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UNIVERSITÀ DEGLI STUDI

INGEGNERIA
CIVILE, INFORMATICA E DELLE TECNOLOGIE AERONAUTICHE

Information Visualization

Interaction

M. Patrignani

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Overview

- Definition of interaction
- Classifications of interaction
- Examples of interaction

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Interaction's definition

- From the Human Computer Interaction research field
  - Interaction is direct manipulation and instantaneous change
    - [Becker *et al.*, 87]
  - Interaction is the communication between user and the system
    - [Dix & Ellis, 98]
- From the Information Visualization research field
  - Interaction allows for direct manipulation of the graphical representation of the data
    - [Waterson 02]
  - Interaction provides users with the ability to directly or indirectly manipulate and interpret representations
    - [Yi *et al.*, 07]
  - Finding a solid definition of interaction is challenging
    - [Yi *et al.*, 07]

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Interaction & information visualization

- Interaction is at the heart of modern information visualization
  - changing one's view of the data greatly enhances comprehension
  - often no single all-inclusive view is likely to lead to insight

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Interaction classifications

- Based on response time
- Based on atomic actions
- Based on supporting technologies
- Based on functional degree
- Based on immersive experience degree
- Based on its paradigm
- Based on user intents

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Classification – response time

- Response times of computer must be tuned to human response times
  - From [Waterson ‘02] and [Stasko ‘13]
- 0.1 sec
  - motion, animation, visual continuity
- 1 sec
  - dialogue, conversation break
- 10 sec
  - cognitive response, unit task

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Classification – atomic actions

- Press key
- Move pointer (hover)
- Point and click
- Drag and drop
- Voice
- Gesture
- Rotate
  - tilt, roll
- Touch, grab
- …

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Classification – supporting technologies

- Different kinds of devices allows different kinds of interactions with the user
  - desktops and laptops
  - tablets and smartphones
  - gaming stations
  - wearable devices
  - experimental environments
  - …

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Desktops and laptops input devices

- Keyboards
  - allows key selection
- Pointing devices
  - allows hovering, point and click, drag and drop

Mouse

Touchpad

Trackball (Apple)

Trackpoint (IBM)

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Traditional gaming input devices

Joystick
(Logitech Extreme 3D Pro)

Game controller
(Nintendo)

Console controls
(Xbox)

Steering wheel
(Thrustmaster T300 Ferrari GTE)

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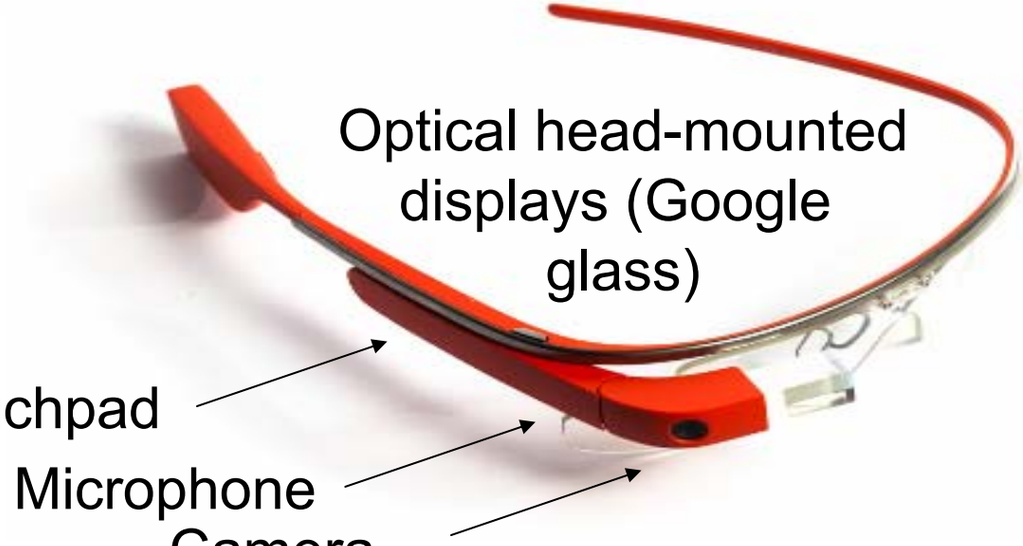
Wearable input devices

One handed keyboards
(Frogpad 2)

Gloves
(Keyglove)

Chording keypads
(twiddler)

Eye tracking glasses
(Tobii glass)



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Gesture recognition

- Aim: react to the user movements
  - usally of hands or face
- Timings of gesture regognition
  - offline gesture recognition
    - reacts to a conventional gesture after the movement is performed
  - online gesture recognition
    - reacts while the movement takes place
- Gesture recognition devices
  - wired gloves
  - stereo cameras
  - based on motion and position sensors

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Gesture recognition

… with wired gloves and stereo cameras

Wired gloves
(Nintendo Powerglove 1989)

Wired gloves
(MetaMotions Cyberglove II 2005)

Motion capture
(Xbox 360 Kinect)

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Gesture recognition

- ...based on motion and position sensors
  - Accelerometers
    - single and multi-axis
    - measure linear acceleration relative to freefall
  - Gyroscopes
    - measure the angular rate of rotational movement about one or more axes
  - Compasses
    - magnetic sensors
  - Barometers
    - pressure sensors
    - measure relative and absolute altitude
  - Load sensors

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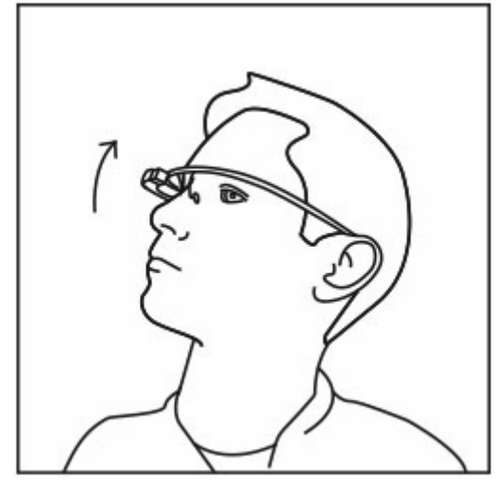
Gesture recognition

- …based on motion and position sensors

Motion controller
(Wii remote)

Balance board
(Wii U BB)



Google Glass Head nudge

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Tablets and smartphones input devices

- Common input devices
  - stylus
    - may be used to realize soft keyboards
  - touchscreens
    - may be used to realize soft keyboards
- Usually available
  - motion and position sensors
    - accelerometers, gyroscopes, compasses, and barometers
  - voice command capabilities

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Experimental input devices

Brain-computer interfaces
(Emotiv EPOC)

3D pointer
(Novint Falcon)

Brain-computer interfaces
(Neural Impulse Actuator)

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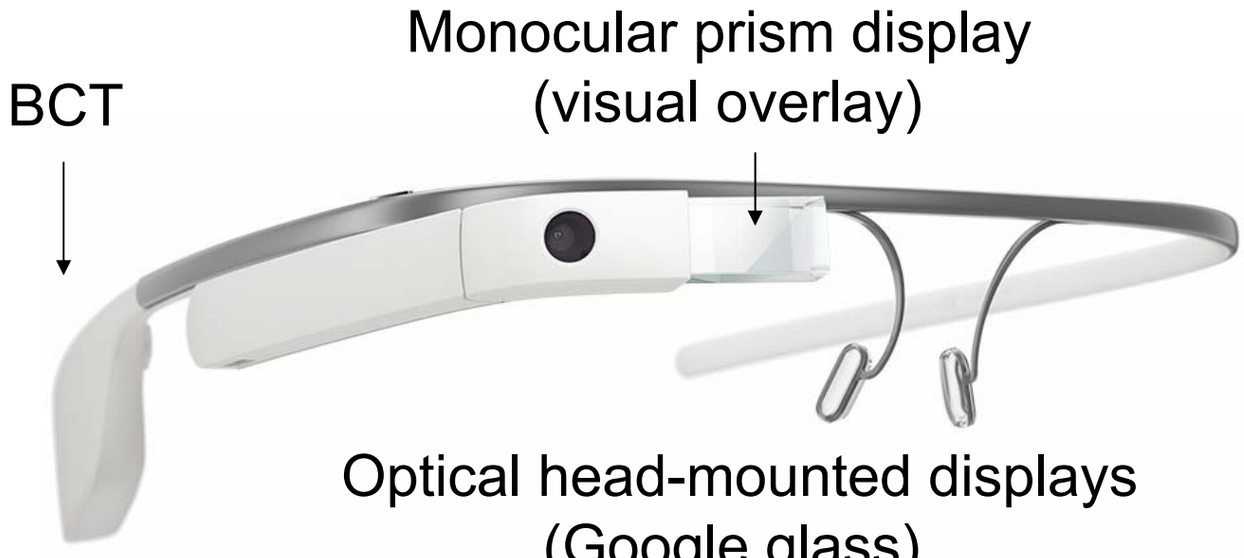
Wearable output devices

- Bone Conduction Transducer (BCT)
  - conduction of sound to the inner ear through the bones of the skull

- Actuators for haptic vibrations
  - simulate touch sensations



Optical head-mounted displays
(Google glass)

Data Gloves
(Gloveone)

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Head-mounted displays

Sony HMZ-T3W

Google cardboard
for Android

Samsung Gear VR
for Galaxy S6

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Classification – functional degree

- From [Mazza 09]

1. Static
   - users are not allowed to perform any type of interaction
   - only a single, unmodifiable view is generated
2. Manipulable
   - users are allowed to manipulate the process that generates the view, via zooming, rotation, panning,…
3. Transformable
   - users are allowed to manipulate, in the preprocessing phase, the input data of the representations
     - for example through data filtering

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Classification – immersive experience degree

1. Traditional
   - the interaction is mediated by some “point of communication”
2. Augmented reality
   - computer-generated output is mixed with the environment the user is familiar with
3. Virtual reality
   - the computer reproduces the whole environment for the user to live in
   - immersive multimedia

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Classification – interaction paradigm

- Top-down exploration
  - Shneiderman mantra [Shneiderman 96]
    - Overview first, zoom and filter, then details on demand
    - Overview first, zoom and filter, then details on demand
    - Overview first, zoom and filter, then details on demand
- Bottom-up exploration
  - When data are massive, overview may be impossible to get, hence
    - Search, show context, expand on demand
    - Search, show context, expand on demand
    - Search, show context, expand on demand
      - From [van Ham and Perer 09]

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User-centered classification

- Proposed by [Yi *et al.*, 07]
- Survey of 59 papers and 51 systems
- 311 individual interaction techniques were collected and grouped by user intent
  - what a user wants to achieve through a specific interaction technique

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User-centered classification

- Seven categories of interaction based on user intents [Yi *et al.*, 07]
  1. Select
  2. Explore
  3. Zoom
  4. Reconfigure
  5. Encode
  6. Filter
  7. Connect

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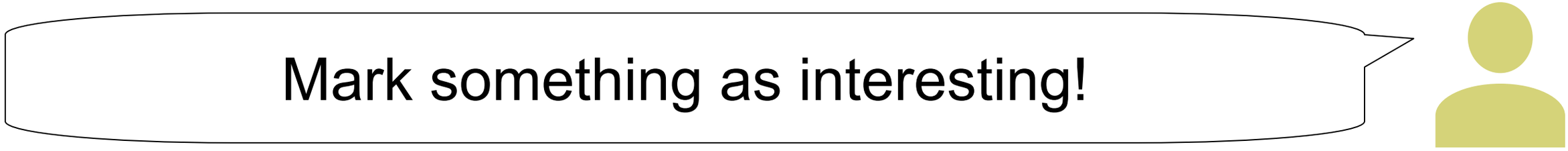
1. Select



- Mark items of interest to keep track
  - often works as a preceding action to subsequent operations
- Examples
  - selecting a placemark in Google Map
  - the Focus feature in TableLens

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Generalized Selection

- Selection of a category rather than a specific item
  - select items matching some attribute(s) of the pointed out item

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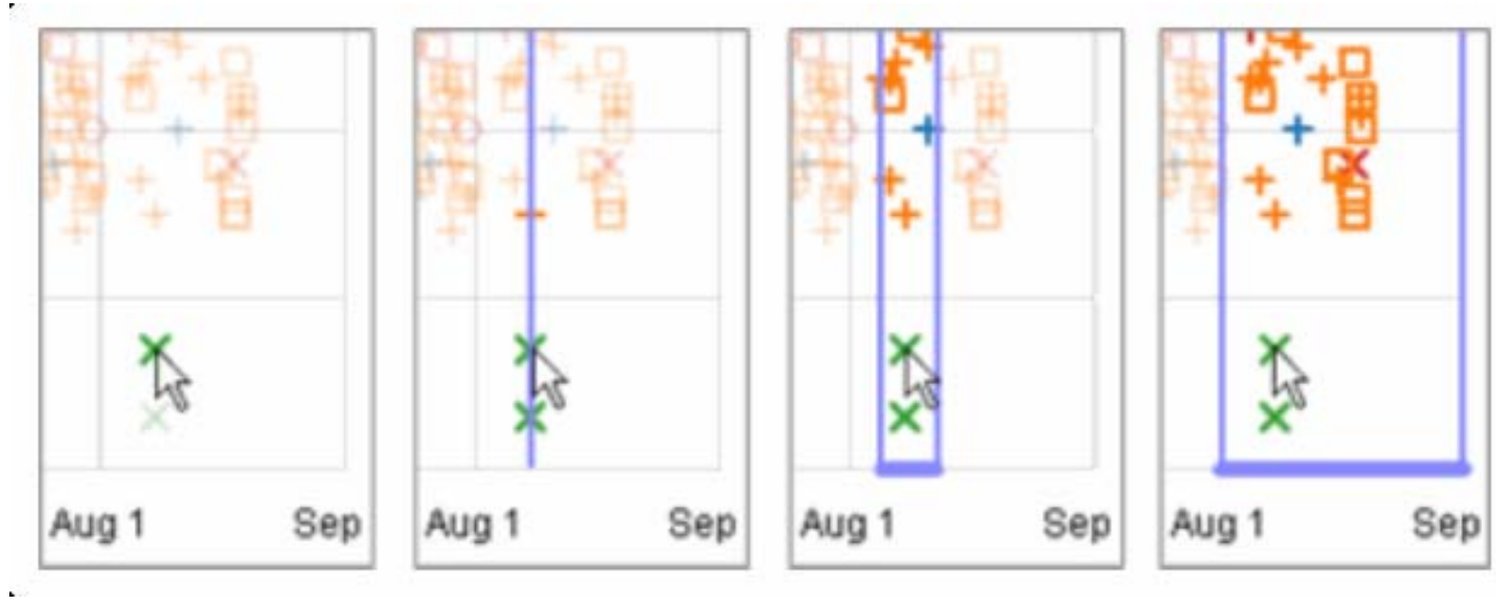
Query relaxation

