-tokyo.ac.jp/~takeo/java/autozoom/autozoom.htm

CZSaw


SemanticZoomView_0
Add All
Colour:
Actions:
View Controls:
Zoom Out All
Grid Documents
TurkeyAndSyria
Italy
Newspaper-19
Nicolai
InterceptOffline-31
April 17, ...
December...
Dubai
Kenya
Moscow
Nairobi
Call
MV Tanya
Nahid Owi...
Nicolai Ku...
Yemen
Blog-1
(c)
SomaliPirates
USGovIntel-14
USGovIntel-16
USGovIntel-17
USGovIntel-18
USGovIntel-19
Blog-6
Blog-7
The pirates' spokesman said in Oct. 2008 that M/V Tanya was originally destined for the Kenyan port city of Mombasa. Later, the pirates changed their story and insisted that the arms were destined for Sudan. As we have said from the beginning -- the most interesting part of this may be what becomes of M/V Tanya after the release -- as the world watches.
SouthAmerica
(a)
Pakistan
(b)
Kenya - all
Sabaot
Mt. Elg
Kenya
Abasi G
Gakere
Ministr
Ita Ado
Narok
Parliam
Ngong
Mwaka
Internal
Jimiyu
Govern
Rural B
the For
Nairobi
British
Oliver T
Thabiti
Wanjoh
Nanyuk
Chilem
Nahid
Octobe
Kiliman
Kagund
Yaabet
Nairobi
1 May
Ethan K
Bud Wa
Jonatha
Ethel Nj
Tamara
Washin
Lois Ny
Edsel N
Nebras
Nigeria
InterceptOffline-25
Intercepted phone call from Mikhail Dombrovski, Moscow, to a pre-paid cell phone in Lagos, Nigeria
Speaker 1: Success! To our endeavors and our families in our noble causes, friend Dr. George!
Overview
Search
Display Entities
Layout documents by common entities:
Choose the entity types to consider:
All entity types
date
location
money
organization
person
Place document randomly before force-directed layout.
Apply only to selected
Layout
Apply quick highlighting:
Colour:
Clear Highlights
Mouseover a cell below to highlight the matching documents
Sunday
Monday
Tues...
Wedn...
Thurs...
Friday
Satur...
Jan
Feb
Mar
Apr
May
J...
July
Aug
Sept
Oct
Nov
Dec
2008
2009
Group documents by date:
Group By Month
Group

View Infinity

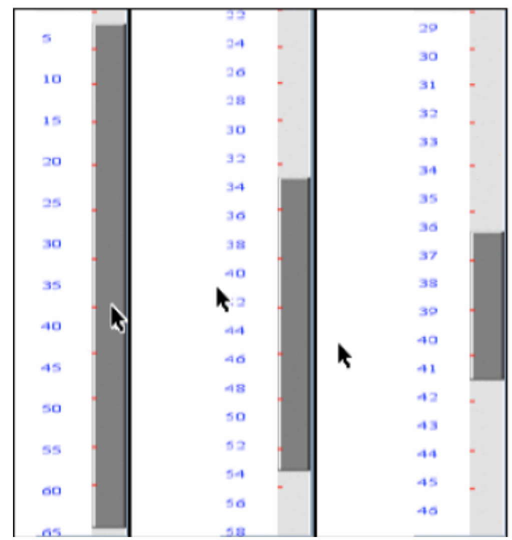
Model-based discrete semantic zoom



[*View Infinity: A Zoomable Interface for Feature-Oriented Software Development*]()

OrthoZoom: 1D Multiscale Navigation

- Control area itself larger than representation allows
- Zoom factor is orthogonal cursor-slider distance



- Pan with slider
- Zoom with horizontal movement
- Improves target finding in very large 1D spaces
- Uses levels of data structure to determine “snappable” points
- Demo

OrthoZoom Scroller: 1D Multi-Scale Navigation. Catherine Appert and Jean-Daniel Fekete. Proc. SIGCHI 06, pp 21-30.]

Panning and Zooming

- Is it actually useful?
  - Is it better to facet into multiple juxtaposed views?
- Would keeping a separate global overview help with navigation?
  - The research literature suggests overview+detail is usually better than pan & zoom.
- Navigation alone can't maintain overview
  - Have to hold overview in working memory

Overviews

- Helps present overall patterns
- Assists user with navigation and search
- Orients activities

- Strategies: filter and aggregate
  - Simple: geometric zoom out
  - Complex: aggregation
- Methods
  - Temporal (navigation)
  - Separate views
  - Embedded: focus + context

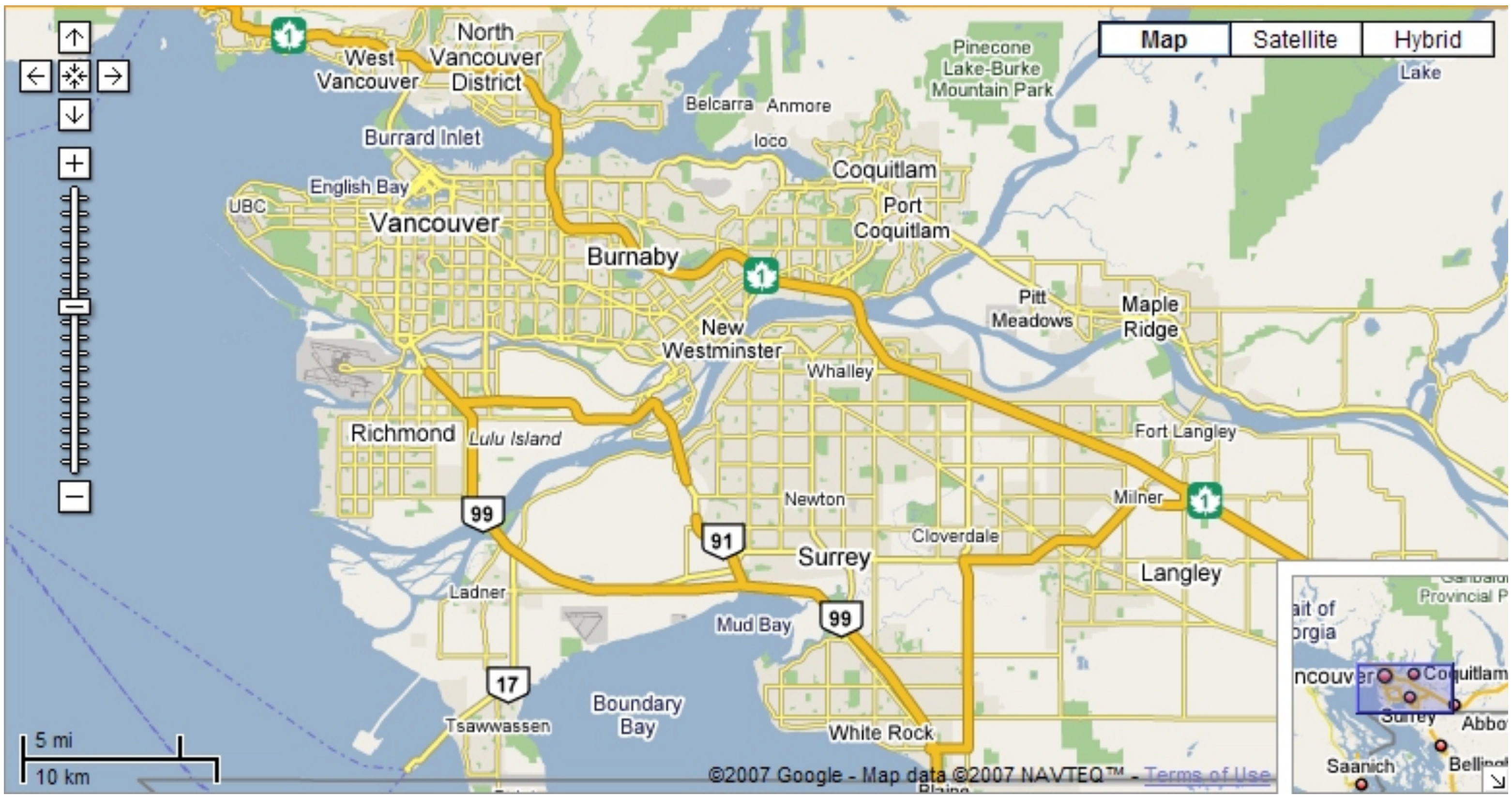
Overview + Detail

- Overview + Detail displays can be combined via either time or space
  - Time - Alternate between overview and details sequentially in same place
  - Space - Use different portions of screen to show overview and details
- Big question in Vis:
  - Develop visualization and interface techniques to allow flexible alternation

