Interactive Visualization

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I247

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Acknowledgments

- Thanks to slides and publications by Marti Hearst, Tamara Munzner, Colin Ware, Ben Shneiderman, George Furnas and Ben Bederson.

Today

- Interactive visualization
- Basic interaction processes
- Infovis data type and task taxonomy (Shneiderman, 96)
- Space-scale diagrams (Furnas & Bederson, 95)

Interaction

- Distinguishes infovis from static paper visualizations.
- Analysis is a process, often iterative, with branches and sideways paths.

Interactive Visualization

- Three classes of interlocking feedback loops: (from low-level to high-level)
  – Data manipulation loop
    - Basic hand-eye coordination skills
  – Exploration and navigation loop
    - Navigating in large visual data space
  – Problem-solving loop
    - Form hypotheses about data and refine them

Data Selection and Manipulation

- Reaction time
  - Person in optimal state of readiness (finger over button)
    - Can react to visual signal in about 130 msec (Kohlberg, 1971)
  - But if signals are infrequent, reaction time increases
    - As much as 700 msec (Warrick et al, 1964)

Choice Reaction Time

- Making a choice after reacting
  - E.g. press one button if red light goes on, another if green light goes on
- Reaction times can be modeled by the Hick-Hyman law (Hyman, 1953)

$$Reaction\ time = a + b \log_2 (C)$$

where C is the number of choices and a and b are constants.

  - $\log_2(C)$ can be thought of as the amount of information in bits processed by a human

Choice Reaction Time

- Affected by many factors:
  - Distinctness of signal
  - Amount of visual noise
  - Stimulus-response compatibility
  - Etc.
- Under optimal conditions, response time per bit of information is about 160 msec plus the time to set up the response
  - E.g. with 8 choices (3 bits of info), response time will typically be around 480 msec plus simple reaction time

Choice Reaction Time

- Speed-accuracy tradeoff:
  - People respond faster if they are allowed to make mistakes occasionally
  - See overview by Card et al. (1983)

Acceptable Response Times

- .1 second
  - Animation, visual continuity, sliders
- 1 second
  - System response, pause in conversation
- 10 seconds
  - Cognitive response

Response Times

- Ideally, response times should be as fast as possible
  - However, it's possible to be too fast (e.g. scrolling text that moves past window)
- If immediate response from interface is not possible, provide continuous feedback
  - Via percent-done indicator (Myers 1985)
  - Need percent-done indicators for operations taking more than about 10 seconds
  - Advantages of percent-done indicators:
    - Indicate system has not crashed
    - Let user know how long the wait is (so they can do other things while waiting)
    - Give user something to look at (makes wait less painful)

2D Positioning and Selection

- Fitts' Law (Paul Fitts, 1954)
  - Time required to move to target area is function of distance to and size of target. (originally physical pointing)
  - Selection time using input device (e.g. mouse, joystick, trackball, etc., confirmed in many studies)

$$T = a + b \log_2 (D/W + 1)$$

where:

D = distance to center of target

W = width of target

$\log_2 (D/W + 1)$ is called the *index of difficulty*

$1/b$ is the *index of performance* (in bits per second)

a = start/stop time of device

b = inherent speed of device

The Effect of Lag

- Fitts' law can be modified to include lag:

$$Time =$$

$$a + b\,(HumanTime + MachineLag)\log_2(D/W + 1)$$

where:

D = distance to center of target

W = width of target

Shneiderman's Taxonomy of Information Visualization Data Types

• **1-D Linear**	text documents, program source code
• **2-D Map**	GIS, medical imagery, maps, floorplans
• **3-D World**	CAD, medical, molecules, architecture
• **Multi-Dim**	relational DBs with items with n attributes (points in n-dimensional space)
• **Temporal**	timelines, items have start and finish
• **Tree**	hierarchies or tree structures
• **Network**	items linked to an arbitrary number of other items

Adapted from Shneiderman 96

Shneiderman's Taxonomy of Information Visualization Tasks

- Overview: see overall patterns, trends
- Zoom: see a smaller subset of the data
- Filter: see a subset based on values, etc.
- Details on demand: see values of objects when interactively selected
- Relate: see relationships, compare values
- History: keep track of actions and insights
- Extract: mark and capture data

Shneiderman’s Visualization Mantra

- Overview, zoom & filter, details on demand
- Overview, zoom & filter, details on demand
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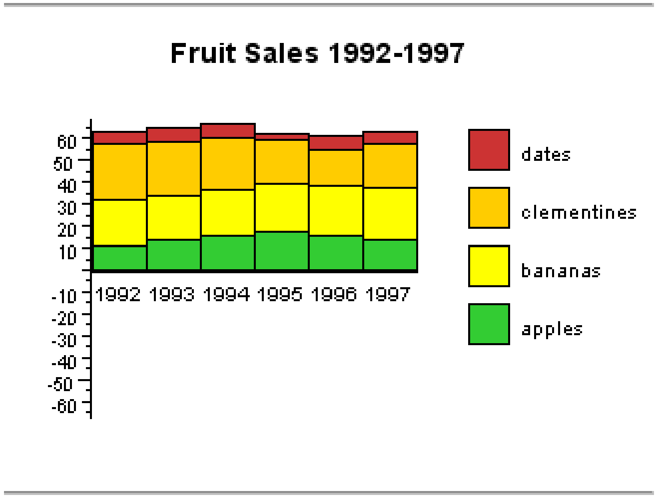
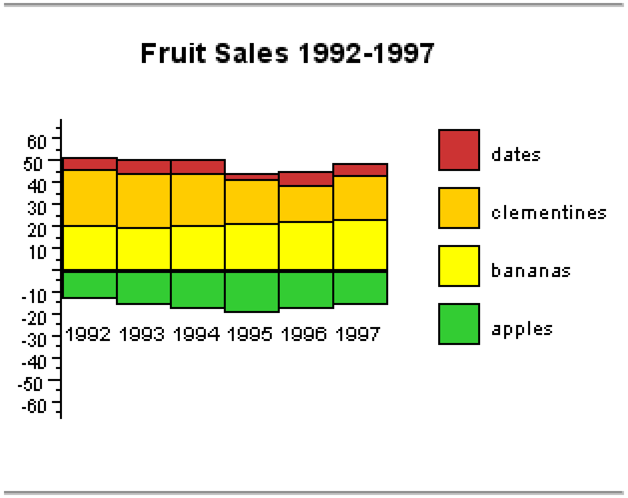
- Overview, zoom & filter, details on demand