- Proposed by [Heer *et al.*, 08]
- Allows the users to generalize their selection dynamically



Video at: https://www.youtube.com/watch?v=LVMjfsoMZfg

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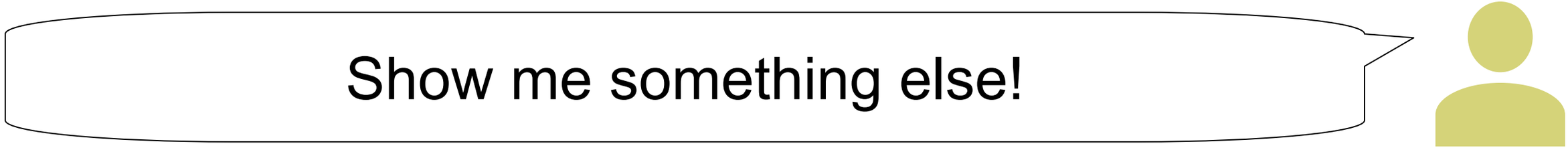
2. Explore



- Enables users to examine different subsets of data
  - overcoming the limitation of display size
- Moves the viewing focus from one position in information structure to another
  - usually the movement is as smooth as possible
- Two main types of exploration
  - panning / scrolling
  - direct walking

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Explore by panning

- Panning
  - movement of a camera across a scene, or
  - scene movement while the camera stays still
- Interaction technique
  - the user presses ←→↑↓ keys
  - the user slides scrollbars
  - the user grabs the scene and moves it with a mouse
  - the user rolls the mouse wheel
- Examples
  - panning in Google Earth / Google Map
    - http://maps.google.com

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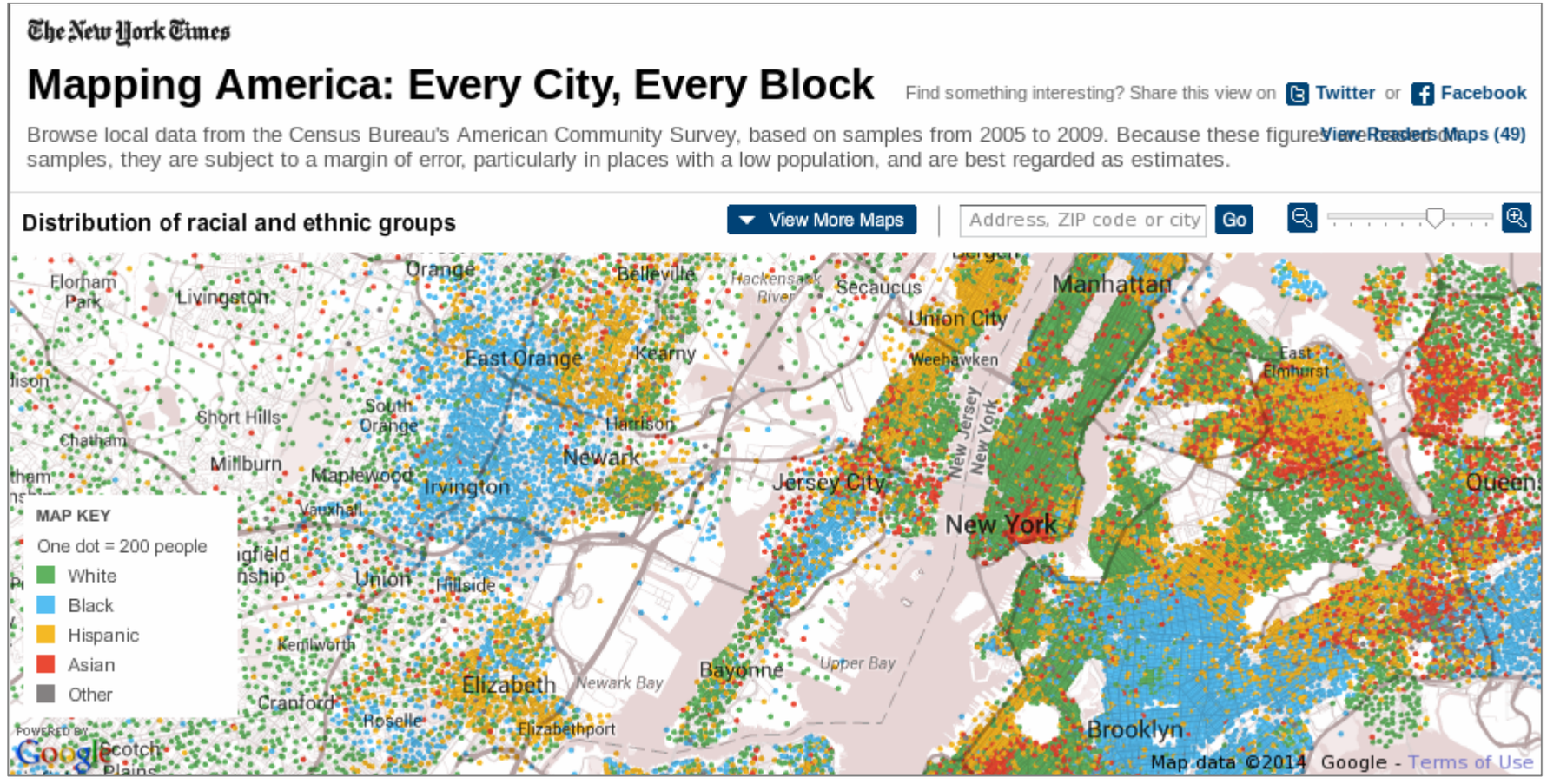
Mapping America

- Panning example



http://projects.nytimes.com/census/2010/map

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Explore by direct walk

- Direct walk
  - moving in the view by a series of mouse points or other direct-manipulation methods
  - a hyperlink is a direct walk where the change is usually not smooth
- Examples
  - moving in Google StreetView
  - visual Thesaurus
  - browser navigation

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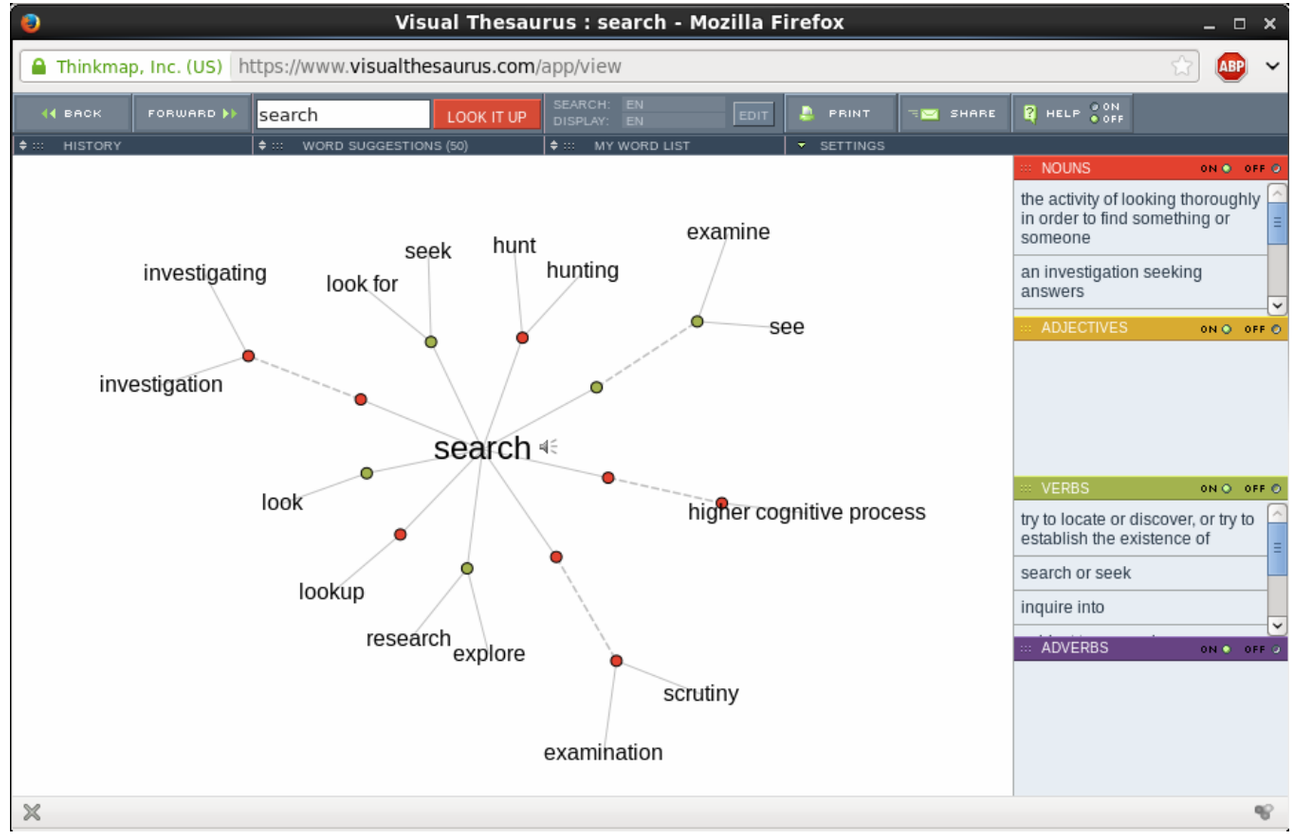
Direct walking in Visual Thesaurus

- Walking through terms semantics



https://www.visualthesaurus.com/

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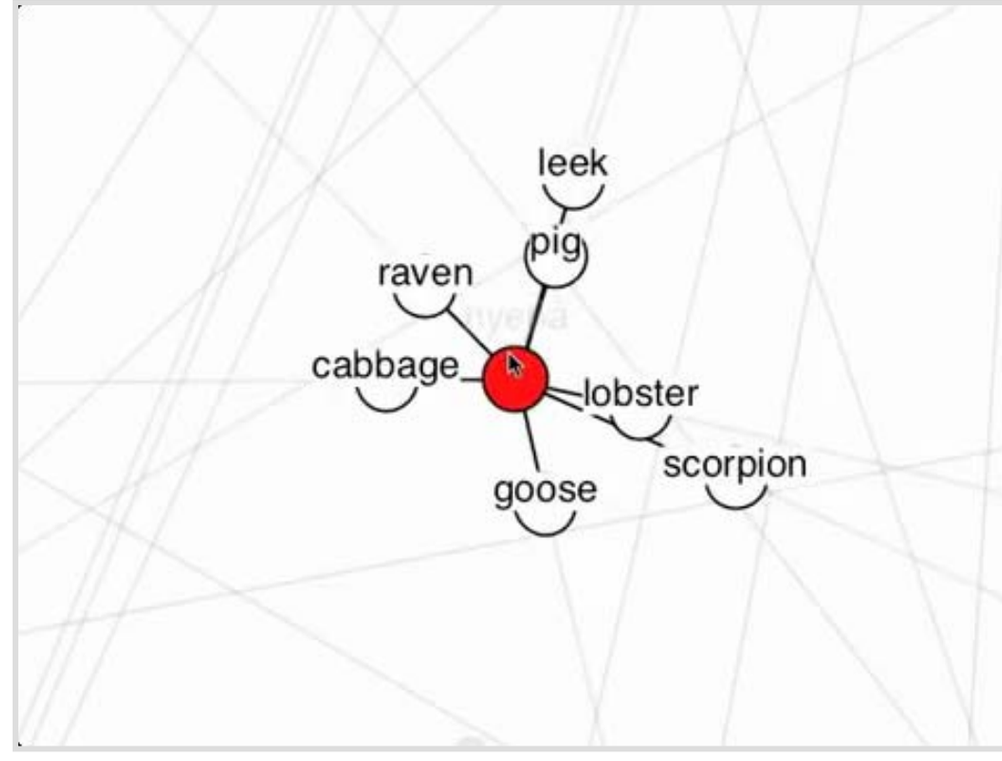
Link-Sliding and Bring&Go