Objective

- Allow viewer to examine cases and/or variables in detail while still maintaining context of those details in the larger whole
- Concession
  - You simply can't show everything at once
- Be flexible, facilitate a variety of user tasks
- **Visualization + Navigation**

You are here



Map
Satellite
Hybrid
North Vancouver District
West Vancouver
Burrard Inlet
English Bay
UBC
Vancouver
Burnaby
Belcarra
Anmore
Ioco
Pinecone Lake-Burke Mountain Park
Lake
Coquitlam
Port Coquitlam
Pitt Meadows
Maple Ridge
New Westminster
Whalley
Richmond
Lulu Island
Fort Langley
Milner
Newton
Cloverdale
Surrey
Langley
Ladner
Mud Bay
Tsawwassen
Boundary Bay
White Rock
5 mi
10 km
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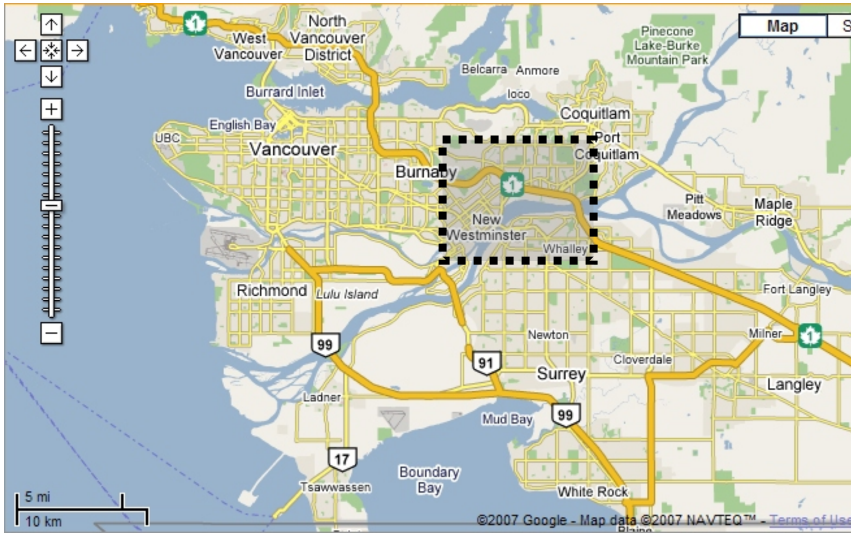
Provincial P
Saanich

Managing detail

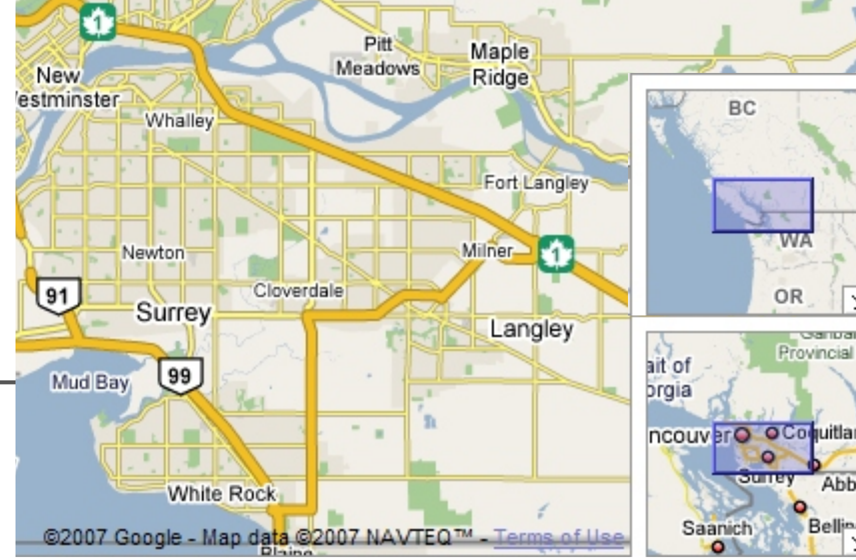
- Single window with horizontal and vertical panning
  - Works only when image/space is not too much larger than the window

Single Window

- Single view with Selectable Zoom area
  - Selected zone is new view
  - Magnification and adjustment can follow
  - Context switch disorienting

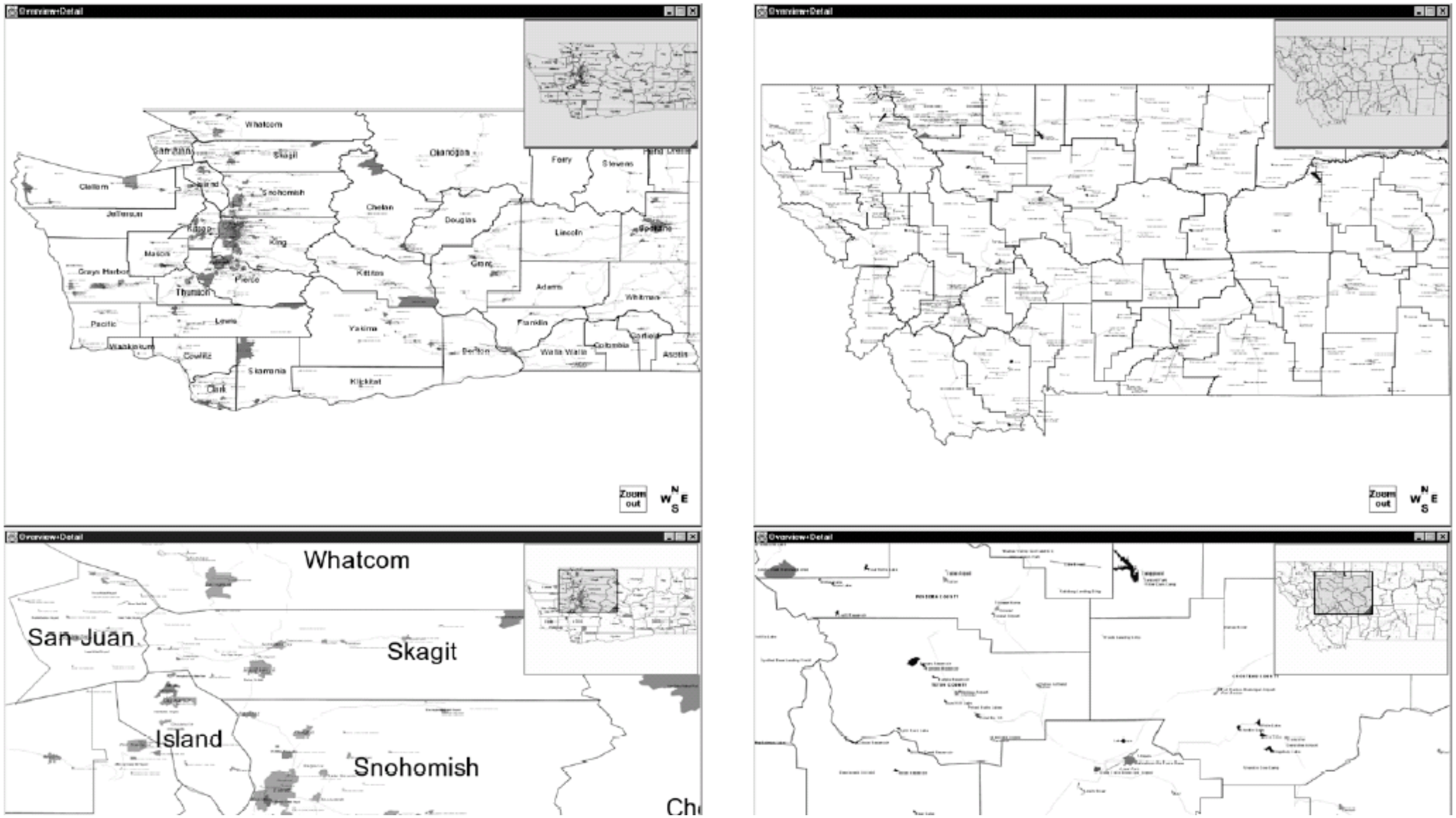


Single Window



- Main + mini-map
- Sometimes the *Overview* gets the most space
  - Depends on the user's familiarity with the object of interest
  - Panning in one affects the other
- Could be extended to 3 or more levels
- Issue: How big are different views and where do they go?