Adapted from Shneiderman

Interactive Stacked Histogram

- Even a simple interaction can be quite powerful
  - http://www.meandeviation.com/dancing-histograms/hist.html





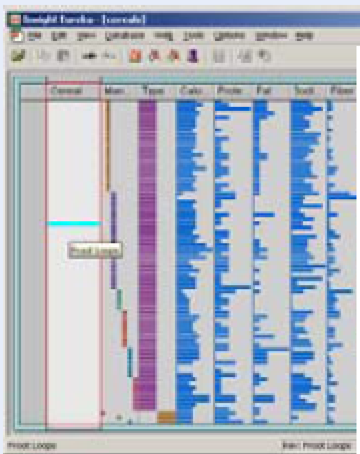
Basic Interaction Techniques

- Selecting
  - Mouse click
  - Mouseover / hover / tooltip
  - Lasso / drag
- Rearrange
  - Move
  - Sort
  - Delete

Selecting

Pop-up tooltips

Hovering mouse cursor brings up details of item



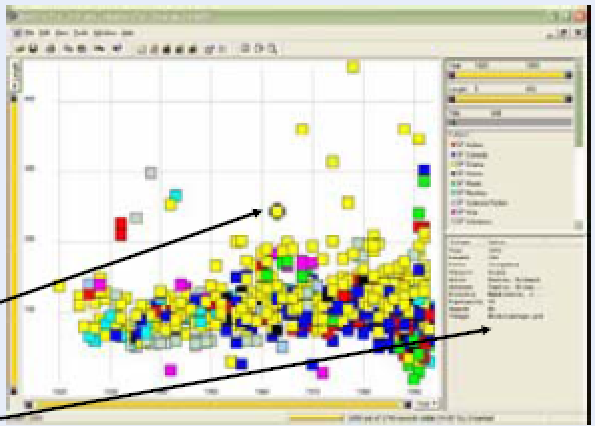
Slide adapted from John Stasko

Mouse Selection

Clicking on an item selects it and attributes of the data point are shown

Selected item

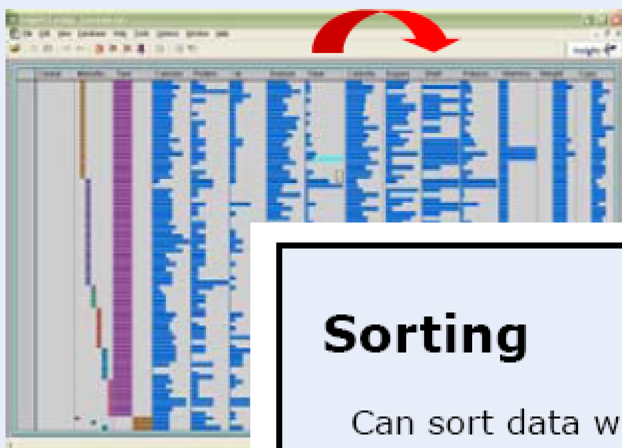
Attributes



Slide adapted from John Stasko

Rearrange

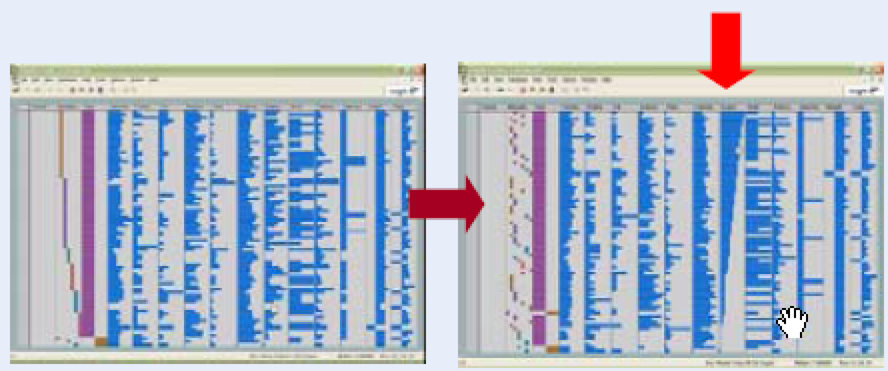
In TableLens you can move columns (attributes) left and right



Slide adapted from John Stasko

Sorting

Can sort data with respect to a particular attribute in Table Lens



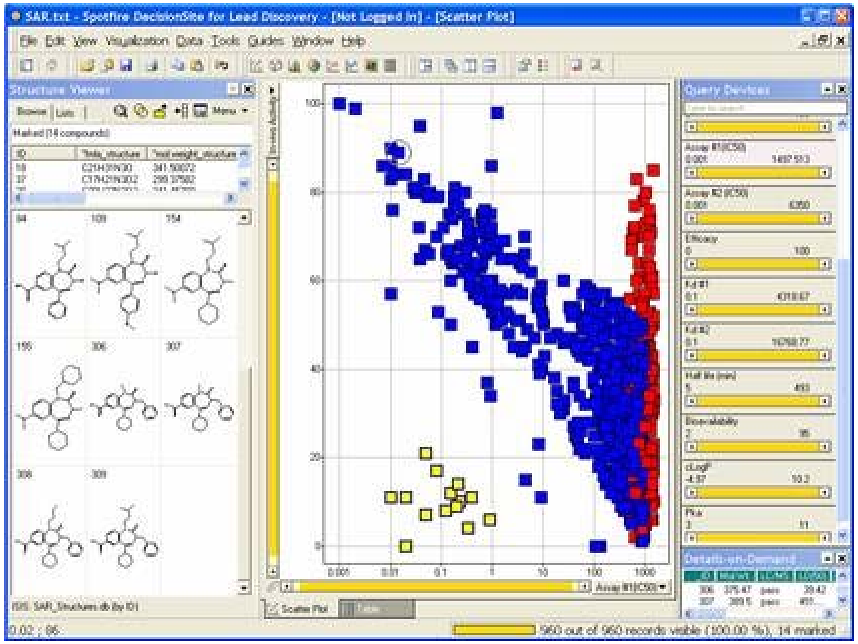
Slide adapted from John Stasko

Advanced Interaction Techniques

- Brushing and Linking
- Overview + Detail
- Focus + Context
- Panning and Zooming
- Distortion-based Views