- Two techniques introduced in [Moscovich *et al.*, ‘09] to navigate large networks



https://www.youtube.com/watch?v=R07e5dSQQeQ

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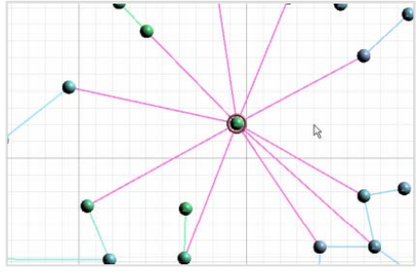
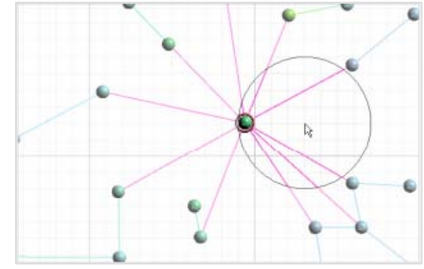
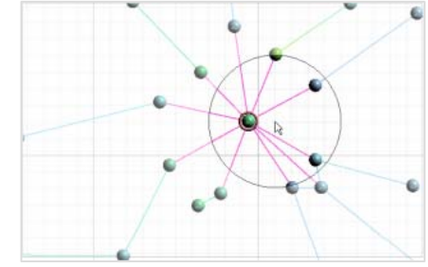
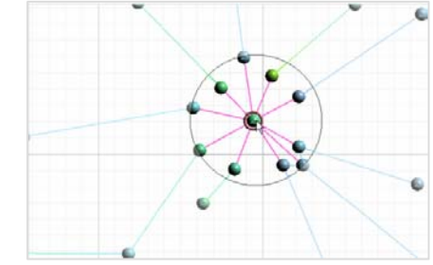
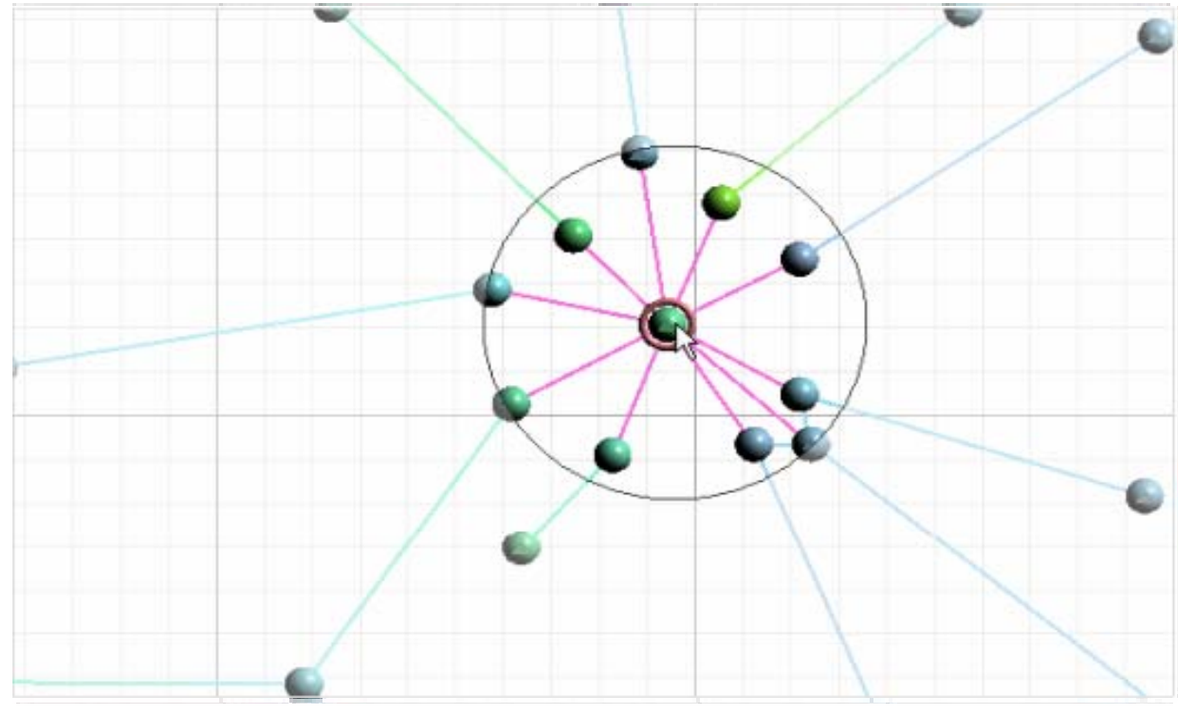
Bring neighbors lens

- The lens “attracts” neighbors
  - [Tominski *et al.*, ‘06]

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Scrolling

- OrthoZoom scrollbars [Appert & Fekete, 06]
  - 1D multi-scale navigation
  - panning is performed along the slider dimension
  - zooming is perfomed along the orthogonal one

www.youtube.com/watch?v=fwz04BNRQQQ

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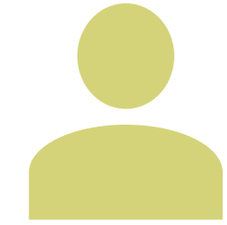
3. Zoom

Show me more or less detail!



- Called “Abstract/Elaborate” in [Yi *et al.*, 07]
- Adjust the level of abstraction (overview and details)
  - fundamentally without changing the representation
- Examples
  - geometric zooming in Google Earth / Google Maps
  - pop-up tooltips
  - selected rows in Table Lens
  - unfolding sub-categories in an interactive pie chart
  - details-on-demand in Sunburst

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Zooming examples

- Explore these two examples
  - http://micro.magnet.fsu.edu/primer/java/scienceoptic su/powersof10/index.html
  - http://htwins.net/scale2/
- What are the limitations of zooming?
  - zooming relies on your memory!

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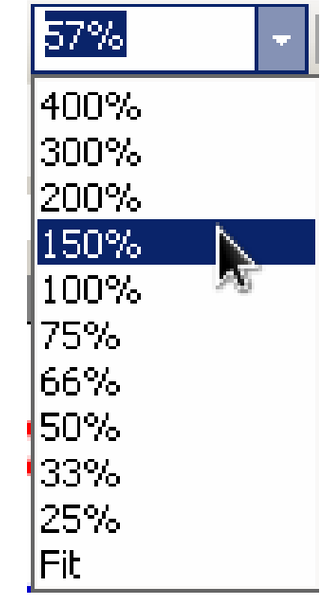
Zooming interaction

- Explicit input of zooming factor
- Area zooming
  - select a zoom area that will become entire view
  - context switch can be disorienting
  - example: CAD/CAM
- Point zooming
  - select the zoom+ or zoom- tool and click the area you want to magnify
- Scrollbar zooming
- Mouse controlled zooming
  - pointer selects the point to zoom
  - wheel controls zooming factor



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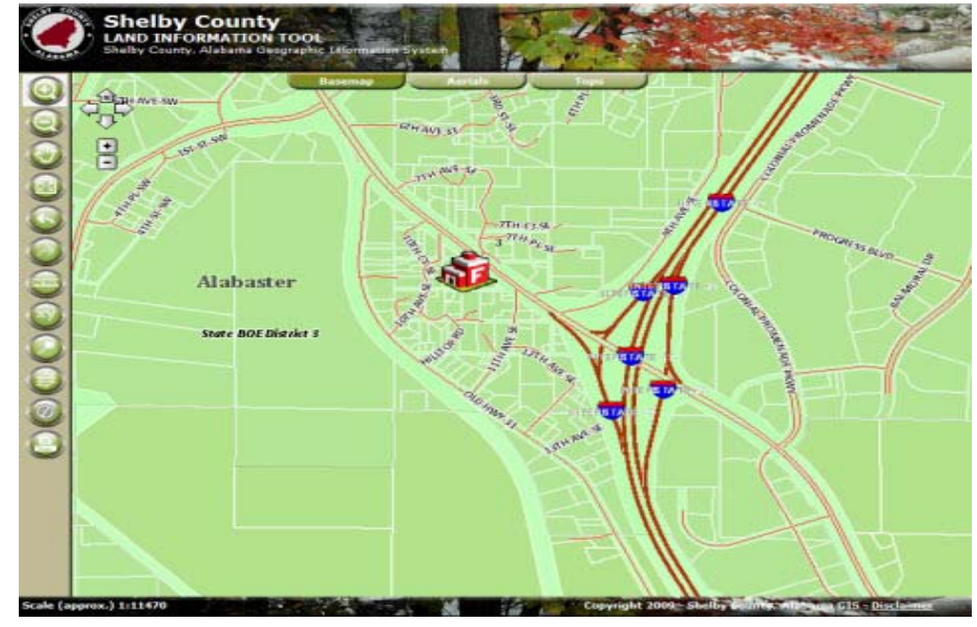
Area zoom example

- Shelby County, Alabama Land Information Tool
  - left-click and drag a box onto any part of the map
  - release the mouse button
  - the map zooms in accordingly



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A model for zooming and panning

- [Furnas & Bederson, ’95] introduced the idea of “space-scale diagram”
  - characterizes operations in zooming and panning
- Goals
  - understand multiscale systems
  - guide design
  - authoring tool

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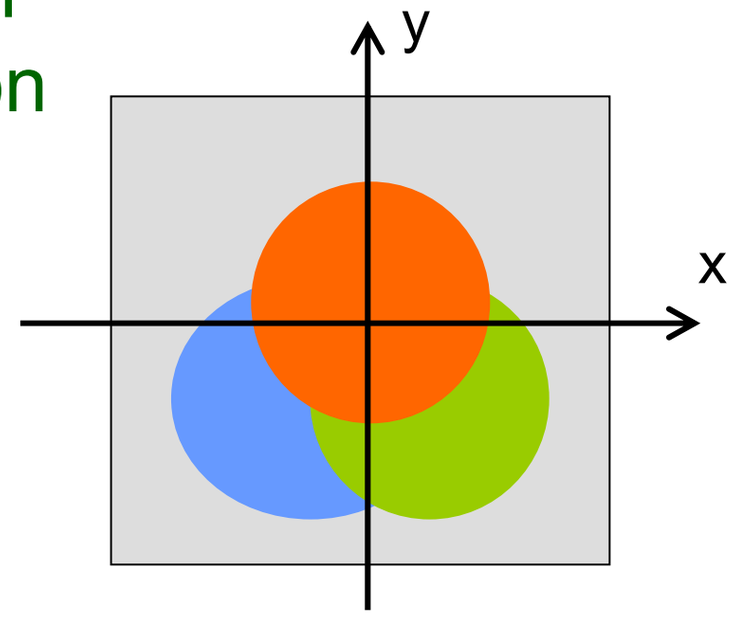
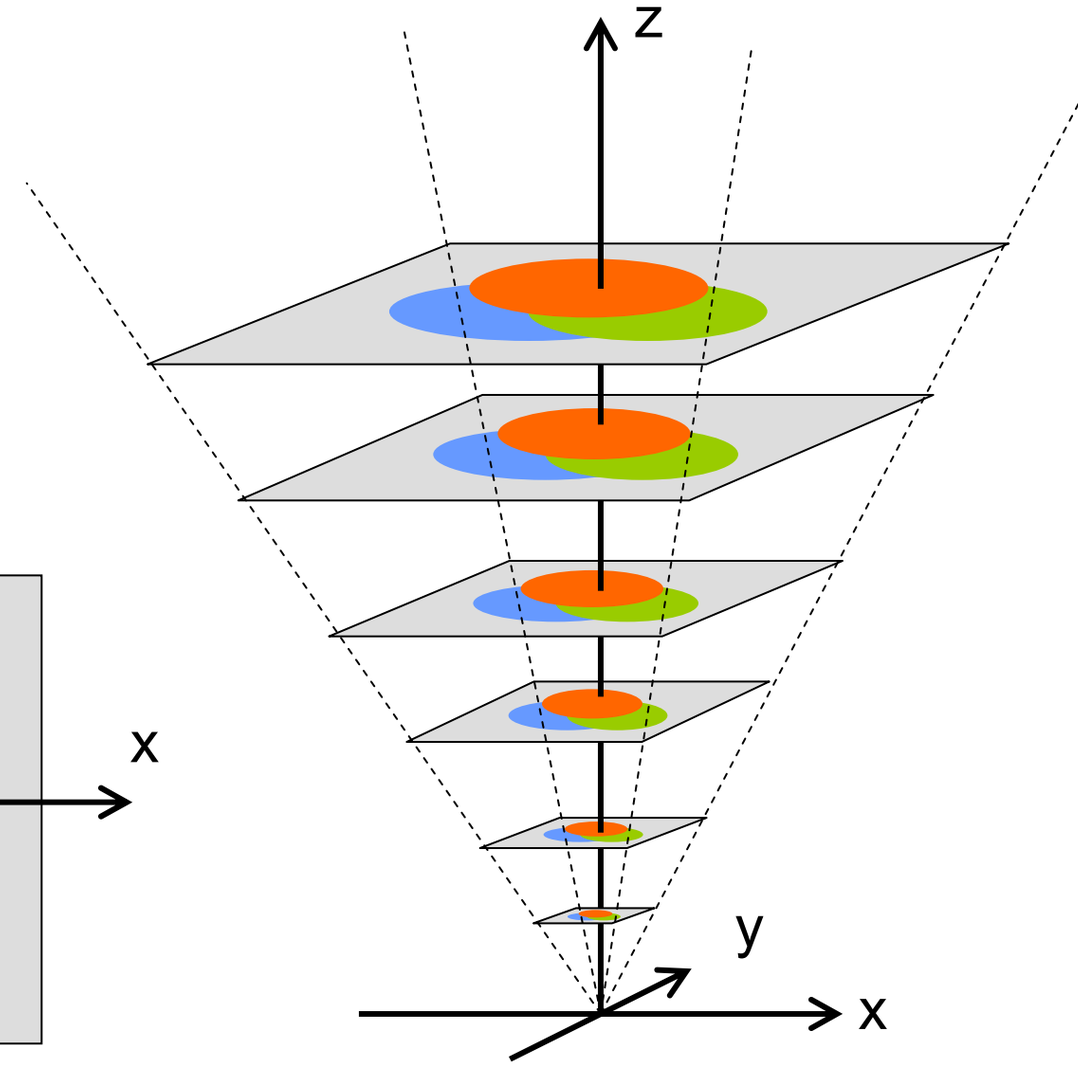
Space-scale diagram