Overview + Detail



K. Hornbaek et al., Navigation patterns and Usability of Zoomable User Interfaces with and without an Overview, ACM TOCHI, 9(4), December 2002

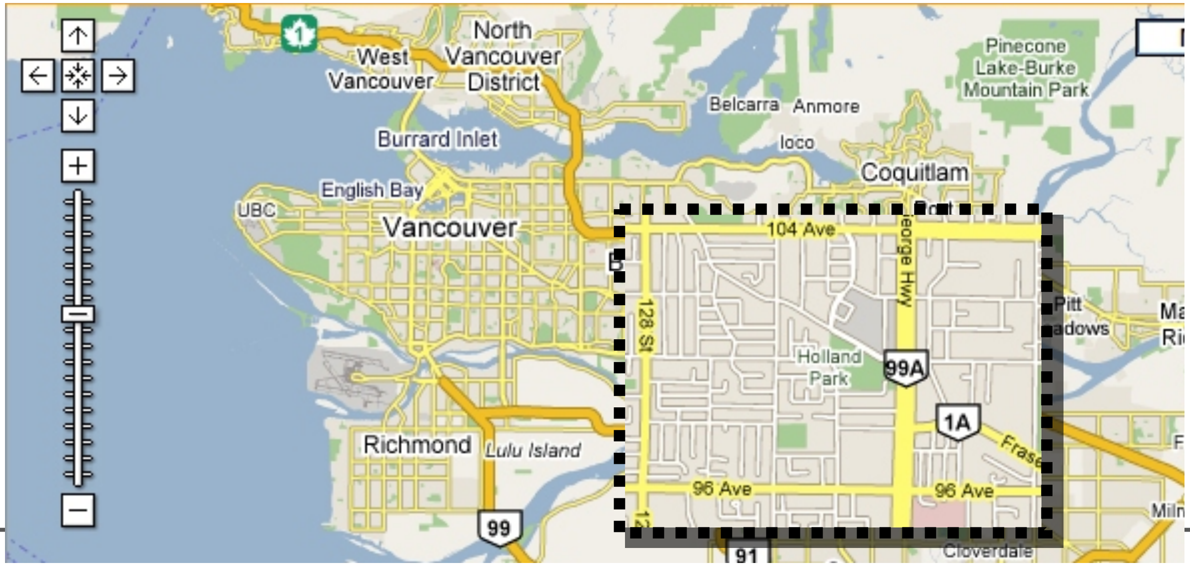
Overview + Detail

- A study on integrating Overview + Detail on a Map search task
  - Incorporating panning & zooming as well.
  - They note that panning & zooming does not do well in most studies.
- Results seem to be
  - Subjectively, users prefer to have a linked overview
  - But they aren't necessarily faster or more effective using it
  - Well-constructed representation of the underlying data may be more important.
- More research needed as each study seems to turn up different results, sensitive to underlying test set.

K. Hornbaek et al., Navigation patterns and Usability of Zoomable User Interfaces with and without an Overview, ACM TOCHI, 9(4), December 2002

Lens Technique

- Enlarged image floats over the overview
- Neighbor objects obscured by the detail view



Overviews

- How to deal with approximate view?
- Reduce the data elements
  - Eliminate
  - Sample
  - Aggregate

- Reduce the visual representation
  - Need to render to sub-pixel resolution
  - Accumulate visual contributions per pixel

Focus + Context

- **Focus + Context** is an InfoVis term:
  - Present the Detail and the overview in the same window
- Integrate detailed view (focus) in the larger space (overview)
- Maintain continuity