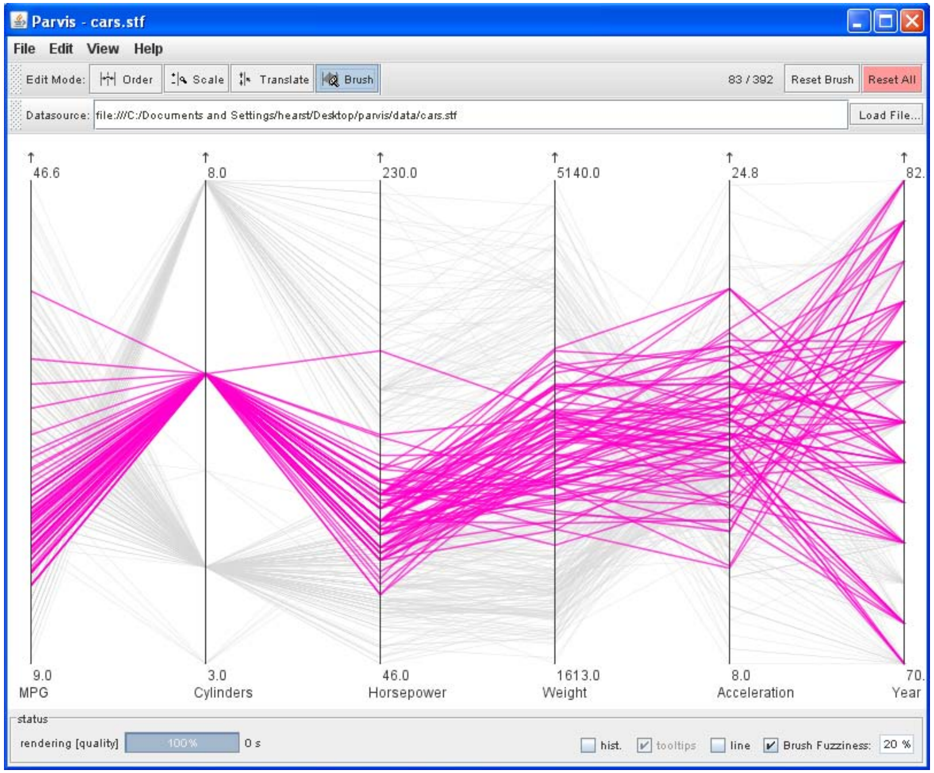
Highlighting / Brushing and Linking / Dynamic Queries

- Spotfire, by Ahlberg & Shneiderman
  - http://hcil.cs.umd.edu/video/1994/1994_visualinfo.mpg
  - http://spotfire.tibco.com/products/gallery.cfm



Highlighting and Brushing: Parallel Coordinates by Inselberg

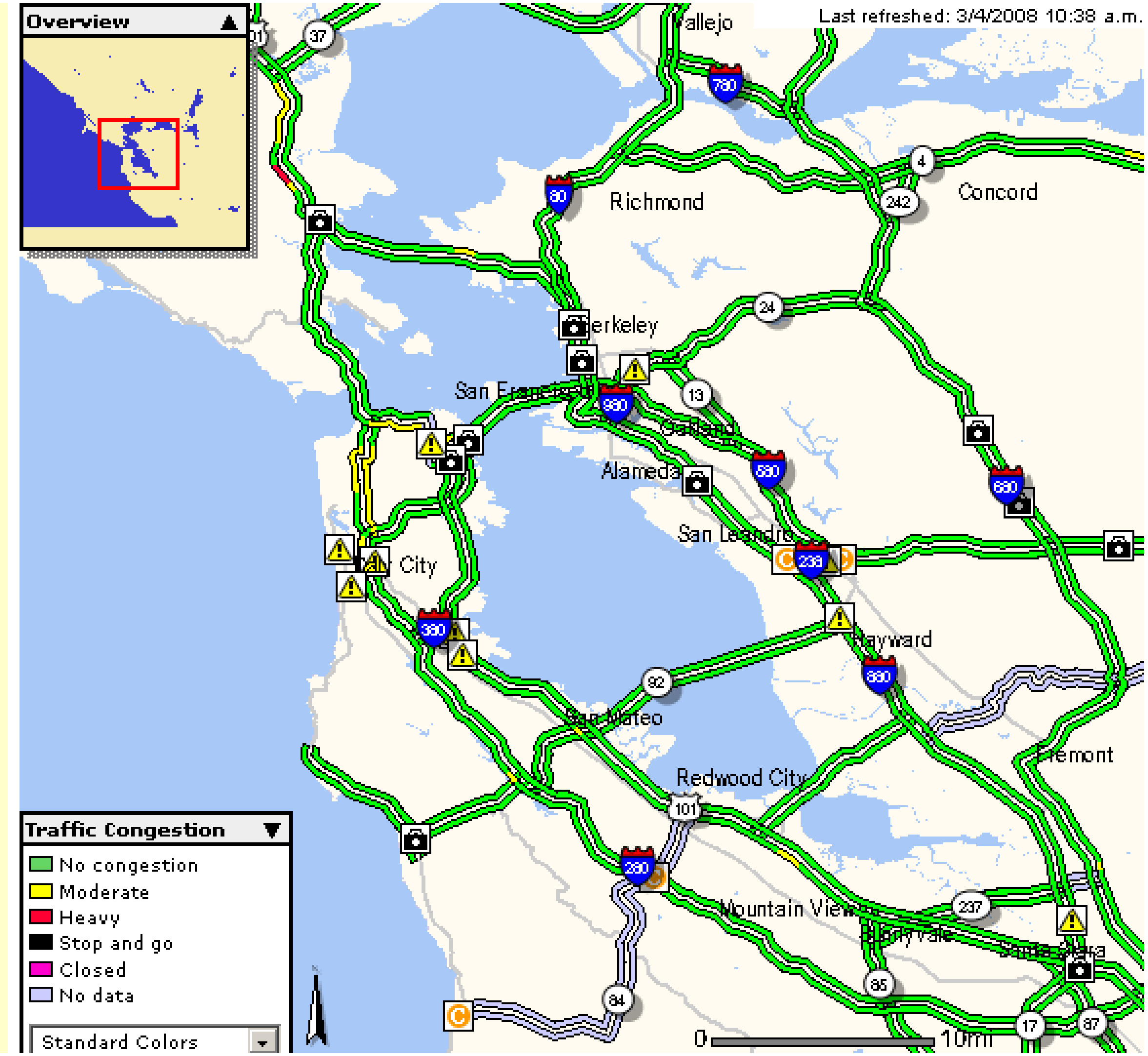
– Parallel coordinates (D'Ocagne, 1885, Inselberg, 1985)



Overview + Details

- Separate views
  - No distortion
  - Shows both overview and details simultaneously
  - Drawback: requires the viewer to consciously shift there focus of attention.