- Abstraction for describing panning and zooming operations
  - associate the 2D image with a 3D projection





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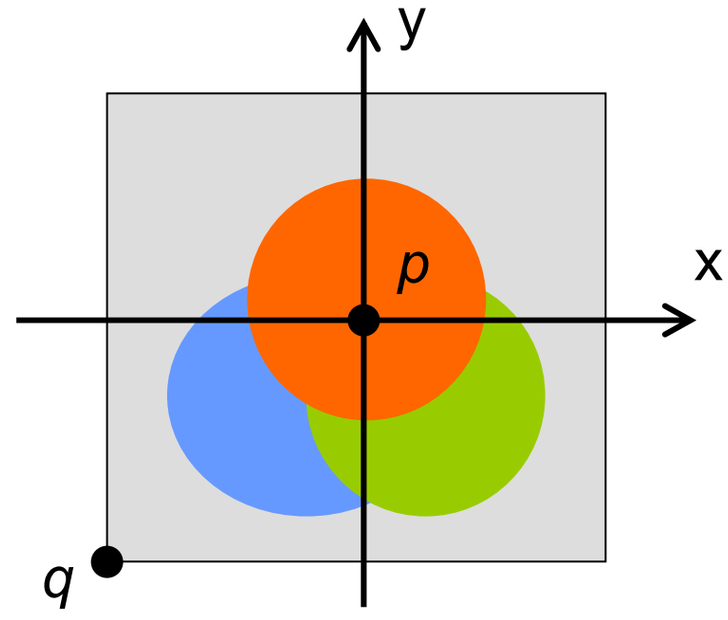
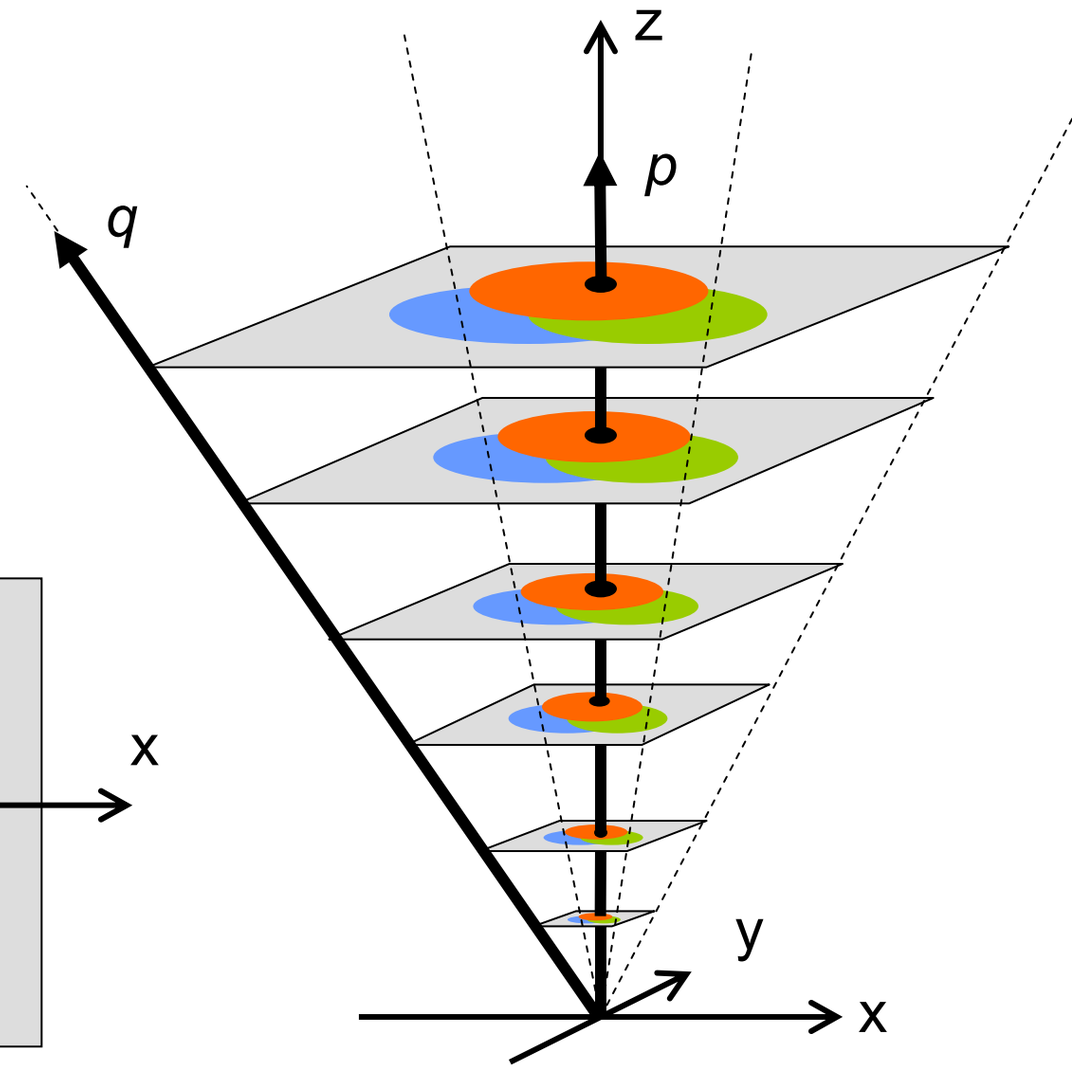
Space-scale diagram: rays

- Points like *p* and *q* in the original 2D surface become rays *p* and *q* in the space-scale diagram
  - the circles in the example picture become cones in the diagram





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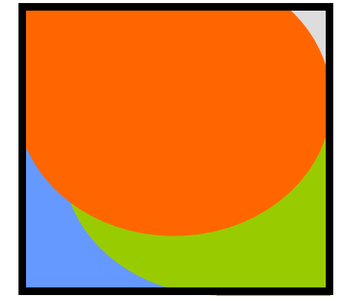
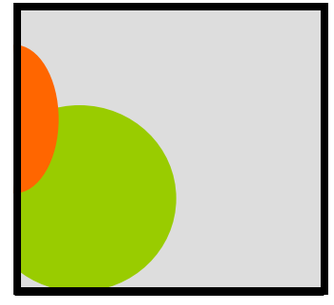
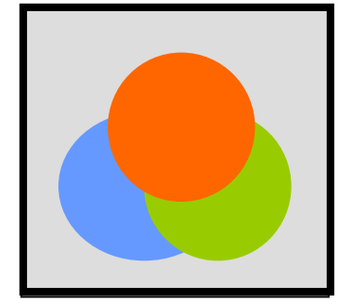
Space-scale diagram: views

- A viewing window is a 2D rectangle of fixed size  placed somewhere in the space-scale diagram







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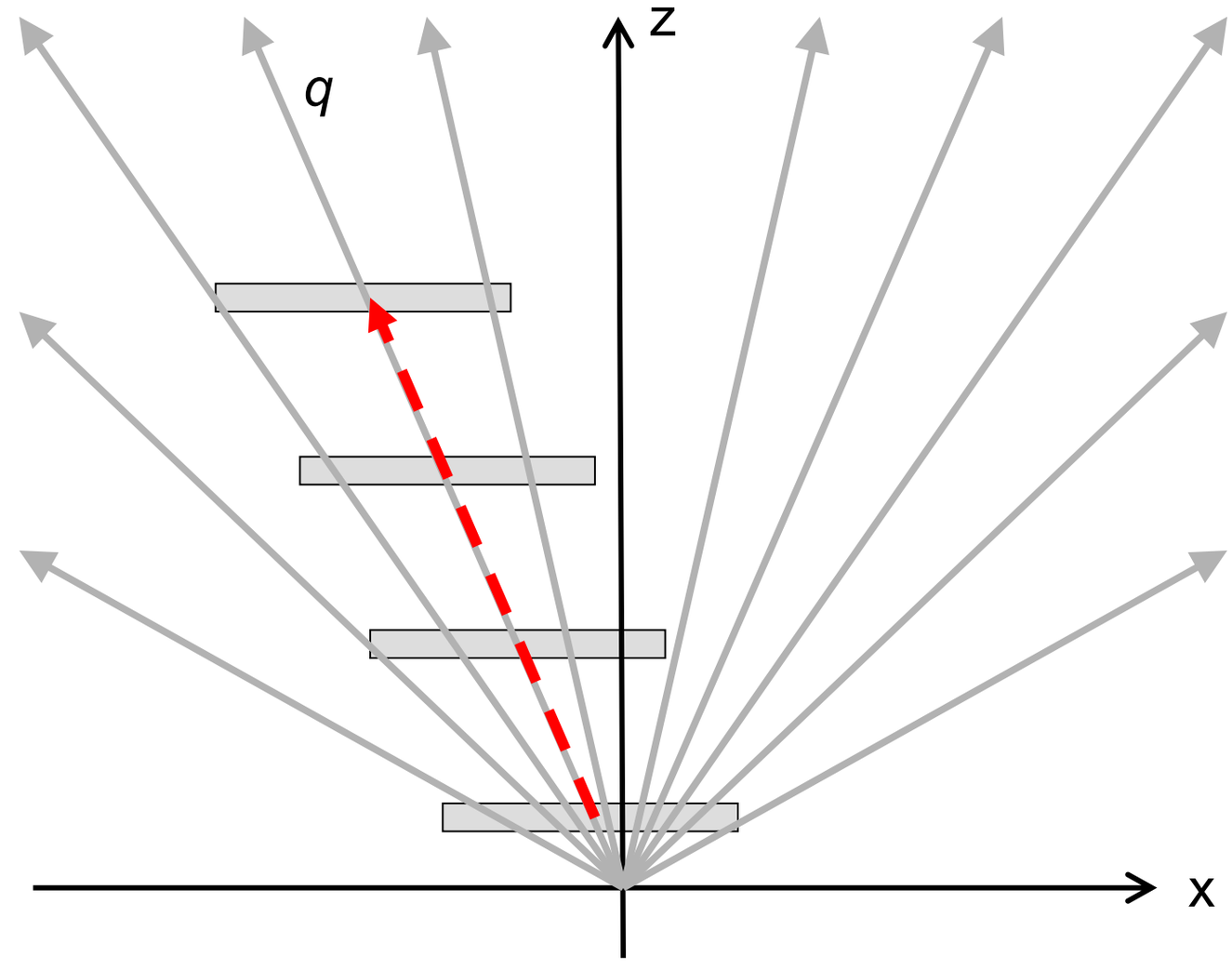
Space-scale diagram: zooming in

- Zooming in corresponds to moving upward along a ray
  - the picture represents a zoom in along the *q* ray



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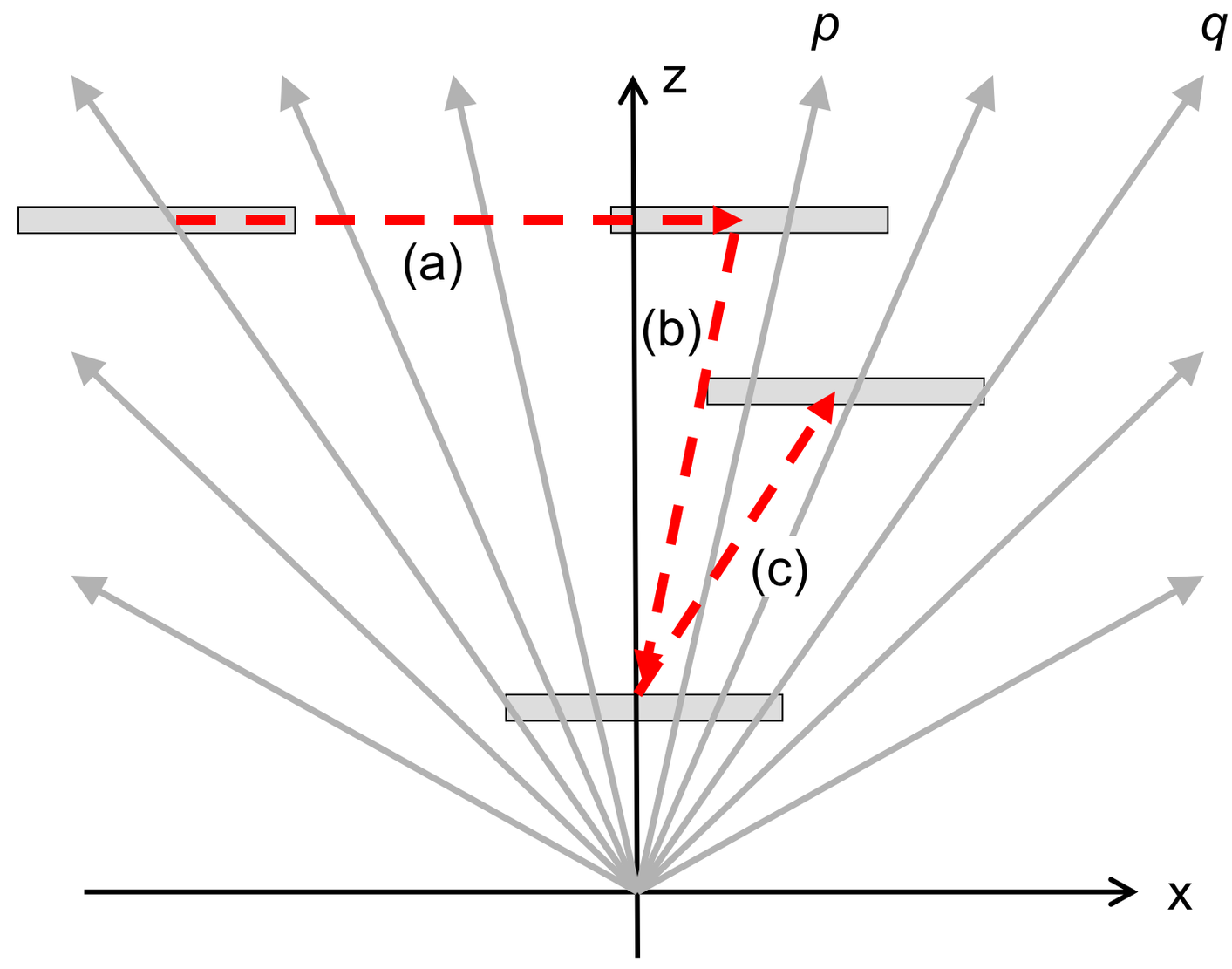
Interpretations of user interactions