Focus

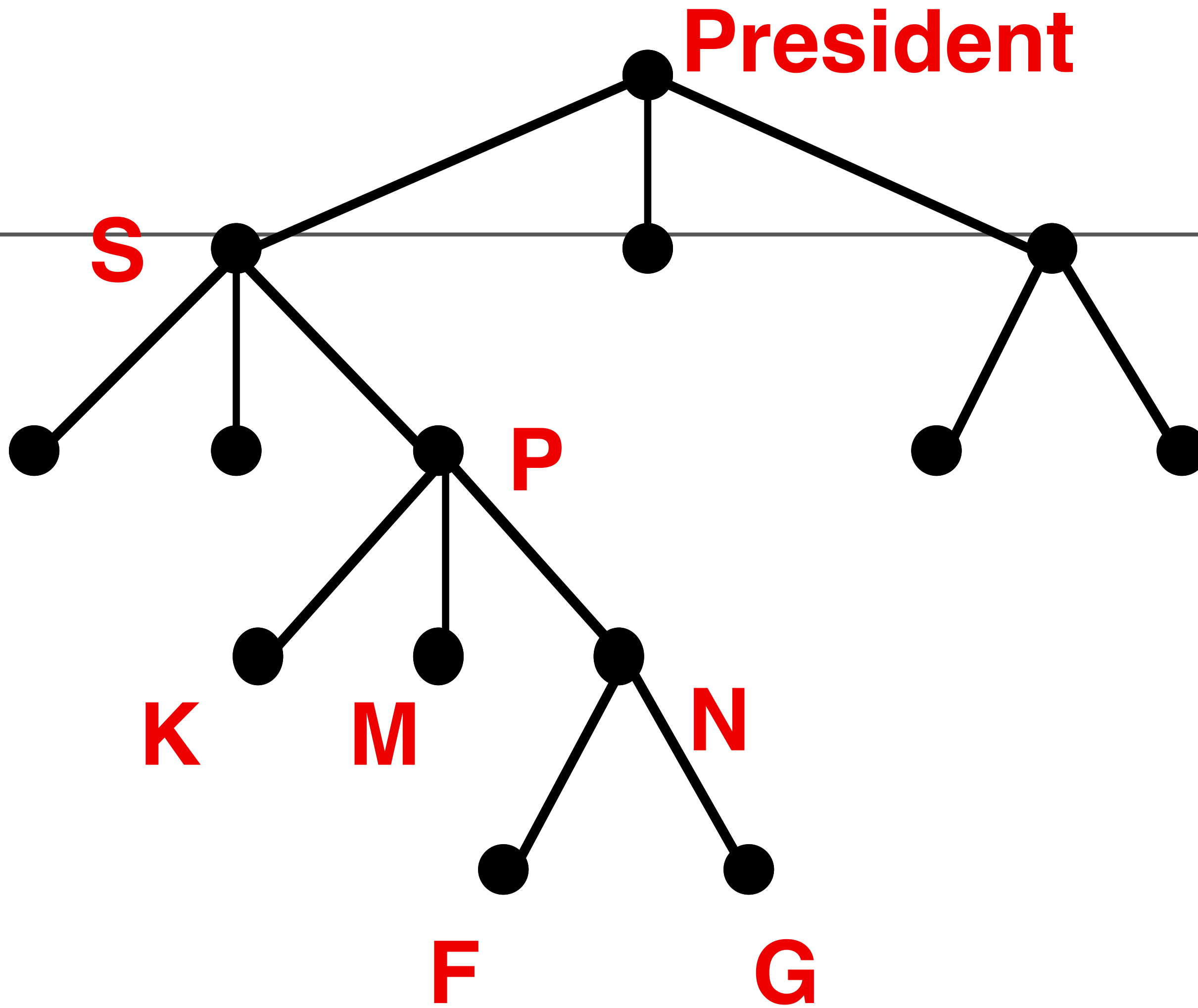


Figure 4.21 The organisation tree of a company

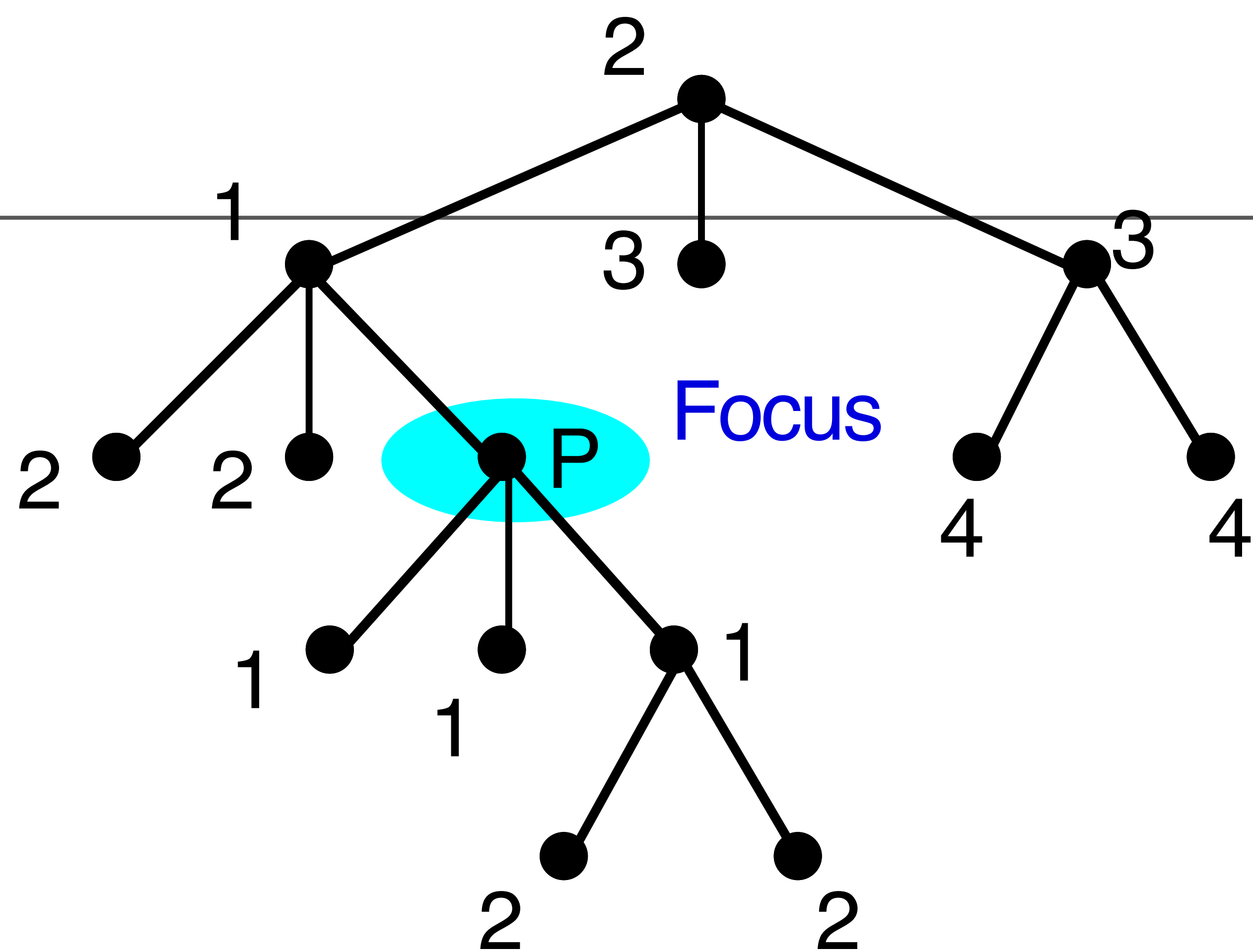


Figure 4.22 Showing the 'distance' of each node from the focus of attention

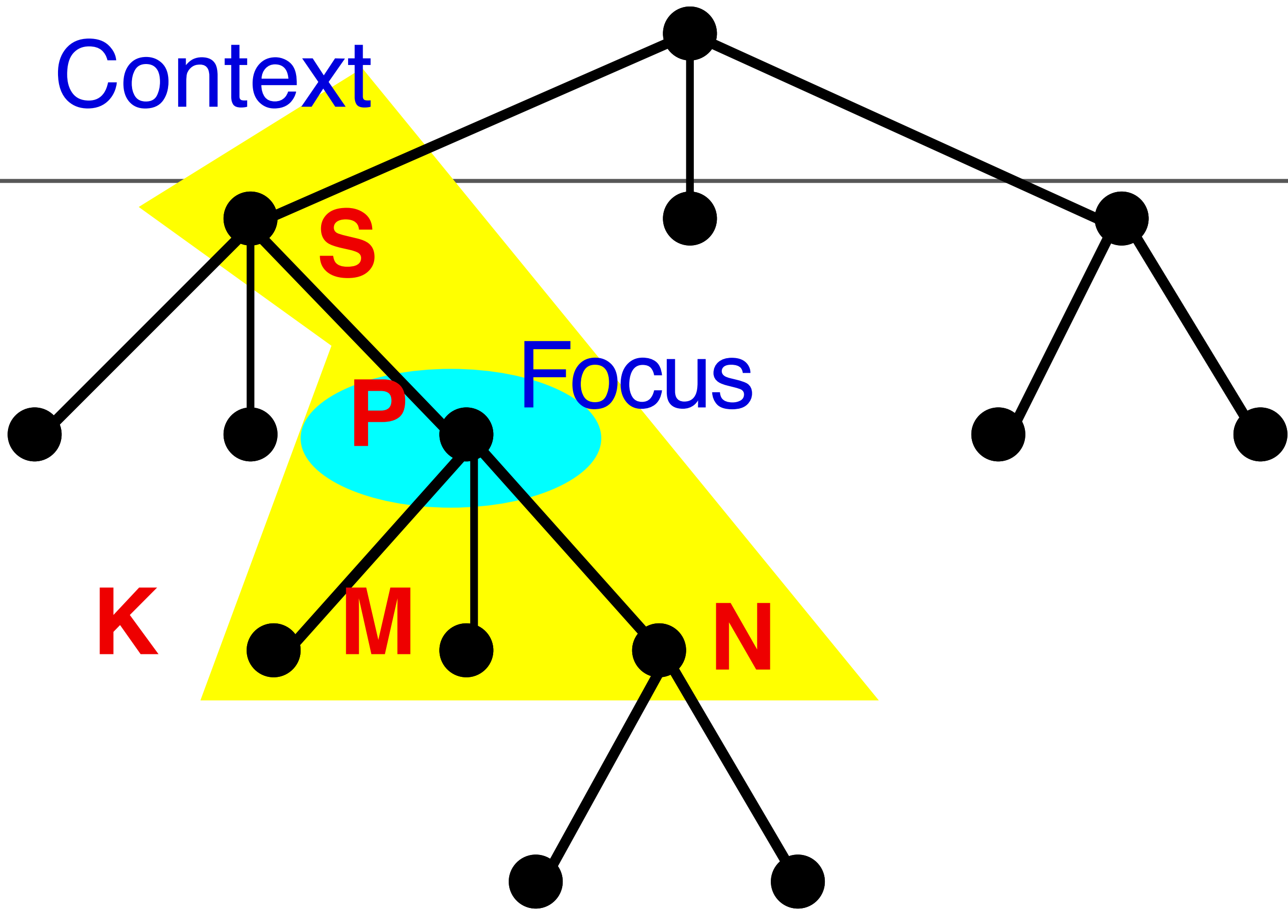


Figure 4.23 The context defined by setting an upper threshold of unity for distance from a focus