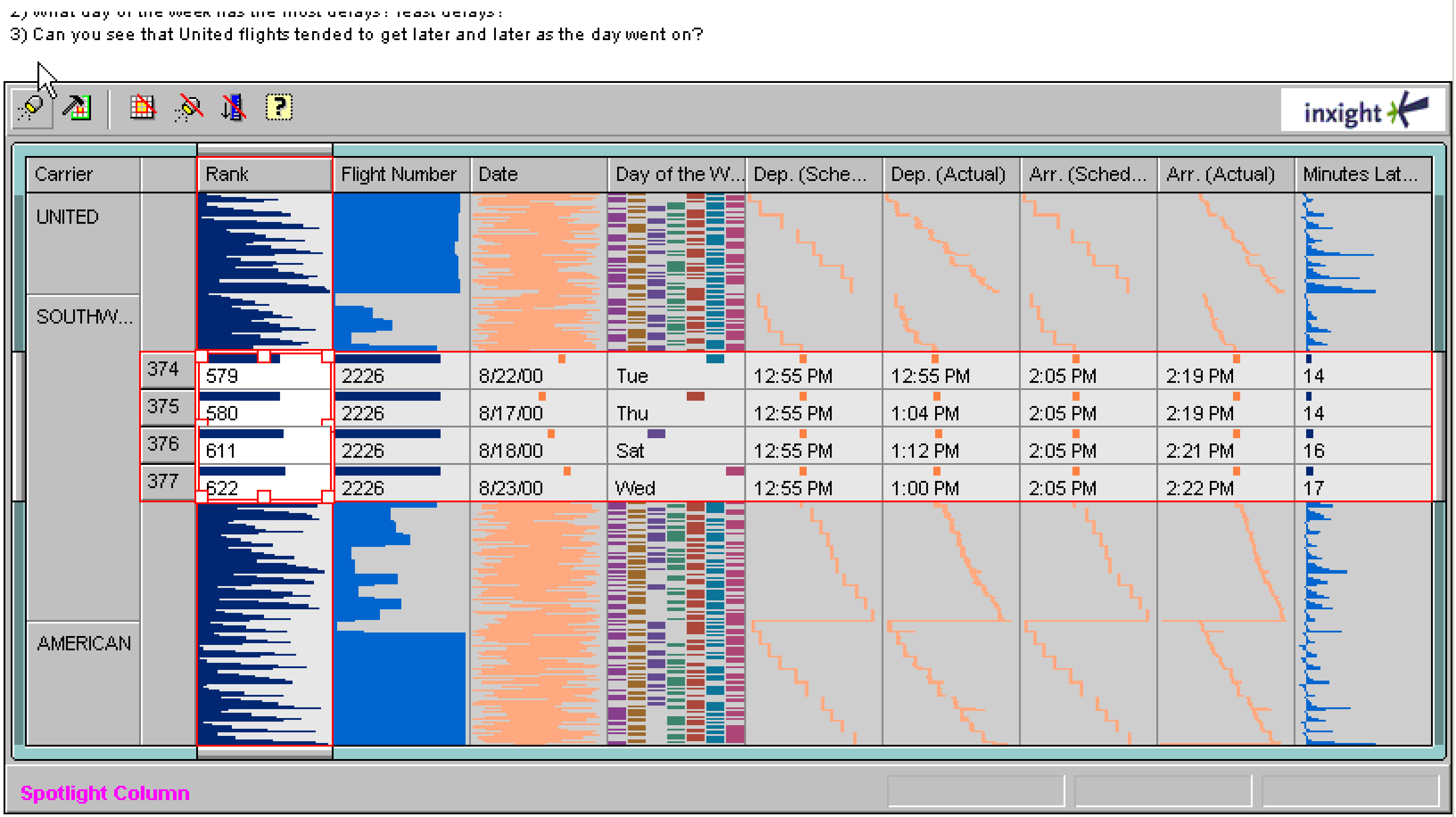
Example: traffic.511.org



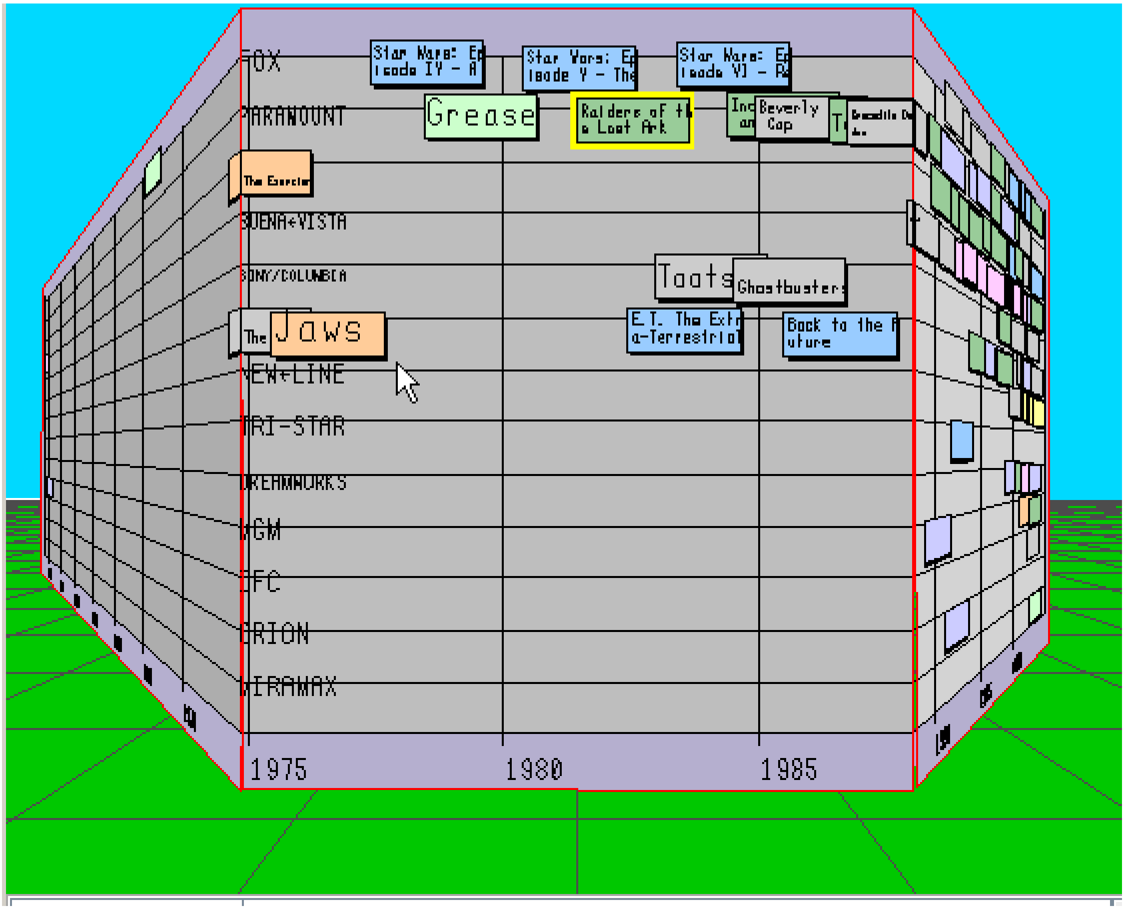
Focus + Context

- A single view shows information in context
  - Contextual info is near to focal point
  - Distortion may make some parts hard to interpret
  - Distortion may obscure structure in data
    - We’ll have a lecture on distortion later
- Examples from Xerox PARC:
  - TableLens
  - Perspective Wall
  - Hyperbolic Tree Browser

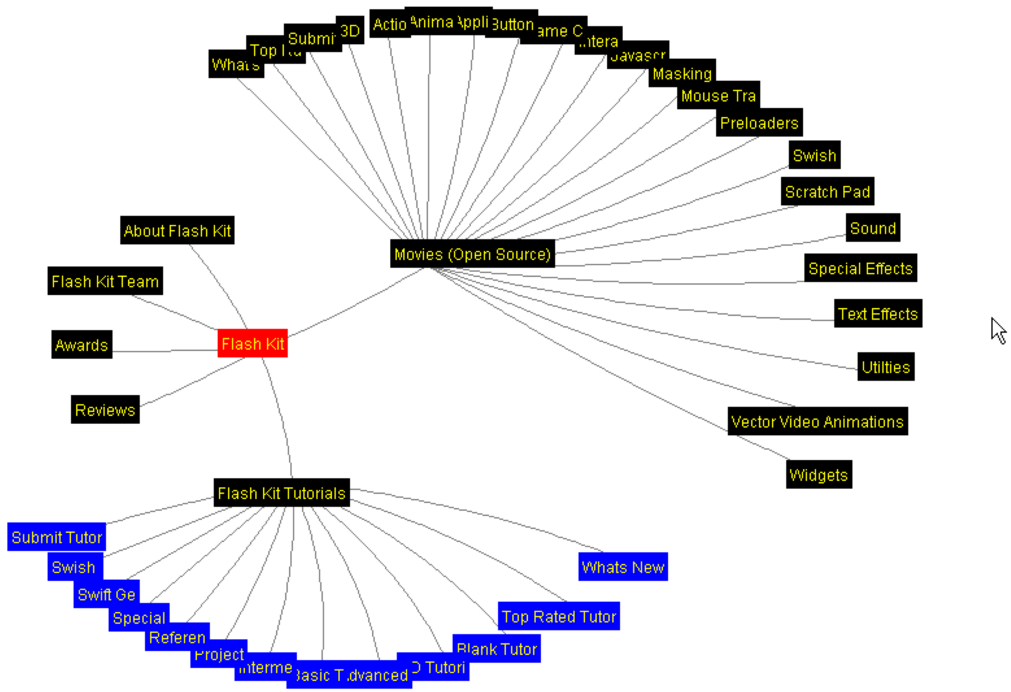
Focus + Context: TableLens from PARC/Inxight



Focus + Context (+ Distortion): Perspective Wall from PARC/Inxight



Focus + Context: Hyperbolic Tree from PARC/Inxight



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
- Distortion-based techniques
  - Keep a steady overview, make some objects larger while simultaneously shrinking others

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
  - Smart speed up and slow down
  - Example: speed-dependent zooming, Igarishi & Hinkley
- Semantic Zooming
  - Zooming can be conceptual as opposed to simply reducing pixels
  - Example tool: Pad++ and Piccolo projects
    - http://hcil.cs.umd.edu/video/1998/1998_pad.mpg

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.

Examples of Semantic Zoom

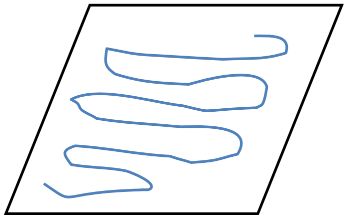
- Information Maps
  - zoom into restaurant
    - see the interior
    - see what is served there
  - maybe zoom based on price instead!
    - see expensive restaurants first
    - keep zooming till you get to your price range
- Browsing an information service
  - Charge user successively higher rates for successively more detailed information