- User interactions can be interpreted as movements in the space-scale diagram
  - (a) panning
  - (b) zooming out along ray p
  - (c) zoomin in along ray q



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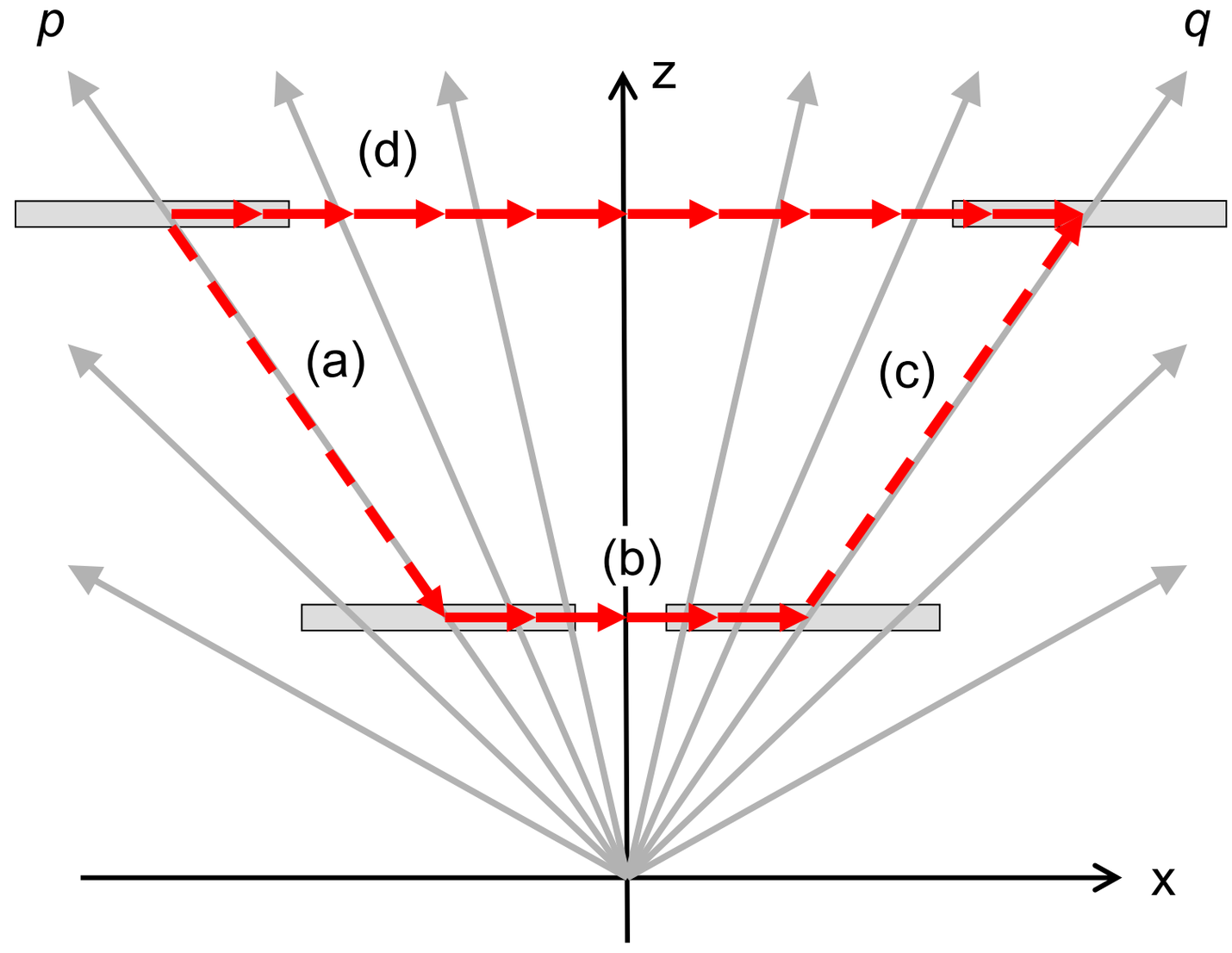
Shortest path between two views

- The shortest path between two views is often not a straight line
  - each arrow represents one unit of cost
- It is often “shorter” to zoom out (a), make a smaller pan (b), and zoom back in (c), than to make a large pan directly (d)
  - this is because zoom is logarithmic



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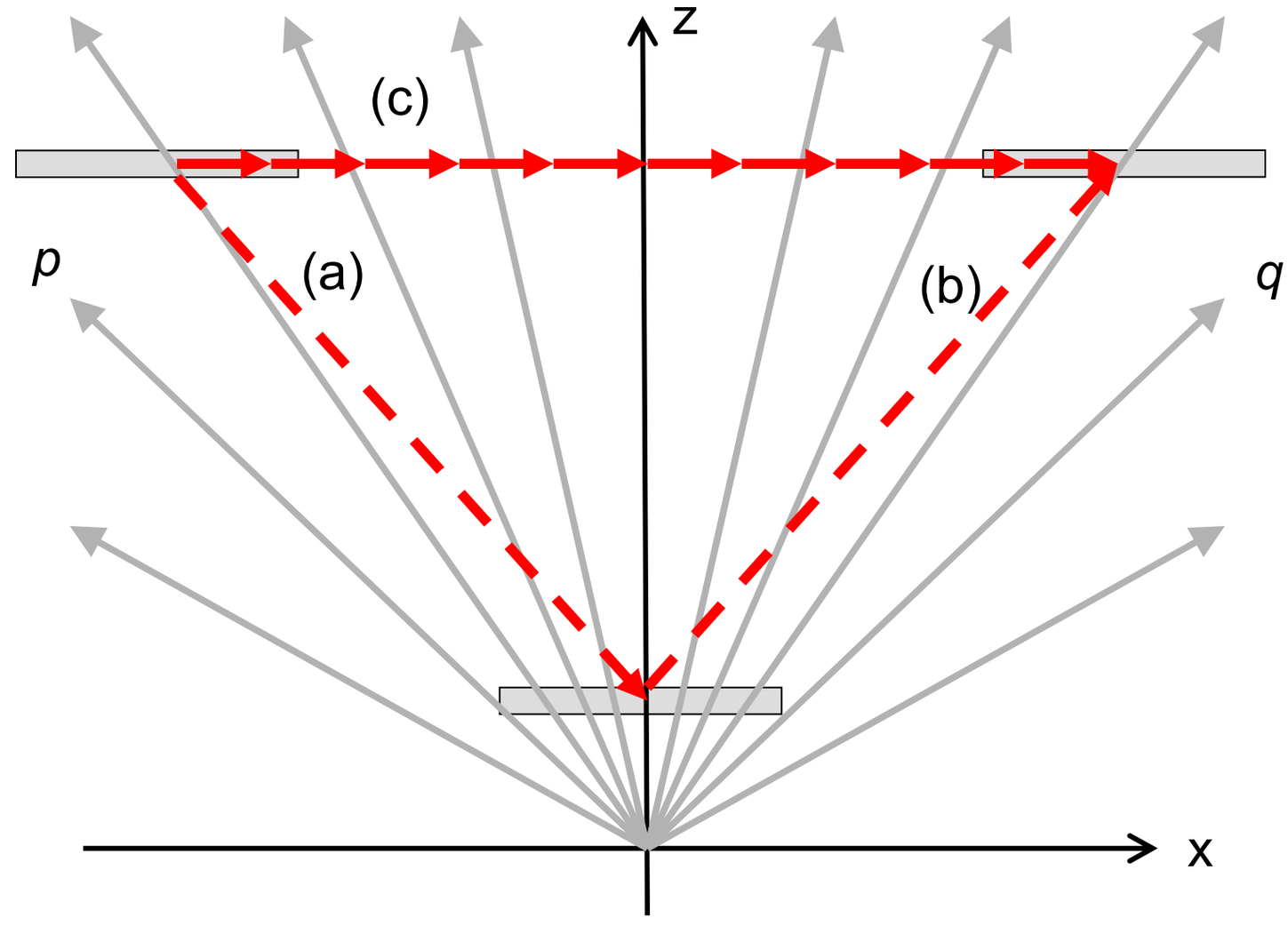
Computing optimal trajectories

- Optimal trajectory between the two views



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Zooming: details-on-demand

- The zoom category also comprises more abstract types of “zooming” consisting of showing more details
- “Details-on-demand” is the term used in infovis when providing the user with more information about data cases
- Examples
  - ask more info about a data case
  - move from aggregation view to individual view
    - some data may be filtered based on scale or represented by some abstraction

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Pop-up tooltips

- Hovering mouse cursor brings up details of item

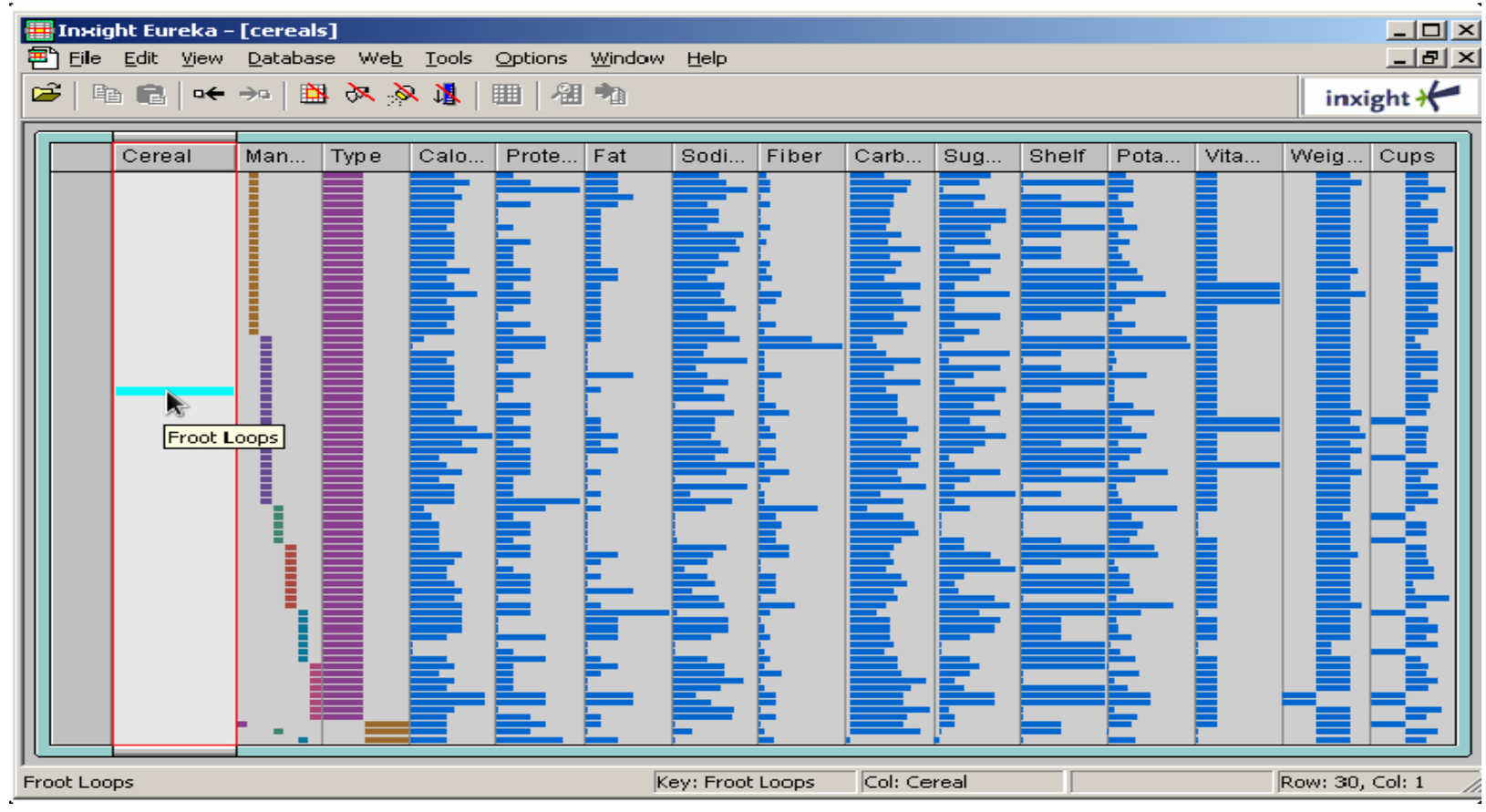

Table Lens [Rao & Card, ‘94]