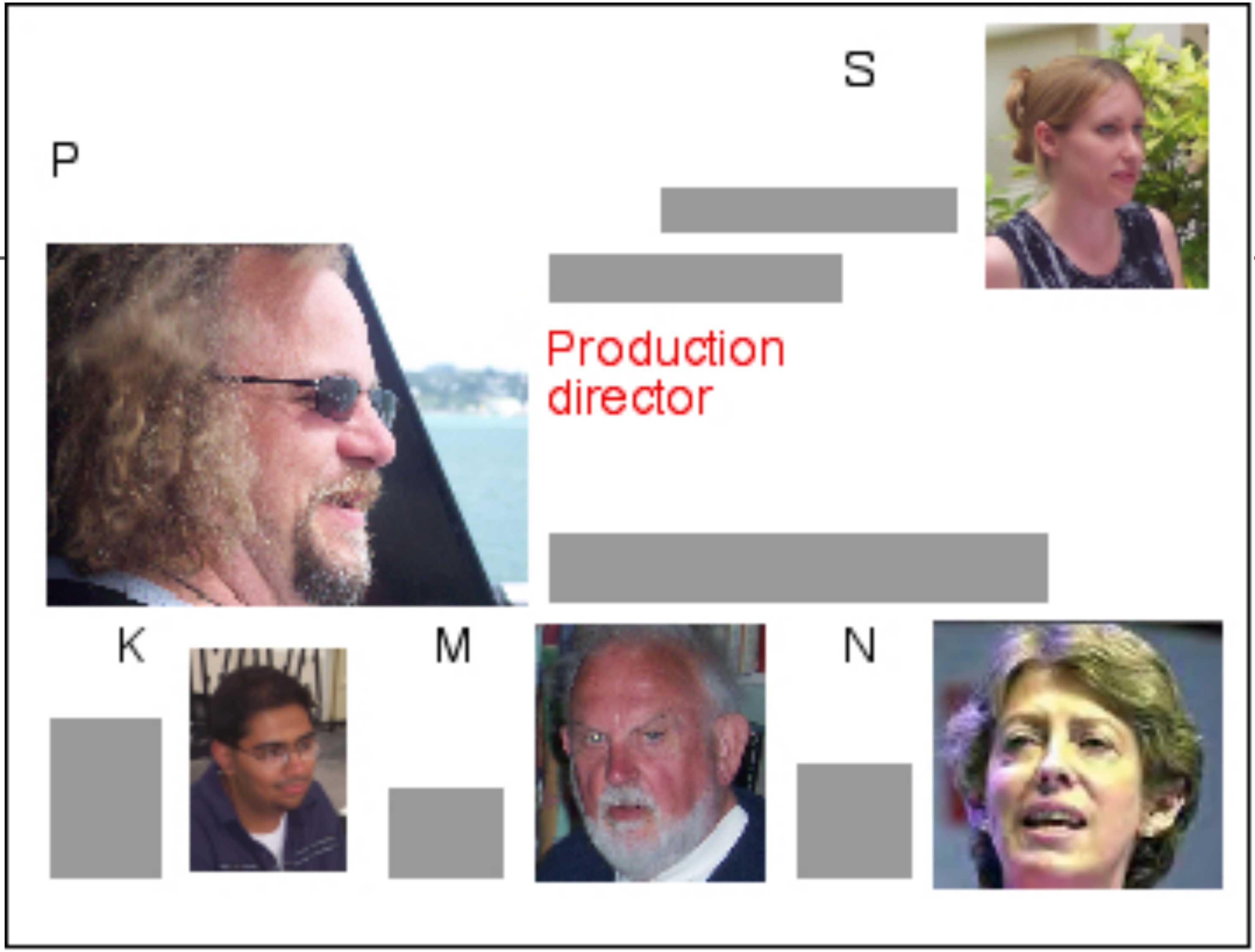


Figure 4.24 Example of a display that might be associated with the focus and context defined in Figure 4.23

SFU

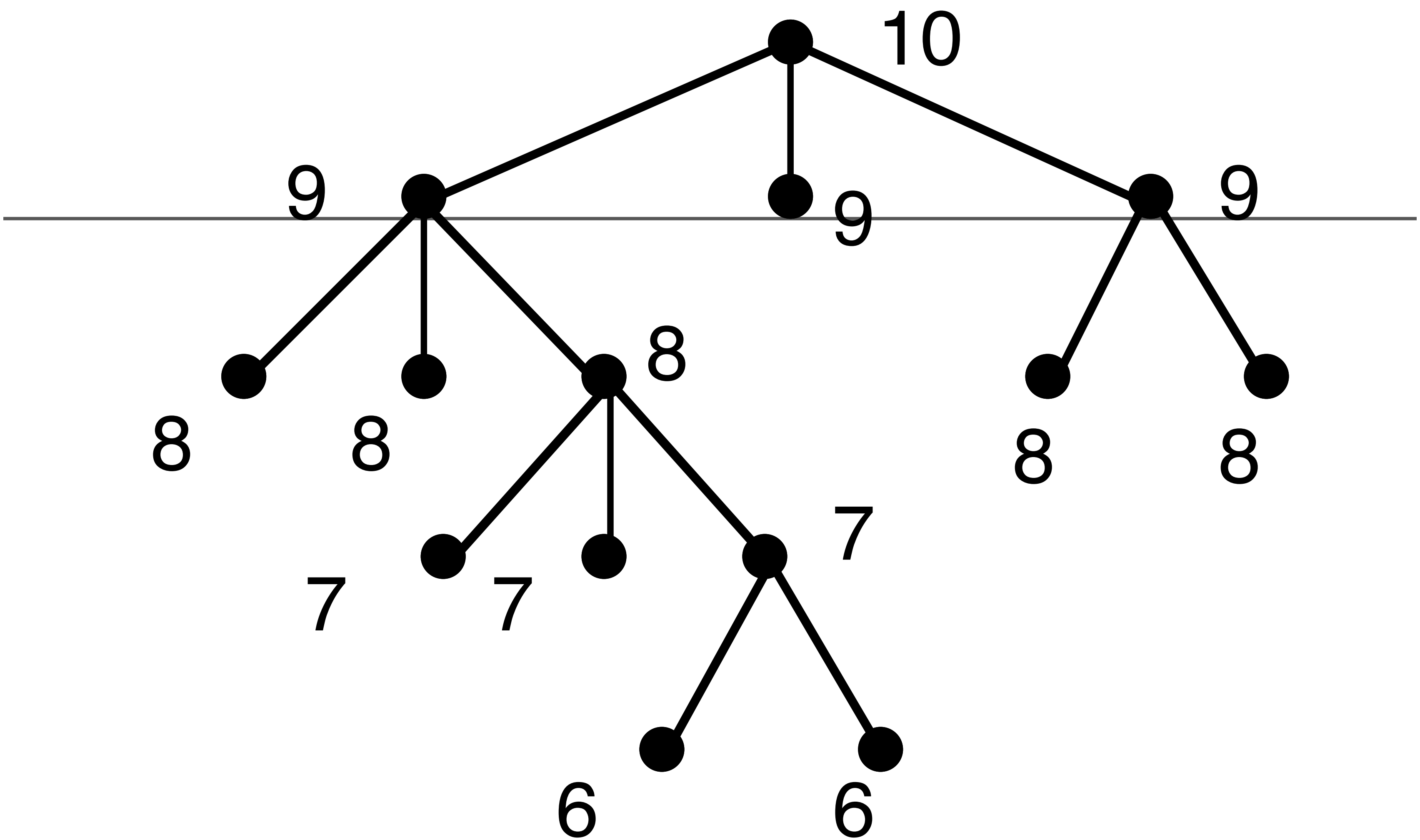


Figure 4.25 Each node in the organisation tree has been assigned an *a priori* importance (API)