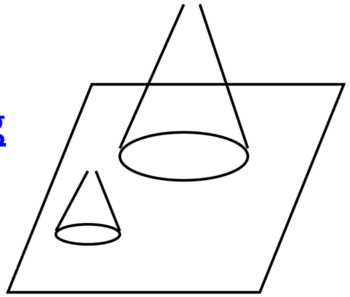
Examples of Semantic Zoom

- 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

Pad++

- An infinite 2D plane
- 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





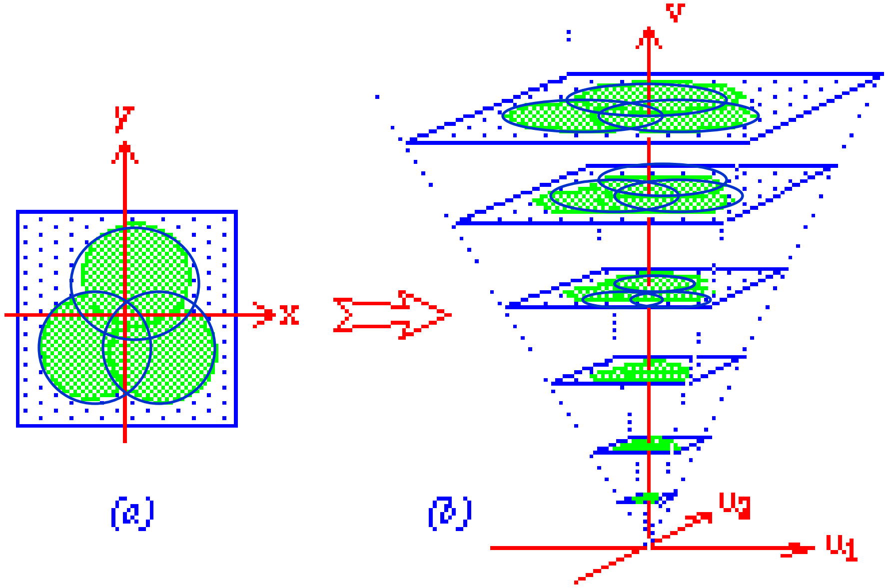
The Role of Portals

- 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

Space-Scale Diagrams

(Furnas & Bederson 95)

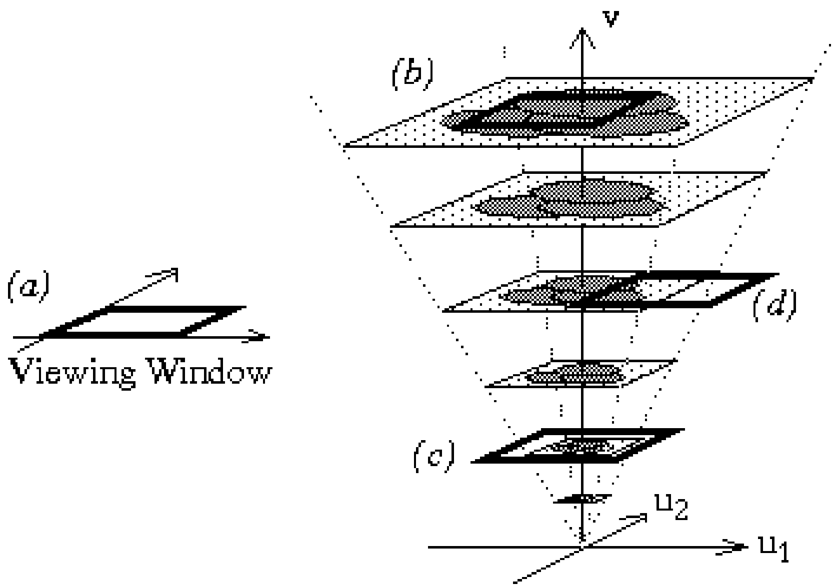
- Original figure, shown at various scales
- Horizontal axis is standard, vertical is scale



Space-Scale diagram

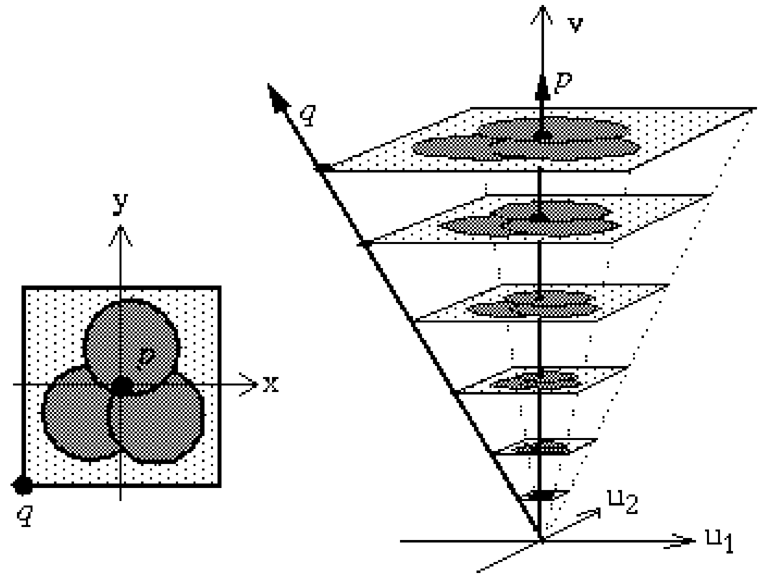
Space-Scale Diagrams
(Furnas & Bederson 95)

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



Space-Scale Diagrams
(Furnas & Bederson 95)

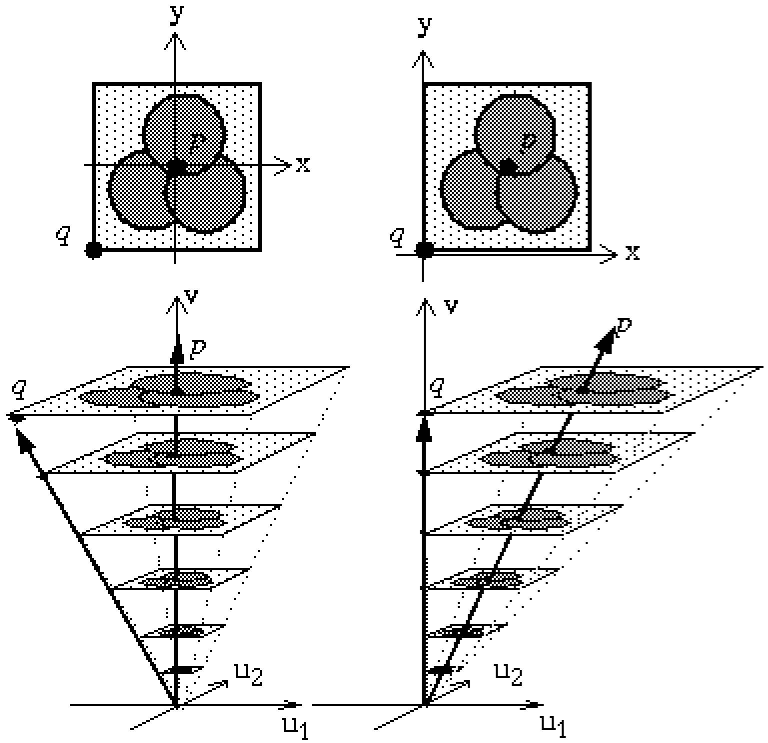
- A point is transformed to a ray
- Circular regions become cones