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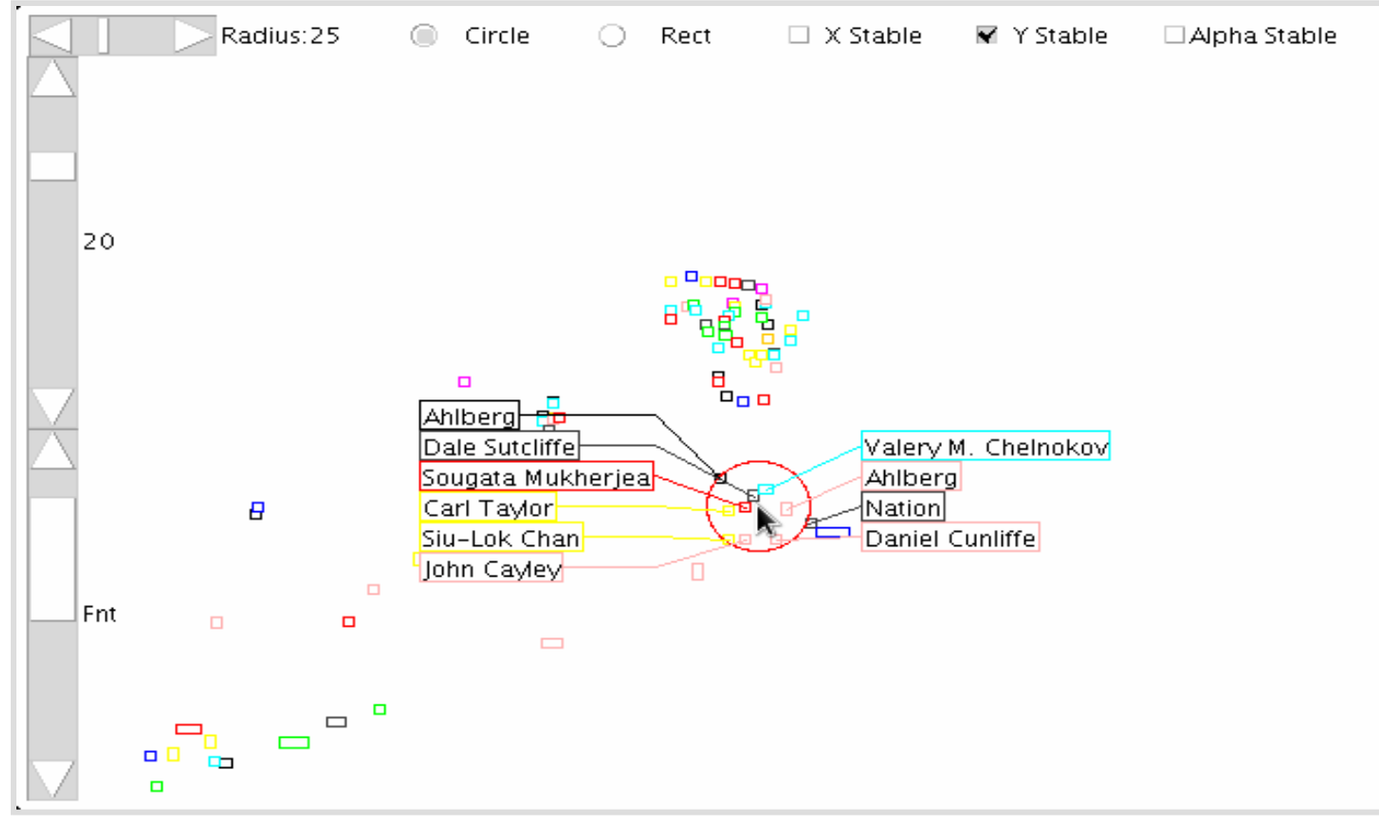
Excentric labeling

- Label a neighborhood of objects located around the cursor
  - [Fekete & Plaisant, '99]



http://www.cs.umd.edu/hcil/excentric/dist/bin/test7.html

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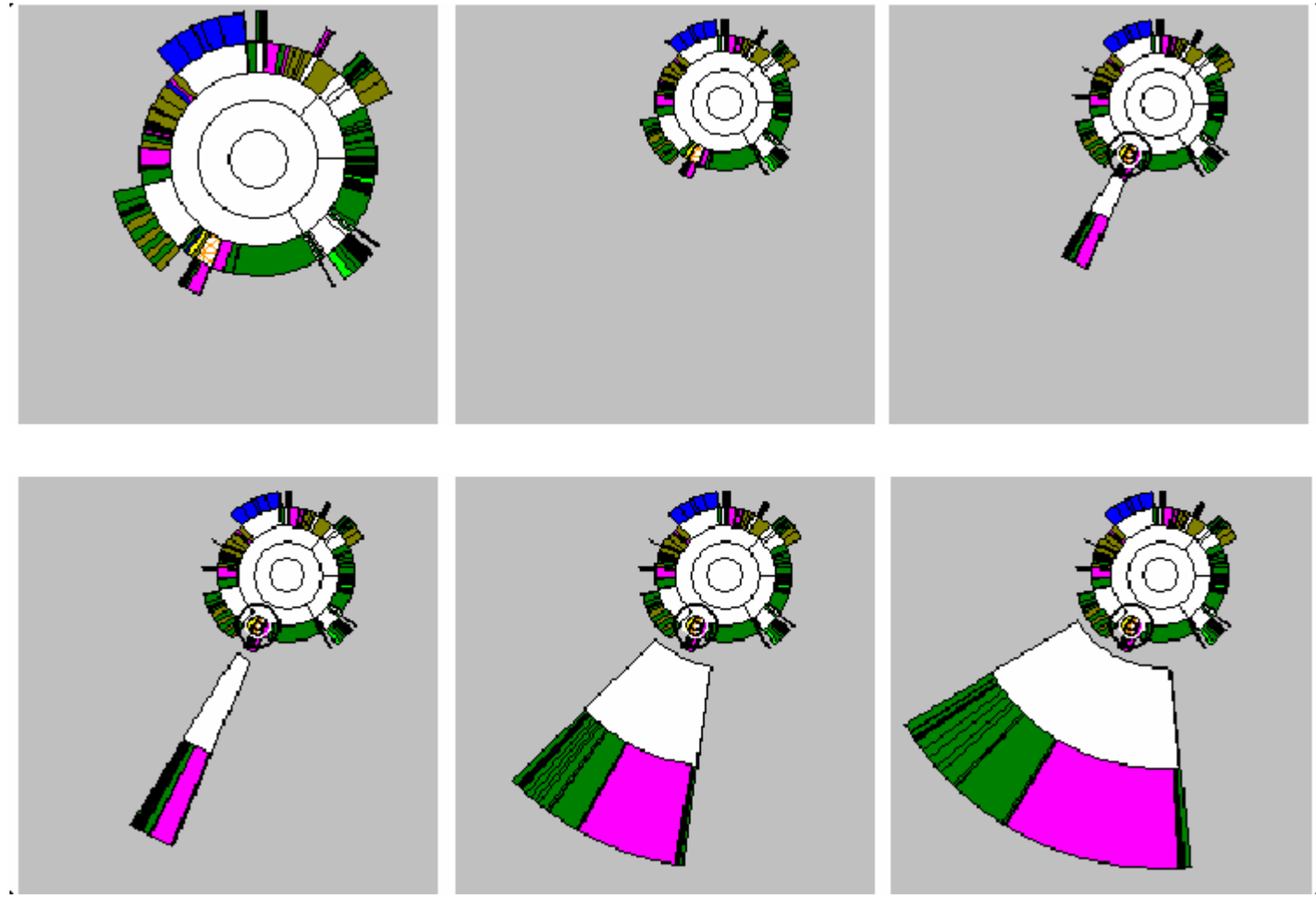
Details-on-demand in SunBurst

- A wedge is enlarged when selected
  - [Stasko & Zhang 00]



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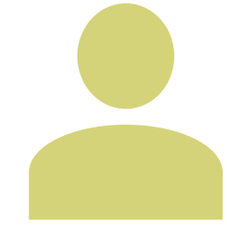
4. Reconfigure

Show me a different arrangement!



- Provide different perspectives by changing the spatial arrangement of representation
- Examples
  - changing the attributes in a scatter plot
  - sorting and rearranging columns in TableLens
  - adjusting the baseline of a stacked histogram

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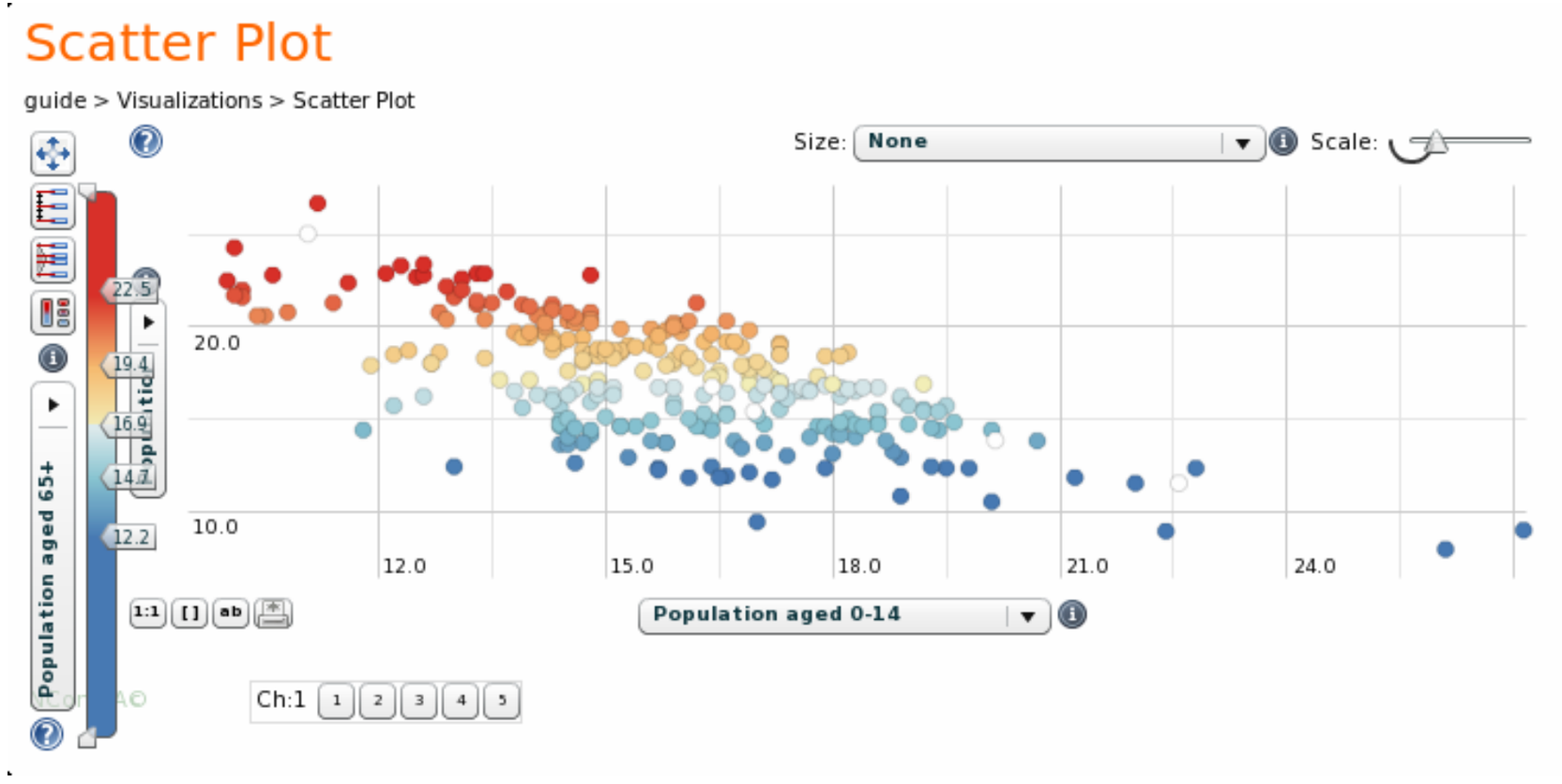
Rearranging a scatter plot