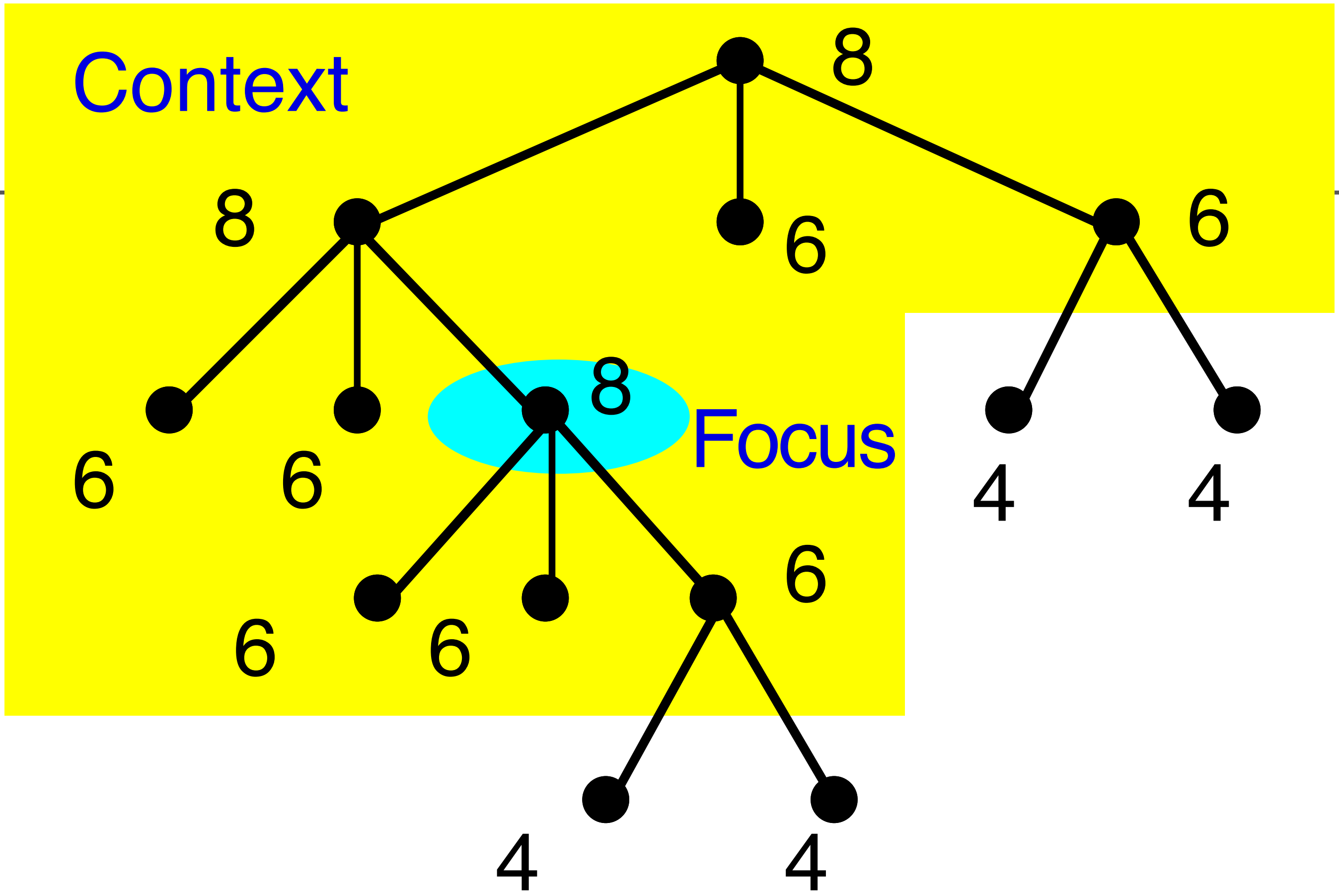


Figure 4.26 Nodal values of degree of interest (=API – D). Setting a lower limit of 6 for DoI identifies the nodes within the shaded region

Focus + Context Methods

- Selective Filtering /aggregation (elision)
- Geometric distortion
- Degree of interest (DOI)
- Benefits and costs

Degree of Interest (DOI)

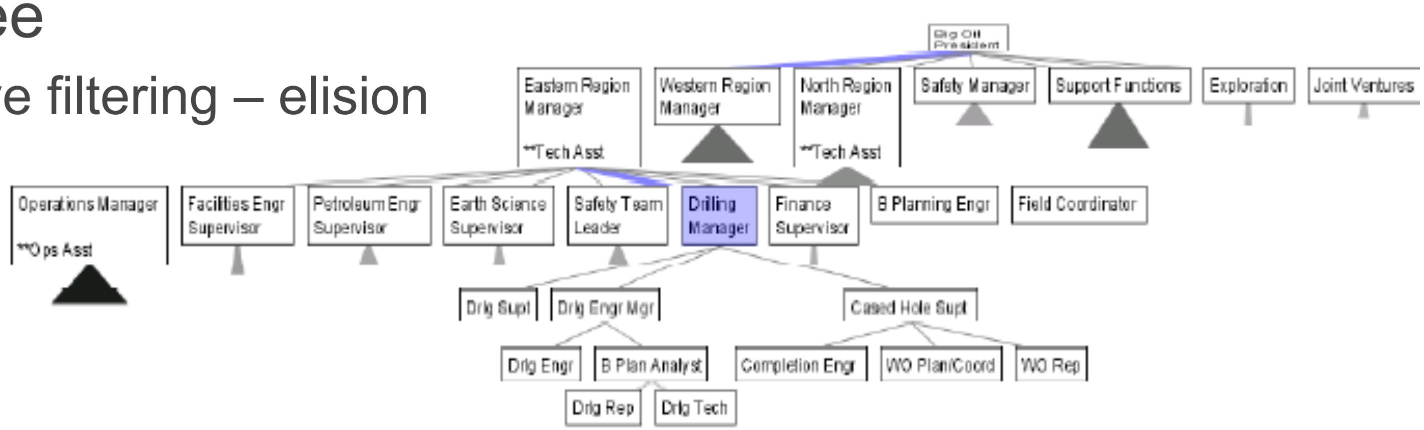
- Degree of interest used to apply view distortions I(x) → D(x,y)
  - I : interest
  - D: distance (semantic or spatial)
  - x: data element
  - y : current focus

- DOI for selective presentation vs for distortion
- Identified by explicit selection or inferred by interaction
- Single vs multiple foci

[A Review and Taxonomy of Distortion-Oriented Presentation Techniques. Leung andApperley, ACM ToCHI 1(2): 126-160, Jun 1994.]

Focus+Context: Filtering/aggregation

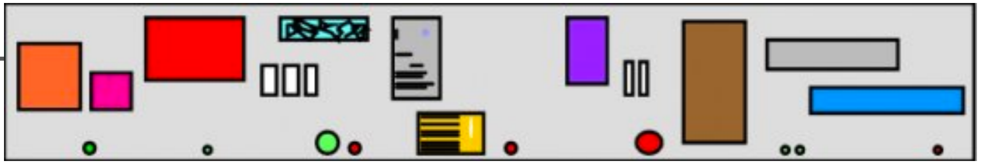
- SpaceTree
  - Selective filtering – elision



  - Semantic zooming / aggregation

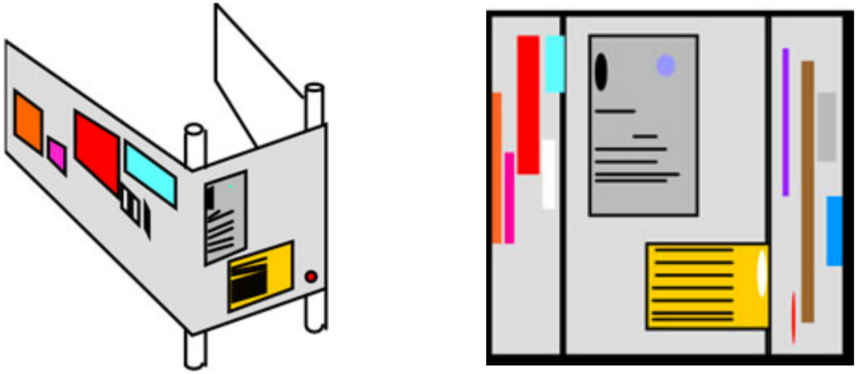
Focus + Context: 3D surfaces

- Bifocal display



An information space containing documents, email, etc

- “Wraps” view onto a 3D surface then flattens perspective view onto 2D plane

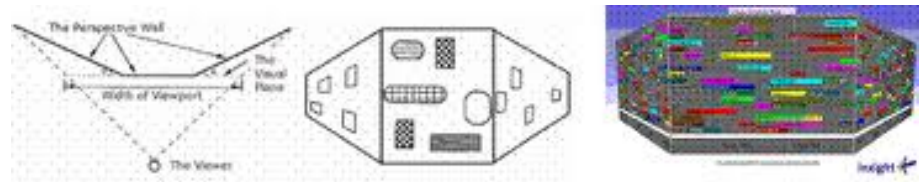


The same space wrapped around two uprights (left); Appearance of the information space when viewed from an appropriate direction (right)

Spence, Robert and Apperley, Mark (2013): Bifocal Display. In: Soegaard, Mads and Dam, Rikke Friis (eds.). "The Encyclopedia of Human-Computer Interaction, 2nd Ed.

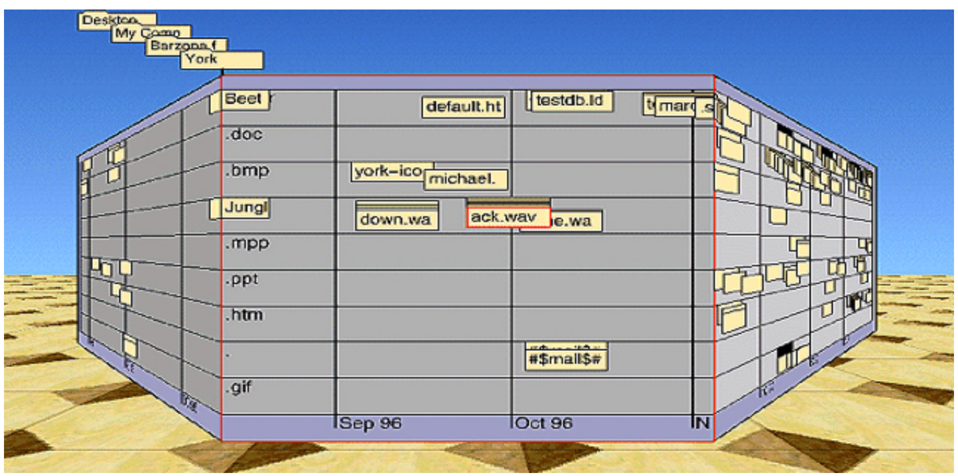
Focus+Context: 3D wrapping

- Moves focus point closer in depth to eye
- Perspective Wall

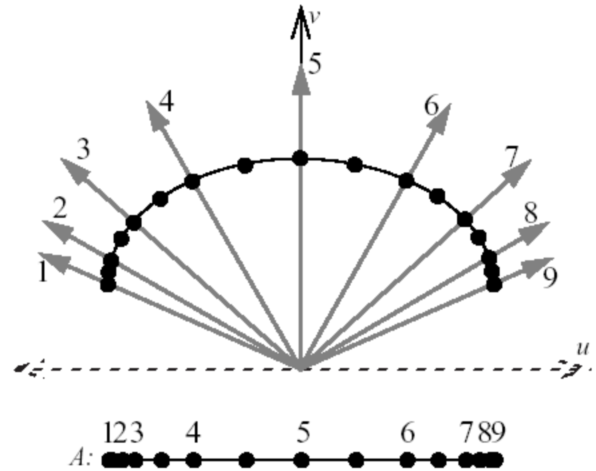


(a) Birds-eye view (b) Head-on view. (c) The running system.