Space-Scale Diagrams

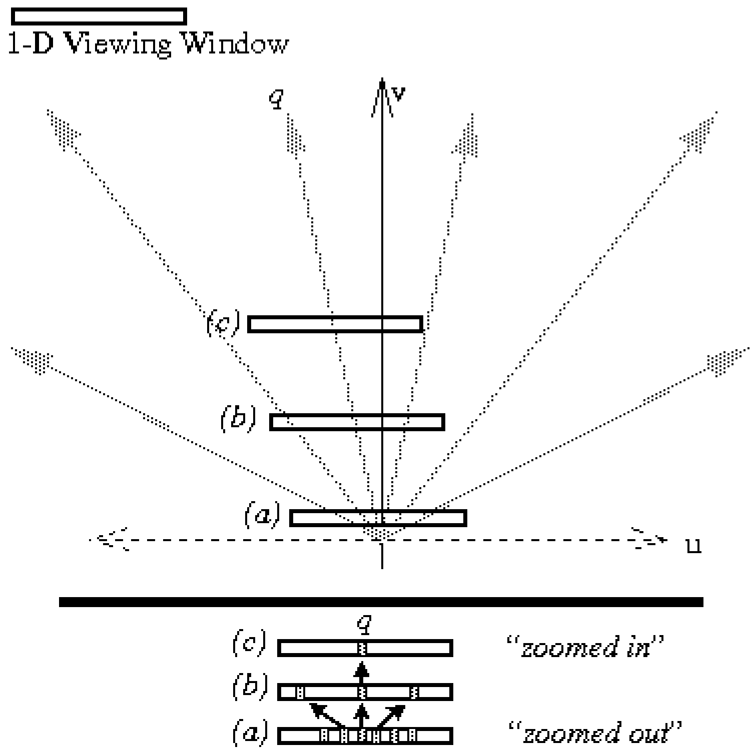
(Furnas & Bederson 95)

- 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



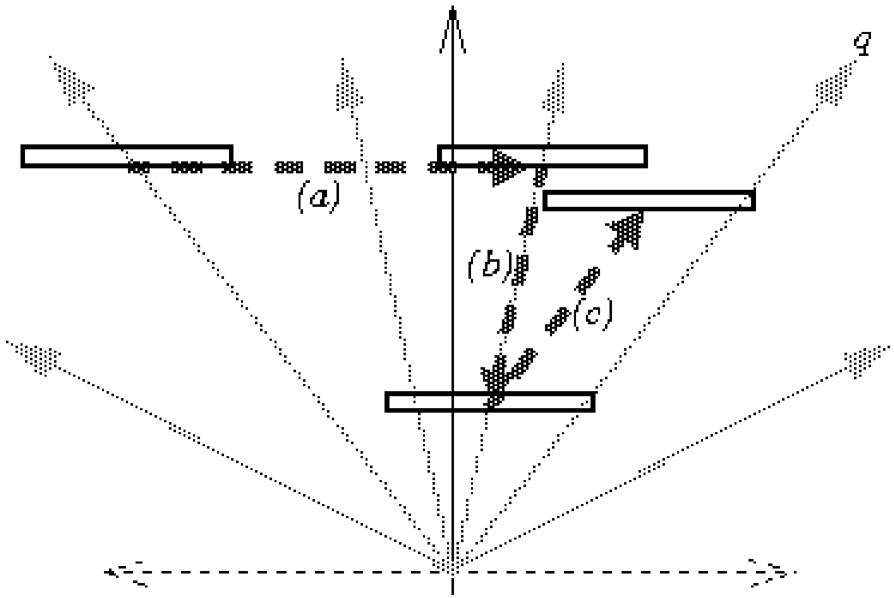
Space-Scale Diagrams
(Furnas & Bederson 95)

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



Space-Scale Diagrams
(Furnas & Bederson 95)

- Pure pan (a)
- Pure zoom (b)
- Pan and zoom keeping q in same position in the viewing window (c)



Space-Scale Diagrams

(Furnas & Bederson 95)

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

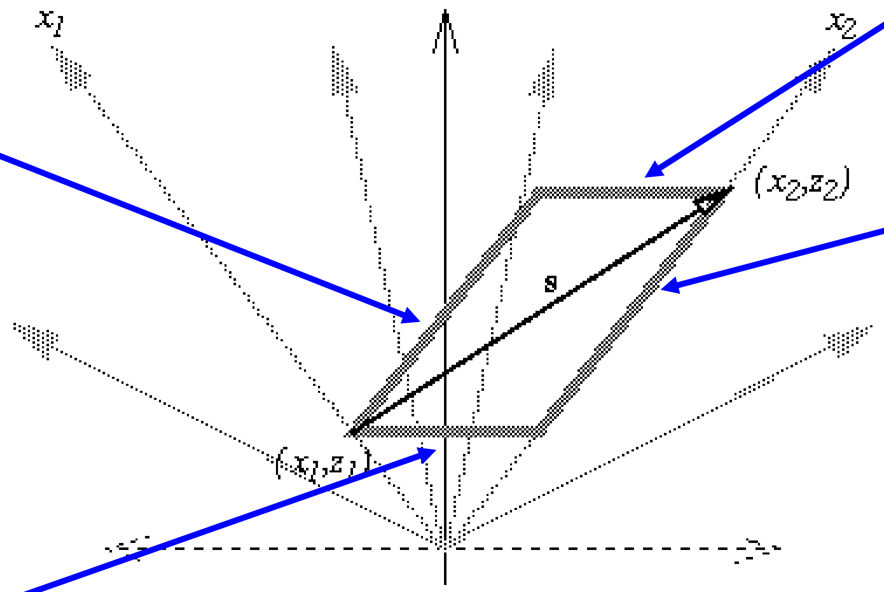
Space-Scale Diagrams

(Furnas & Bederson 95)