- Change the attributes that are used in the x and y axes



http://www.ncomva.se/guide/?chapter=Visualizations&section=Scatter%20Plot

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Table Lens

- Rearranging columns

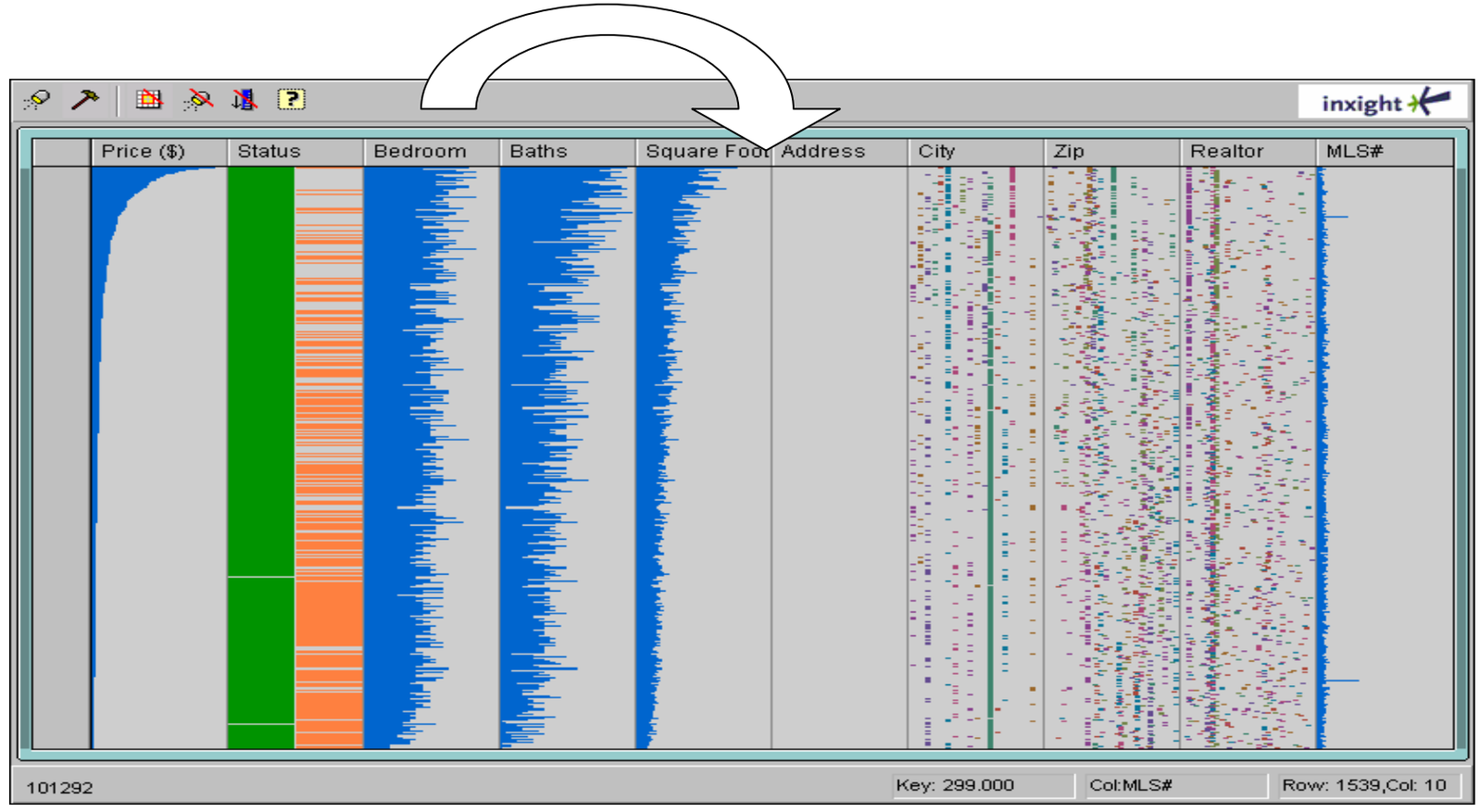

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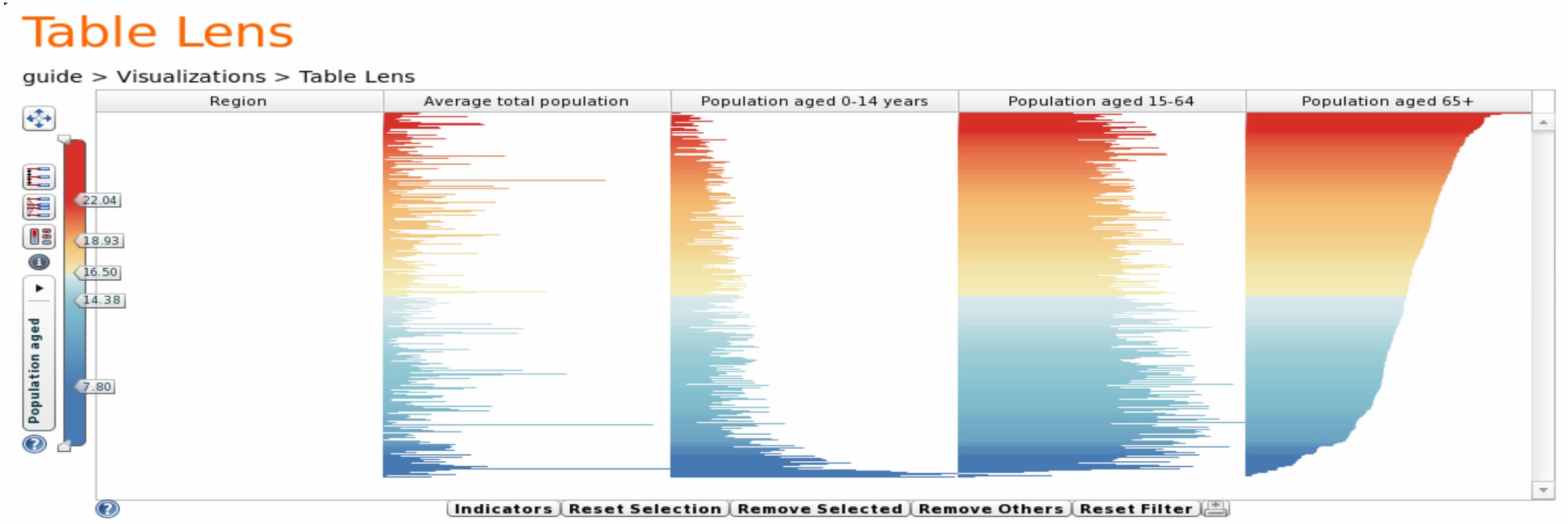
Table Lens

- Sorting in Table Lens



http://www.ncomva.se/guide/?chapter=Visualizations&section=Table%20Lens

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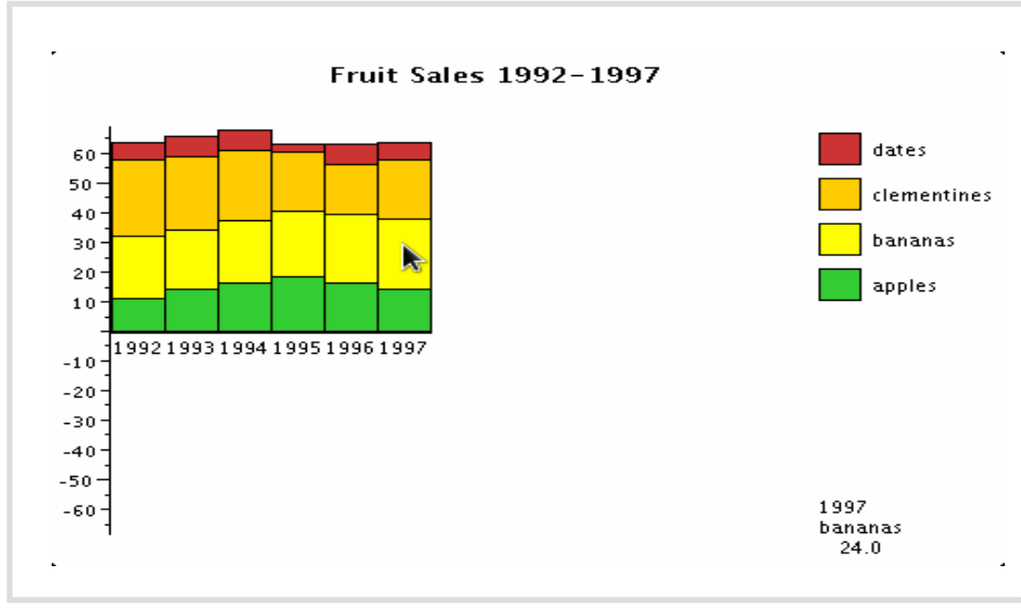
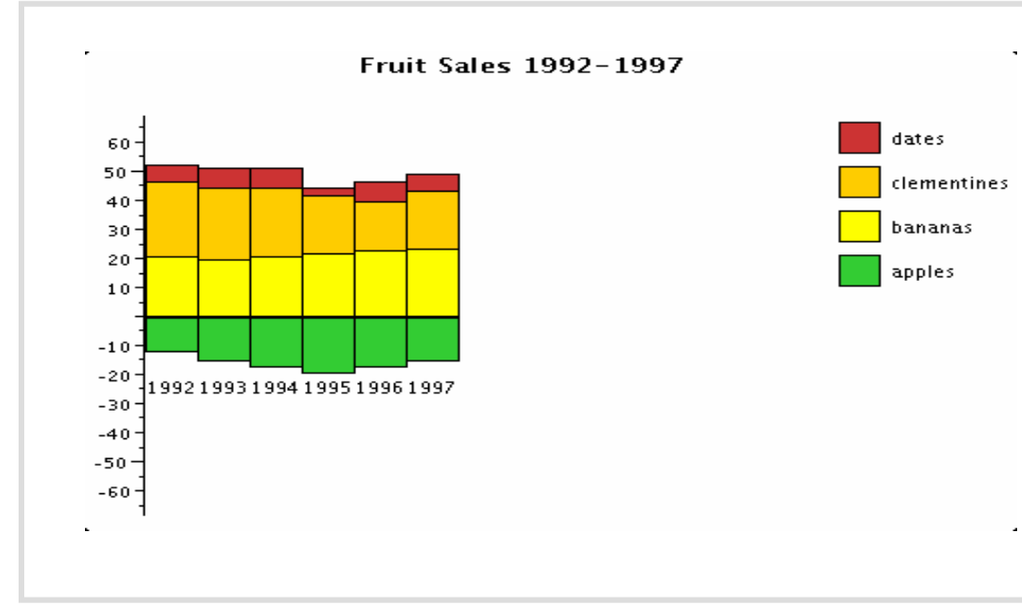
Stacked Histogram

- The baseline adjustment feature
  - Clicking on a variable the histogram adjust to have that variable aligned with the baseline





http://www.meandeviation.com/dancing-histograms/hist.html

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5. Encode

- Change visual appearances
  - Change format
    - color, size, orientation, font, shape, …
  - Change representation type
    - switch from one type of representation (e.g., scatter plot) to a second one (e.g., bubble chart or parallel coordinates)

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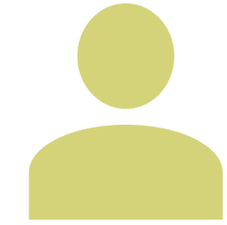
6. Filter

Show me something conditionally!



- Change the set of data items being presented based on some specific conditions
- Examples
  - sematic zooming
  - local edge lens
  - keystoke based filtering in NameVoyager
  - attribute Explorer
  - QuerySketch
  - dynamic query

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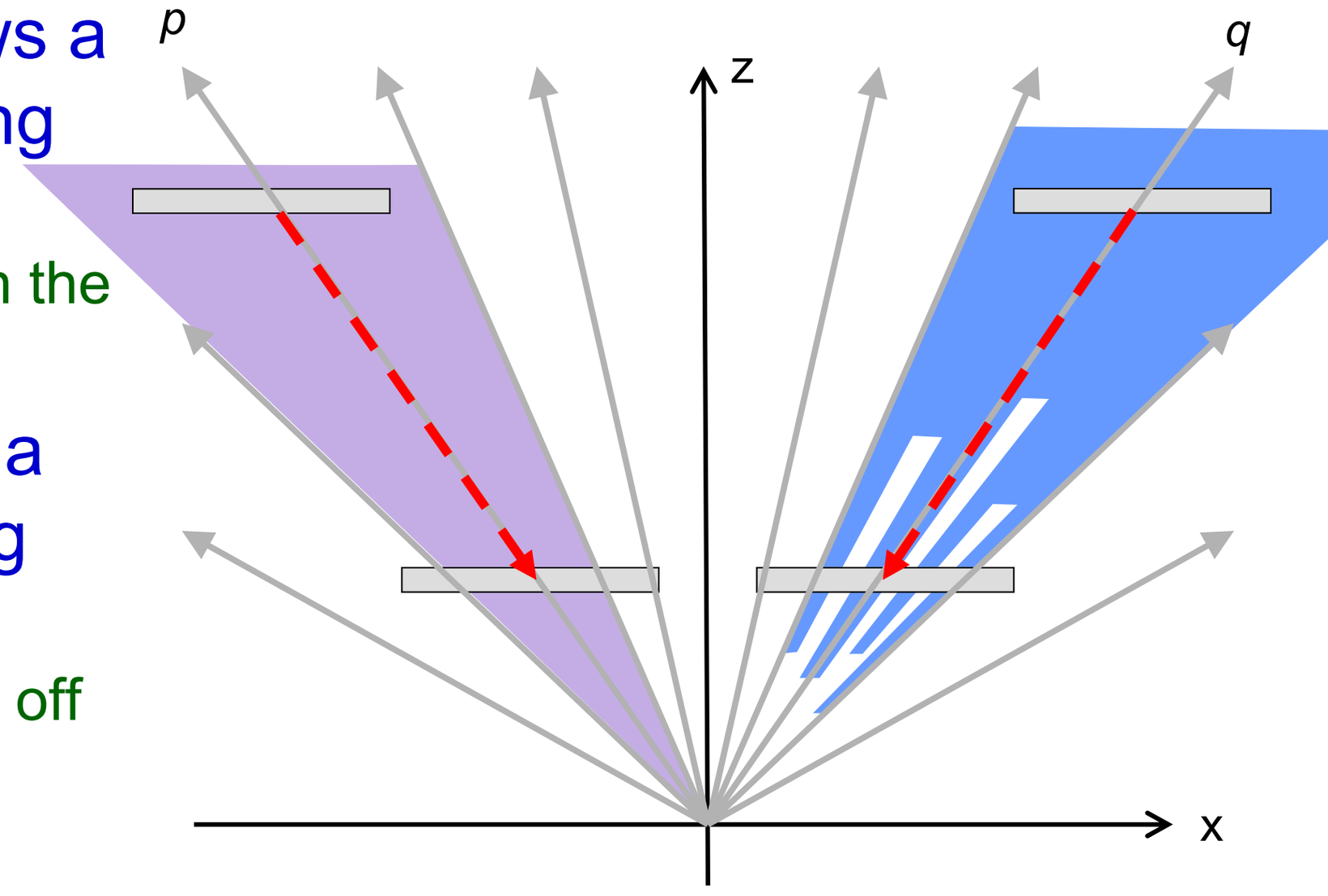
Semantic zooming: space-scale diagram

- Light purple shows a geometric zooming
  - all the details are preserved through the zooming
- Light blue shows a semantic zooming
  - as you zoom out details are filtered off