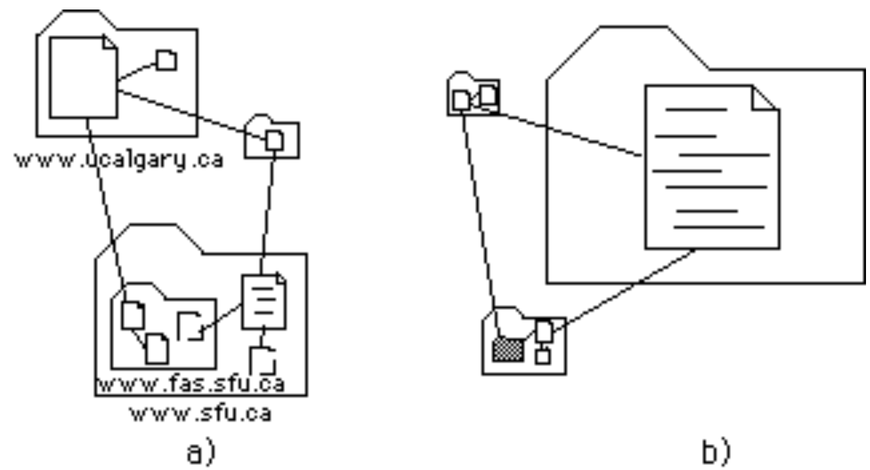
Figure 5. The Perspective Wall (Mackinlay et al. 1991).



F+C Distortion: Fisheye

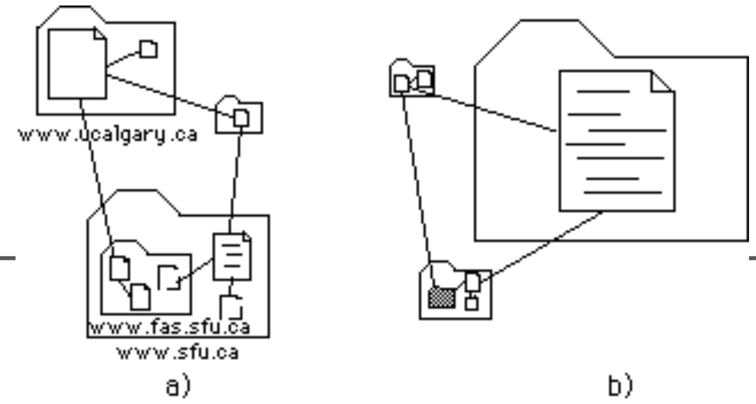


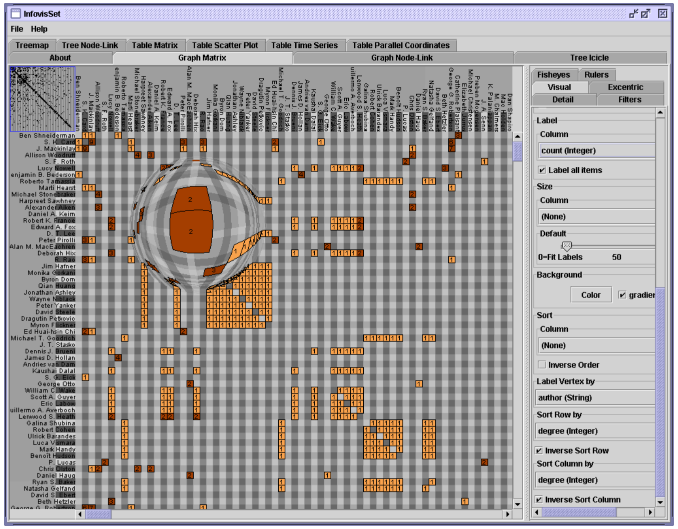
- Magnify an area of interest without obscuring its neighboring unmagnified imagery
- Low-level details elided
- Invented by Furnas, 1991



Fisheye Terminology

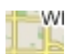
- Focal point
- Distance from focus
- Level of detail
- Degree of interest function (DOI)

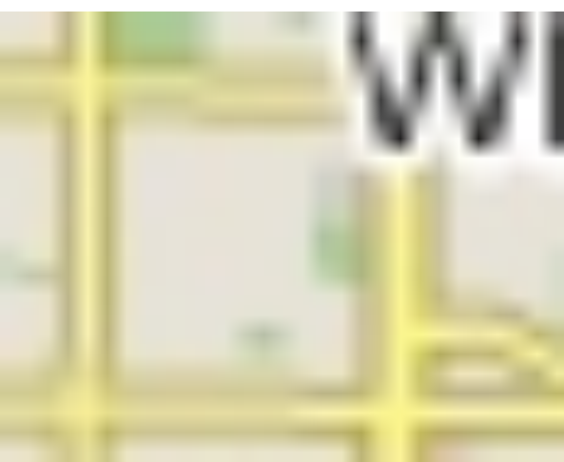




Level of Detail

- A number determines the quantity of visual info you are going to draw for one data element
- In maps: The quantity of imagery that fits in X pixels



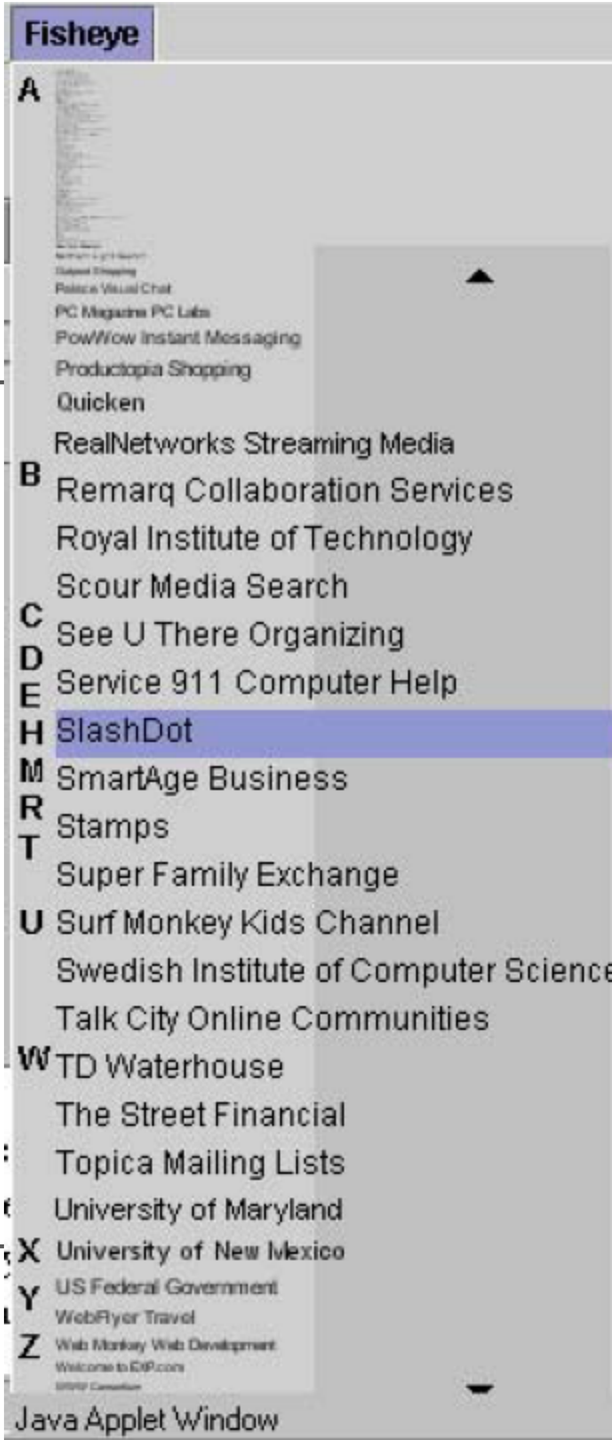




DoI Function

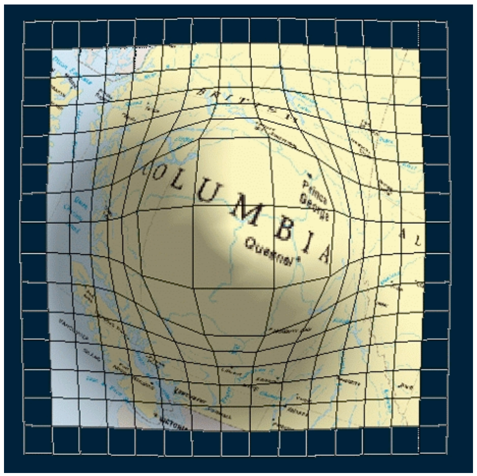
- Can take on various forms
  - Continuous - Smooth interpolation away from focus
  - Filtering - Past a certain point, objects disappear
  - Step - Levels or regions dictating rendering $0<x<.3$ all same, $.3<x<.6$ all same
  - Semantic changes - Objects change rendering at different levels