- Solution: space-scale diagram
- Goal: go from (x1,z1) to (x2,z2)
- Must stay within the parallelogram

if you go out on
the top, you zoomed
past x2

if you go out on
this side, the
target x2
is further from
x1 than when
you began



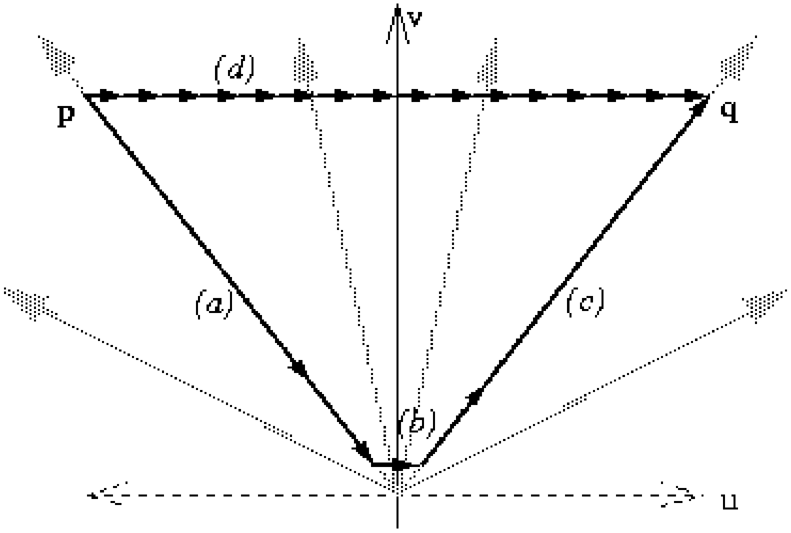
if you go out on
this side, you
overshot the target

if you go out on
the bottom, you
backed up from x1

Space-Scale Diagrams

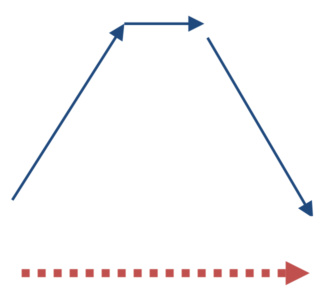
(Furnas & Bederson 95)

- Zooming covers more ground faster than panning
  - zooming is logarithmic, panning is linear
- Alternative way to navigate:
  - Instead of a long pan
  - Do a big zoom, a short pan, a big zoom
  - (count the number of arrows each way)



Navigation in Pad++

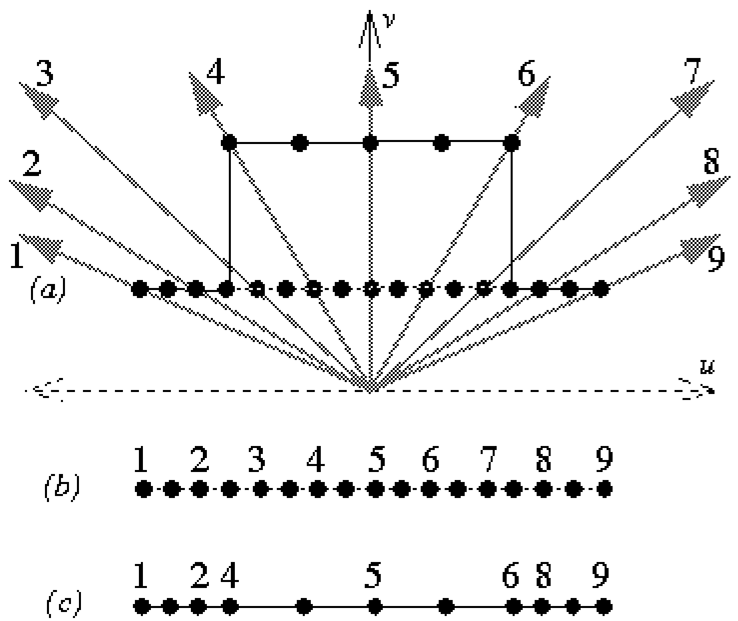
- How to keep from getting lost?
  - Animate the traversal from one object to another using "hyperlinks"
    - If the target is more than one screen away, zoom out, pan over, and zoom back in
  - Goal: help viewer maintain context



Space-Scale Diagrams

(Furnas & Bederson 95)

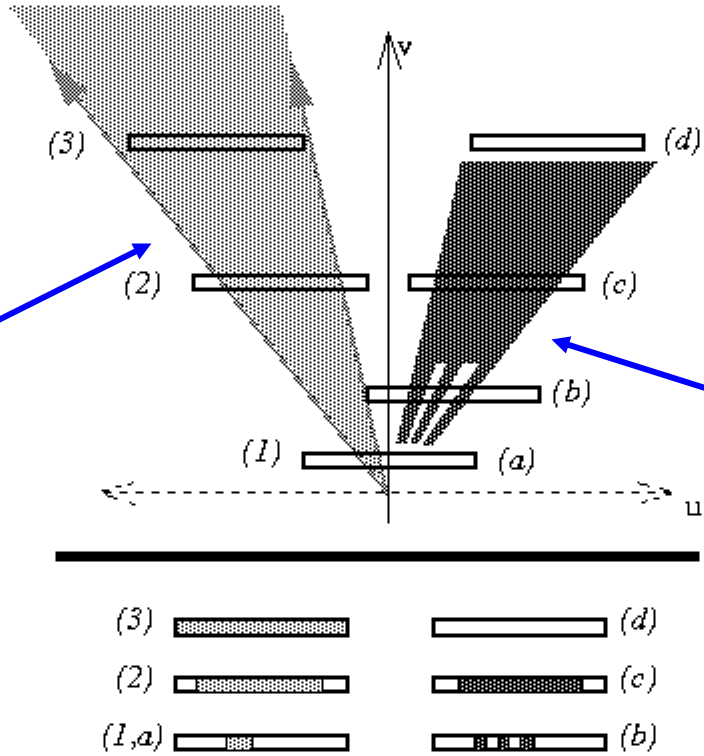
- Combining space-scale zooming and distortion-based techniques
  - Instead of a horizontal slice through scale-space, take a step up and a step down
  - The points in the middle have more room; those on the periphery are squished together



Space-Scale Diagrams
(Furnas & Bederson 95)

- Implementing semantic zooming

standard
geometric
zooming
(a grey line)



semantic zoom:
too far, see nothing
zoom in, see dashed line
get closer, see solid line
get too close, see nothing

Panning and Zooming

- Is it actually useful?
  - Is it better to show multiple simultaneous views?
  - Is it better to use distortion techniques?
- Would keeping a separate global overview help with navigation?
  - The research literature suggests yes, that overview+detail is usually better than pan & zoom.

For Wed.

- Discuss final projects
- Assignment #2 due at 9pm
- More on interactive visualization after spring break