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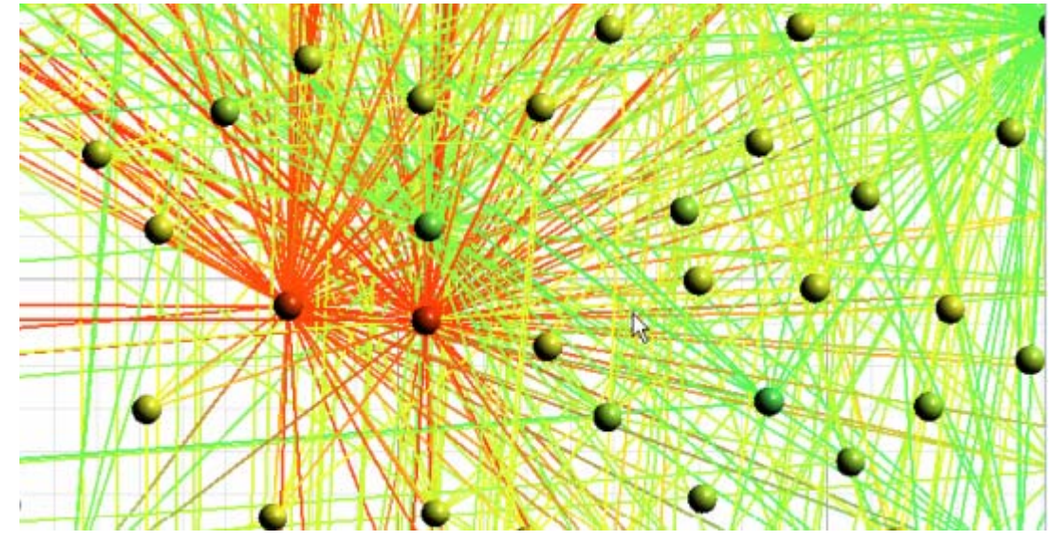
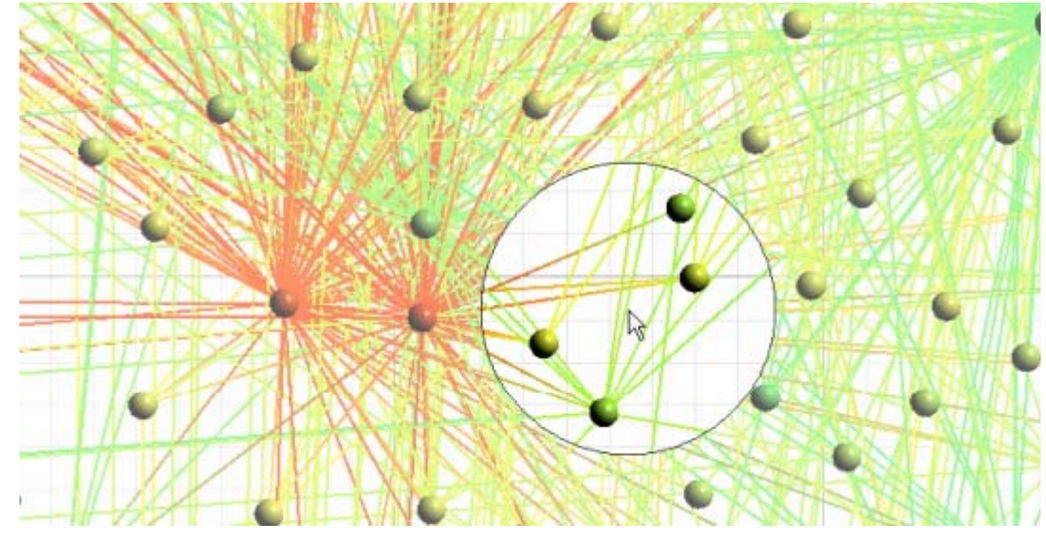
Local Edge Lens

- An example of a semantic lens
  - edges that do not have and endpoint under the lens disappear
    - [Tominski *et al.*, ‘06]
- This metaphora can be generalized





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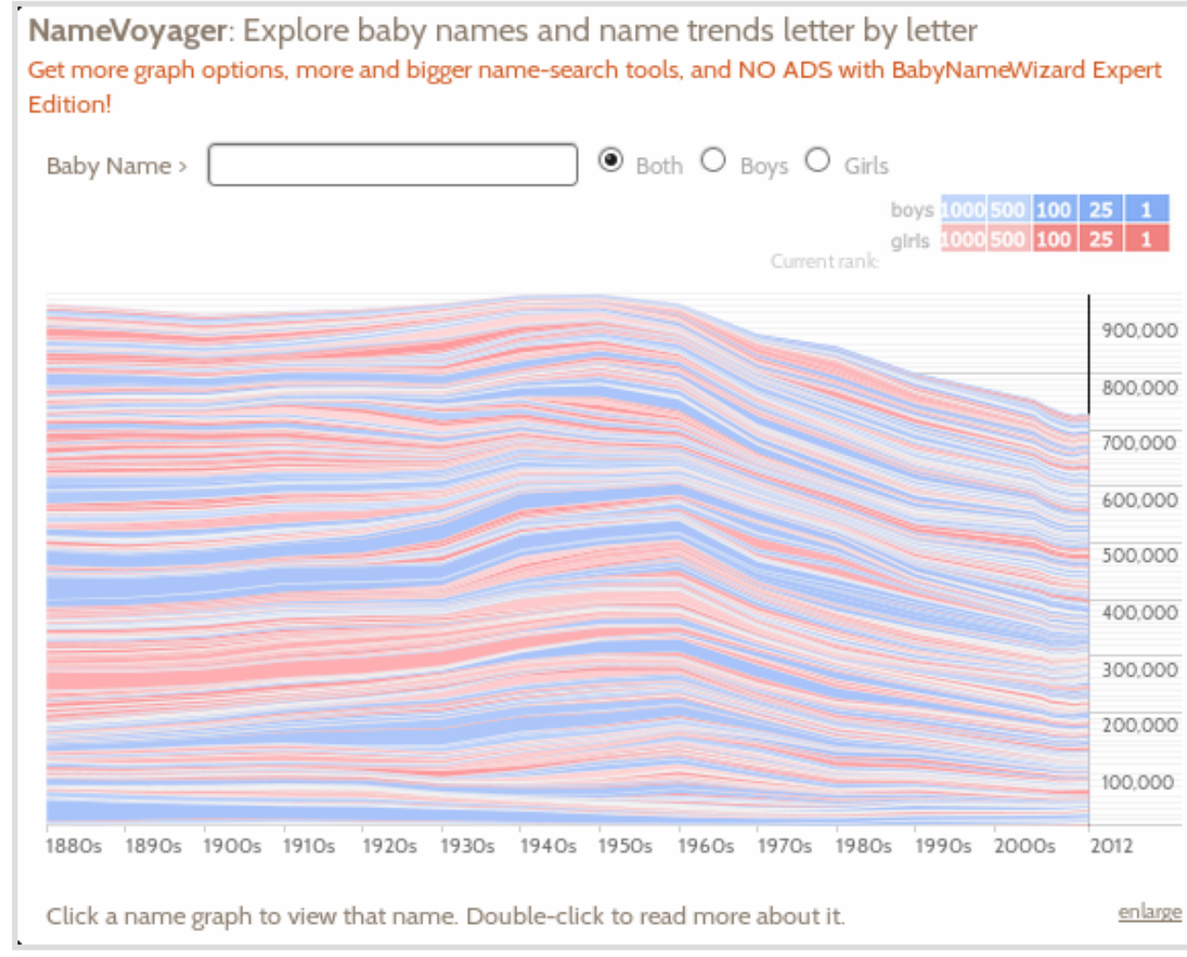
Filter based on keystroke

- NameVoyager



http://www.babynamewizard.com/voyager

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Filtering by dynamic queries

- Work instantly within a few milliseconds as users adjusts sliders or select buttons to form simple queries
  - [Shneiderman ‘94]
- Continuously update the data that is filtered from the database and visualized
- Probably best-known and one of most useful infovis techniques
  - [Stasko ‘13]

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Traditional queries

- SQL queries
  - powerful and flexible
- SQL limitations
  - needs technical skills
  - rigid syntax
  - the magnitude of results is unpredictable
  - only shows exact matches
    - no helpful context is shown
  - refining the query may be slow

```
Select      house-address
From        atl-realty-db
Where       price >= 200,000 and
            price <= 400,000 and
            bathrooms >= 3 and
            garage == 2 and
            bedrooms >= 4
```

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Dynamic queries

- Specifying a query brings immediate display of results
- Responsive interaction (< .1 sec) with data, concurrent presentation of solution
- Allows beginners a faster entrance without having much practice, and still offers experts some mighty functions

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Dynamic query ingredients

- An interface that allows dynamic queries has these properties [Williamson & Shneiderman 92] [Shneiderman 94]
  - graphical representation of the request
    - selection by pointing (not typing)
  - graphical visualization of the results
    - immediate and continuous
    - delivers results immediately when parameters are changed
  - allows rapid, incremental and reversible actions

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Dynamic query limitations

- Operations are fundamentally conjunctive
  - can not formulate arbitrary boolean expressions
    - (x < 20) OR ((x > 20) AND (y > 1.80))
- Operations are global in scope
  - all the data set is affected
- Controls take space
- Real-time interaction becomes increasingly difficult with large data sets
  - sophisticated data structures required

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7. Connect

- Highlight associations and relationships
  - especially in coordinated views or small multiples views
- Examples
  - brushing and linking
  - highlighting directly connected nodes in Vizster
    - http://vis.stanford.edu/papers/vizster
  - bring neighbors lens

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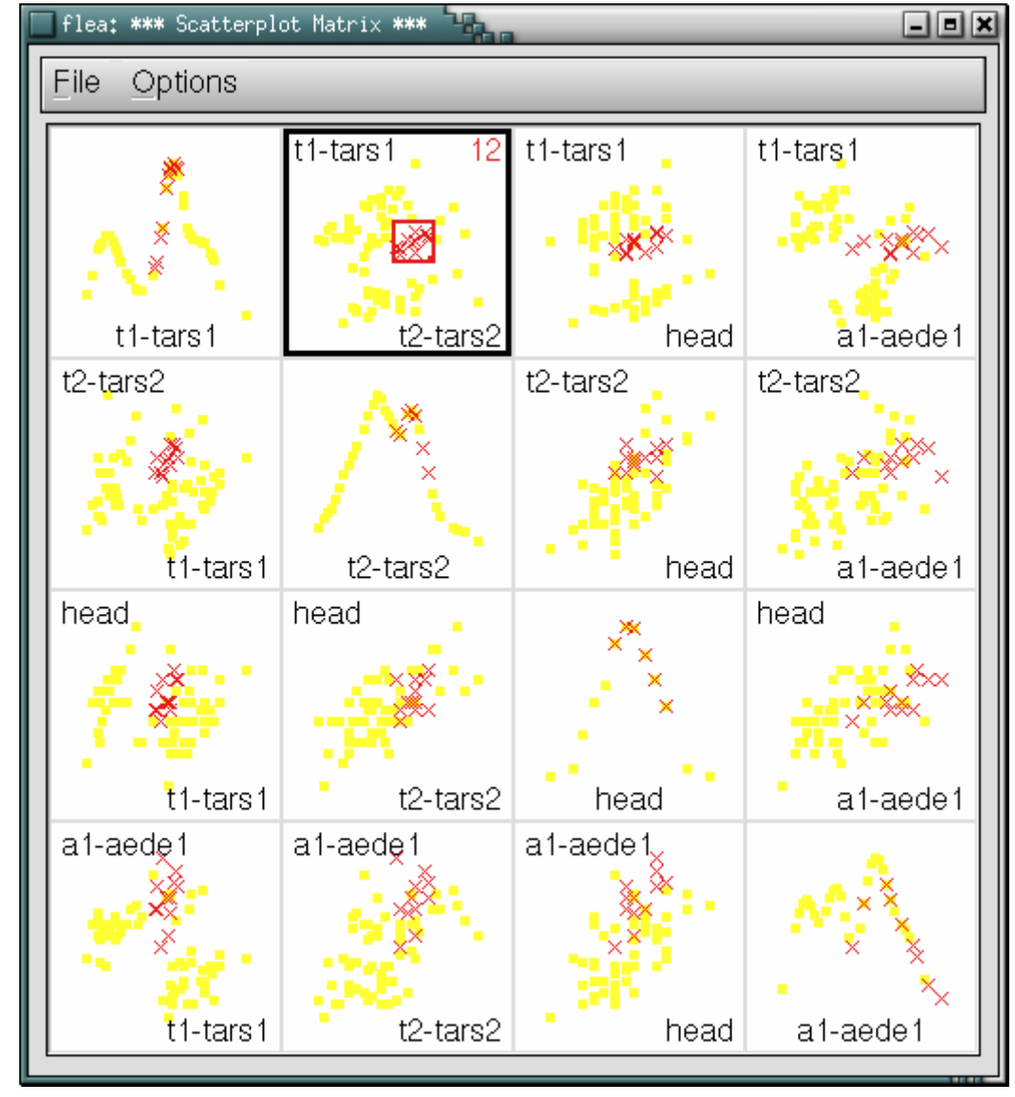
Connect: brushing and linking

- Brushing
  - selecting a subset of the data items
- Linking
  - brushed data is highlighted in different views of a visualization



From [Voigt '02]

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Conclusions

- Interaction is the heart of all effective visualization systems
- In particular it offers three powerful exploration and investigation tools
  1. generalized selection
     - select all items with similar values
  2. dynamic queries
     - immediately assess the effects of changes in filtering parameters
  3. brushing and linking
     - identify the same objects in the different perspectives offered by combined views

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