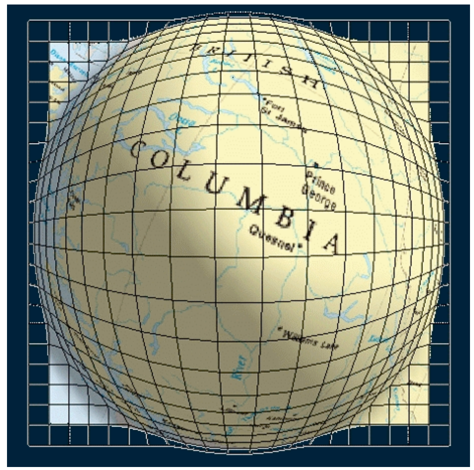
Examples: 1D

- Fisheye Menus – Bederson
  - Dynamically change size of menu item & provide focus area around the pointer
  - Items near cursor displayed at full size
  - Items further away on either side are smaller
  - Uses a distortion function so items will always fill menu
  - Efficient mechanism for long menus
  - Need to “Lock Focus” to hit nearby targets (on right)



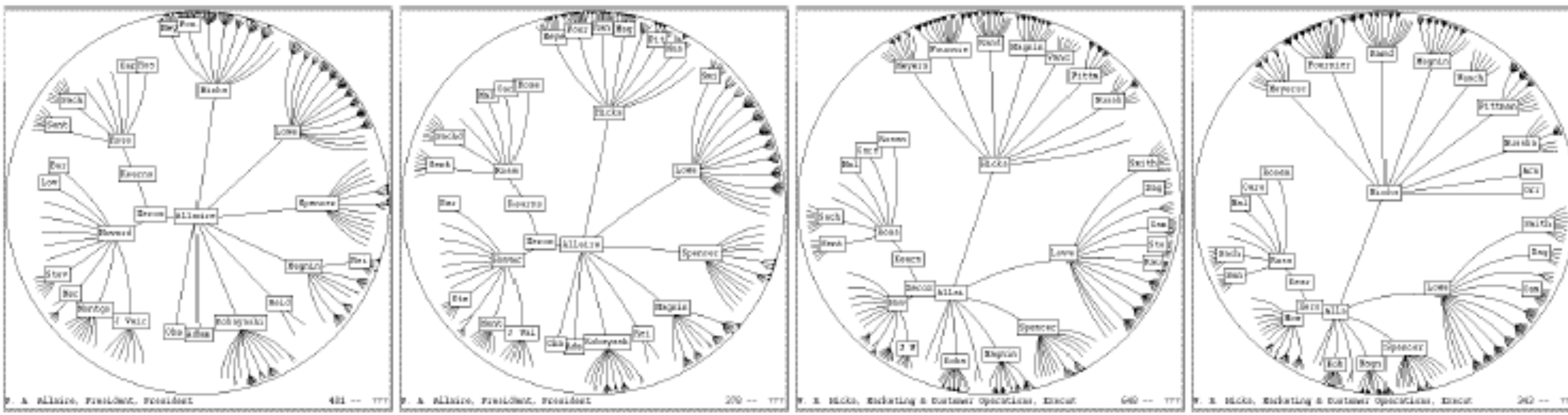
Elastic Presentation Space





2D Hyperbolic Trees

- Fisheye effect from hyperbolic geometry



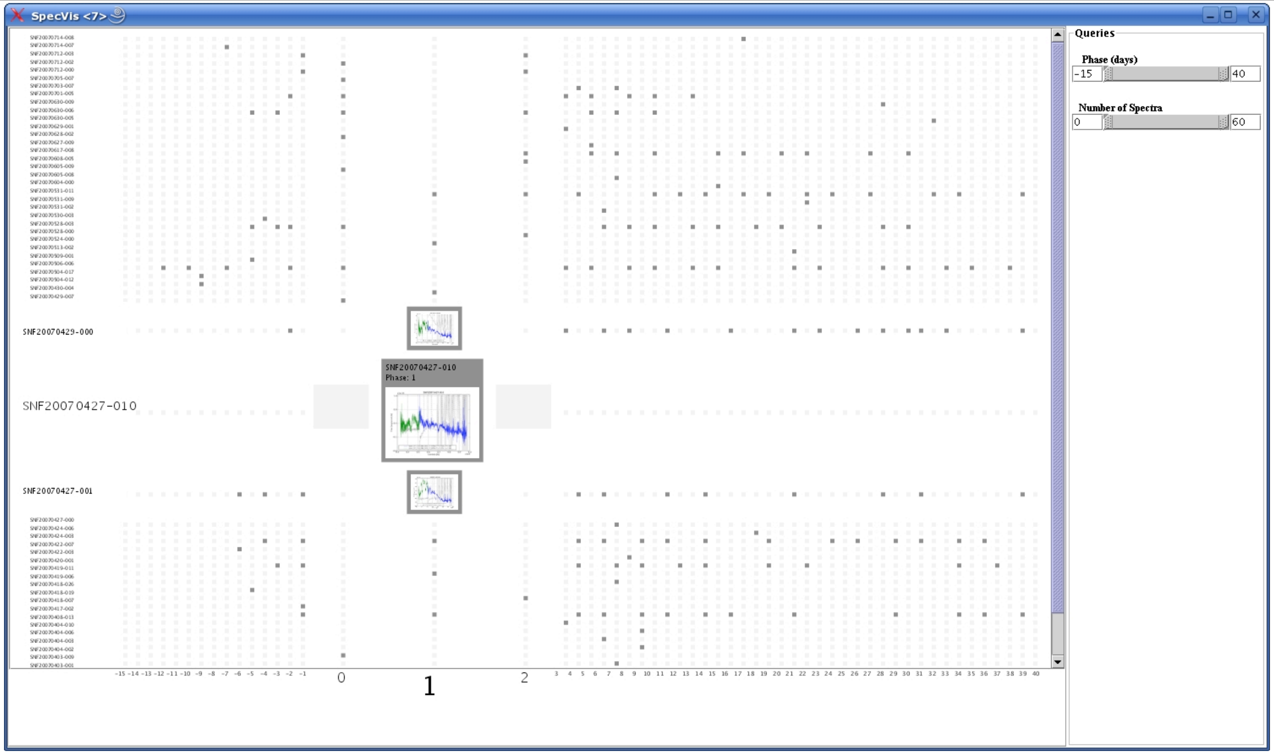
[The Hyperbolic Browser: A Focus + Context Technique for Visualizing LargeHierarchies. John Lamping and Ramana Rao, Proc SIGCHI '95.]

Distortion challenges

- Unsuitable for relative spatial judgments (length, location)
  - Graphs (topology) least problematic?
- Distortion must be tracked
  - Constrained and predictable
- Visual communication of distortion
  - Grid lines, shading, highlighting
- Target acquisition is more difficult (items move away!)
- Mixed results compared to separate views, temporal navigation
- Fisheye concerns
  - What is shown (selective filtering, aggregation)
  - How it is shown (distortion one strategy for spatial representation)

[A review of overview+detail, zooming, and focus+context interfaces. Cockburn,Karlson, and Bederson. ACM Computing Surveys 41(1), 2008.

Semantic fisheye



[SpectraVis: Information Visualization for Supernova Spectra](#)